MORSES POND ANNUAL REPORT: 2015

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 2015. Program elements include: 1) phosphorus inactivation, 2) plant harvesting, 3) low impact development demonstration, 4) education, and 5) dredging.

Phosphorus Inactivation

Operational Background

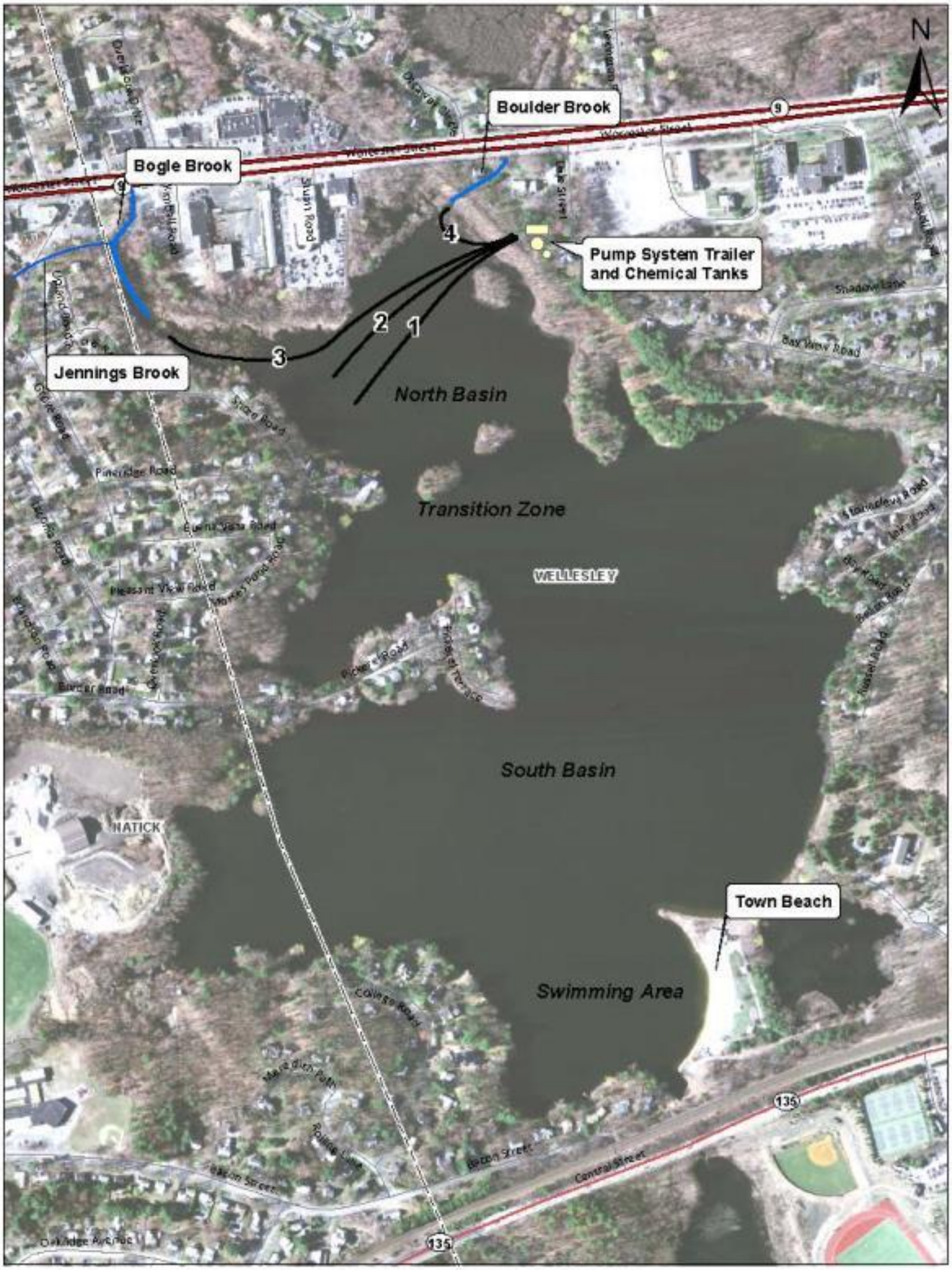
A phosphorus inactivation system was established in the spring of 2008. After testing and initial adjustment in 2008, the system has been operated in the late spring and early summer of 2009 through 2015. The chemical pump station was initially portable, stationed for the treatment period at the Town of Wellesley Dale Street Pump Station, but in 2015 this was made a "permanent" station without the trailer. Four sets of lines initially ran from the pump station into the north basin (Figure 1), each set consisting of an air feed line and two chemical feed lines. The phosphorus inactivation chemicals used for the treatment were aluminum sulfate (alum) and sodium aluminate (aluminate). Both are flocculating agents responsible for the inactivation of phosphorus, with alum creating acidic conditions and aluminate shifting the pH to a more basic level; both were added at a roughly 2:1 ratio (alum to aluminate, by volume) to balance the pH of treatments.

Two lines with single diffusers and sets of chemical ports near the end of each line ran within the north basin to the mouths of Boulder Brook and Bogle Brook. This facilitated inlet treatment, generally considered the most effective means of inactivation, given mixing and settling as the streams proceed into the north basin. The other two lines, each with four diffusers and corresponding chemical ports, were spaced within the north basin itself to allow treatment of water in that basin. This allowed treatment if operation was not possible from the start of a storm, or if additional treatment in the basin appeared necessary. However, as spring progressed, dense vegetation within the north basin limited horizontal mixing and overall system efficiency. Additionally, once a portion of the north basin had been dredged (2012-2013), mixing that would limit particle settling became undesirable, so lines 1 and 2 that had served the north basin were removed in 2013.

The two sets of lines addressing the Bogle and Boulder Brook inlets were operated in 2013, and it was determined that the mixing function of the compressor was not needed for inlet injection to be effective. Therefore compressor use was discontinued in 2014, which eliminated the need for fuel as well; the chemical feed pumps run on electricity, potentially supplied by a generator on the trailer at first, but more conveniently provided from the Dale Street pump station by extension cord. Consequently, the system was greatly simplified in 2014 and was much quieter, with a compressor used only at the end of the season to clear the lines, no generator use, and the pumps being housed in a wooden cabinet. Lines were also extended further up Bogle Brook in 2014.

A further development in 2014 was the switch from alum and aluminate to just one chemical, polyaluminum chloride (PAlCl). Improvement of PAlCl in recent years made it worth testing, as both alum and aluminate are more hazardous to handle and more viscous in the feed lines. PAlCl is not much

Figure 1. Phosphorus Inactivation System for Morses Pond



more viscous that water and does not damage skin rapidly on contact. It is more pH neutral, causing no detectable fluctuation in most waters to which it is applied at typical doses. It is intermediate to alum and aluminate in aluminum content (5.6%, or 0.59 lb/gal) and cost (about $2/gal). Testing in late 2013 and early 2014 with Bogle Brook water indicated phosphorus removal rates in excess of 90% with doses between 3 and 10 mg/L as alumimum. Consequently, the system could be further simplified to have one chemical in each of two chemical tanks, each with a dedicated pump, and each serving one inlet stream. With flows in Bogle Brook being larger than those in Boulder Brook, the larger pump (nominal capacity of 84 gal/hr) and the larger tank (2000 gal) were assigned to Bogle Brook and the smaller pump (nominal capacity 52 gal/hr) and smaller tank (1000 gal) were assigned to Boulder Brook, although swapping of hoses from the tank to the pump or the pump to the delivery lines allows switching if necessary.

Alum and aluminate were added to the north basin in May through at least late June to achieve a target total phosphorus level in the south basin of <20 ppb and preferably close to 10 ppb near the 4th of July. Traditionally, algal blooms started about that time, necessitating copper treatments to regain water clarity and keep the beach open. It was thought that additional treatment during summer might not be necessary if the starting phosphorus level was low enough. No problems were noted in 2009, but algal blooms developed in August of 2010 and 2011. Responsive treatment helped, but was considered too late to prevent some loss of clarity. In 2010 the chemicals were available to respond to declining clarity in late July, but no action was taken. In 2011 the chemicals were not available when a response was deemed appropriate in late July, and it took two weeks to obtain the necessary chemicals. In 2012, sufficient chemical was on hand to respond to reductions in water clarity during summer, but system functionality problems limited the effectiveness of treatment. In 2013, chemicals were ordered and available from mid-July into August, but pump and delivery line issues limited effectiveness.

In 2014, the change to polyaluminum chloride was made and each tank and pump combination was dedicated to a single inlet (Bogle or Boulder Brook). Initial chemical delivery (3000 gal) was at the start of June, and another delivery (just under 3000 gal) was made at the end of June, providing enough material to treat through July, although most chemical was applied prior to July 6^{th}. Precipitation was lower than average in June and all storms were treated. Additionally, the dredged area in the north basin increased detention time in that area. These combined factors resulted in low phosphorus in the main body (southern basin) of Morses Pond and high water clarity.

In 2015 the same approach as in 2014 was applied, but 7900 gallons were applied, most of it between late May and early July. Precipitation was below average from May through August, and some portion of every storm was treated in May and June; the only significant precipitation that was not treated was a continuation of a storm at the end of May when the chemical supply was exhausted and could not be replaced immediately. The result was spectacular, with the lowest phosphorus levels recorded for Morses Pond in over 20 years. Even with a few larger storms in July, phosphorus remained well below the 20 ug/L threshold into August, and clarity was more than acceptable throughout the summer. With two years of highly desirable operational features and in-lake results after the switch to polyaluminum chloride, the time has come to automate the system and minimize labor expense to run the system. This process was initiated in late spring and continued to the end of the year, but an automated and remotely controllable system will be functional going into the 2016 treatment season.

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 3531 and 6720 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.

Table 1. Summary of Phosphorus Inactivation Effort, 2008-2015

Year	Applied Alum (gal)	Applied Aluminate (gal)	Aluminum Mass (lbs)	Period of Application	# of Treatment Days	Notes
2008	2000	1000	2240	6/24 to 7/23	5	Testing and adjustment phase
2009	6002	2900	6595	5/14 to 7/9	16	Very wet spring and summer
2010	4100	2080	4630	5/11 to 7/9 + 8/24 & 8/25	13	Average spring, leftover chemical applied in late August.
2011	5000	2475	5569	5/15 to 7/8 + 8/10 & 8/16	14	Wet spring and summer, attempted August treatments in response to bloom
2012	6000	3000	6720	5/4 to 7/23 + 8/6 to 8/22	19	Poor system functionality hampered dosing during treatment
2013	6055	2785	6476	4/26 to 5/24 +5/28 to 6/27+ 7/23 to 8/2	20	Very wet June. Flushing may have been more important than treatment
	Polyaluminum chloride					
2014	5985		3531	6/2 to 7/5 + 4 dates from 7/16 to 8/2	12	Dry May and June, wet July, first year using polyaluminum chloride
2015	7900		4661	5/14 to 7/1 + 8/4	14	Dry summer, 2nd year using polyaluminum choride

2015 Phosphorus Inactivation

The record of treatment in 2015 is provided in Table 2, including the rainfall record. Storm events occurred on 28 days in May through August of 2015, less than the 35 days in 2014 and the 47 days in 2013. Precipitation was 6.23 inches in May and June, about one inch below normal, with a very dry May and slightly wetter than average June. Precipitation was just over 2 inches in each of July and August, each more than an inch below normal, so it was a dry summer. Overall, treatment occurred for 126 hours on 14 days, but almost half of this time was in May when treatment involved mostly testing at very low discharge rates. The highest doses and most of the chemical were added over just 7 days in June. The treatment pattern was similar to that of 2014 but rather different than in previous years; we have settled into a mode of limited treatment in May, more intensive treatment in June, and touch up on just a day or two in July and August.

A total of 7900 gallons of PAlCL were applied, almost 2000 gallons more than in 2014, but still lower than most years (Table 1). The application rate averaged 62.6 gallons per hour overall, but during the main treatment period (June) the rate was 81.6 gph. Note that the smaller pump was not working at all in June, so the larger pump was basically run at capacity with the discharge split between Bogle and Boulder Brooks. In 2014 the larger pump averaged 80% of capacity, while pumping with the smaller pump averaged 60% of capacity, so the larger pump is marginally capable of handling both inlets.

Table 2. Rainfall record and related treatment actions in 2015.

	May				June				July				August			
	Precip	Treatment			Precip	Treatment			Precip	Treatment			Precip	Treatment		
Day of Month	Inches	Hours	Bogle Bk P.Al.Cl (gal)	Boulder Bk P.Al.Cl (gal)	Inches	Hours	Bogle Bk P.Al.Cl (gal)	Boulder Bk P.Al.Cl (gal)	Inches	Hours	Bogle Bk P.Al.Cl (gal)	Boulder Bk P.Al.Cl (gal)	Inches	Hours	Bogle Bk P.Al.Cl (gal)	Boulder Bk P.Al.Cl (gal)
1	0.00				0.38				0.54	6.0	200	125	T			
2	0.00				0.74				0.00				0.00			
3	0.00				0.00				0.00				0.00			
4	0.00				0.00				T				0.49	4.5	200	100
5	0.02				T				0.00				0.00			
6	0.00				0.09				0.00				0.00			
7	0.00				0.00				0.02				0.00			
8	0.00				T				T				0.00			
9	0.00				T	2.0	250		0.15				0.00			
10	0.00				0.00				1.12				0.00			
11	0.00				0.00				0.00				0.83			
12	0.02				0.00				0.00				0.00			
13	0.00				T				0.00				0.00			
14	0.00	0.2	20	0	0.00				0.03				0.00			
15	0.00				0.40	9.0	666	334	T				0.08			
16	T				T	14.0	533	267	0.00				0.00			
17	0.00				0.00				T				0.00			
18	0.00				0.00				0.14				0.14			
19	0.27	1.9	180	10	0.00				T				0.00			
20	0.00	24.0	495	0	0.04				T				0.00			
21	0.00	24.0	495	0	1.72	12.0	666	334	T				0.63			
22	T				0.00				0.00				T			
23	0.00				0.01	4.0	133	67	0.00				0.02			
24	0.00				0.00				0.01				T			
25	T				0.00	2.0	133	67	0.00				0.00			
26	0.00				T				T				T			
27	0.00				0.20				0.06				0.00			
28	T				1.43	10.0	583	291	0.00				0.00			
29	0.00				T				0.00				0.00			
30	0.00				0.00				0.02				0.00			
31	0.91	12.5	750	1000					0.00				0.00			
Sum	1.22	62.6	1940	1010	5.01	53.0	2964	1360	2.09	6.0	200	125	2.19	4.5	200	100
# of Days	4		5	5	9		7	6	9		1	1	6		1	1
Long term average precip.	3.49				3.68				3.43				3.35			
Departure from normal	-2.27				1.33				-1.34				-1.16			
Greatest daily precip	0.91				1.72				1.12				0.83			

With the change in chemicals applied, the gallons delivered becomes less relevant than the amount of aluminum applied, and in 2015 the dose was 4661 lb of aluminum, up from 3531 lbs in 2014 but lower than any of the previous 3 years and very similar to the 2010 total (Table 1). Although lack of detailed flow records hampers calculation, the average dose appears to have been about 2 mg/L during treatment in 2015, based simply on the amount of runoff expected to be generated during the treatment period divided into the amount of aluminum applied.

While the weather was cooperative, the phosphorus inactivation system also worked extremely well in 2014 and 2015, and these were the most successful treatment years yet. The simplified system, single and more easily managed aluminum formulation, and responsive application led to the best water quality in Morses Pond in 2014 in many years, and conditions in 2015 were even better than in 2014. The stage is set to move toward a more automated system which would reduce labor costs.

Analysis of Program Results

Water quality is assessed prior to the start of treatment, normally in May, again in early summer, and yet again 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 2). 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 2015 (Table 3) incorporates field and laboratory tests at multiple sites. A summary of phosphorus data for key periods since 2008 is provided (Table 4) 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 ug/L tends to lead to algal blooms, while values <20 ug/L minimize blooms and values near 10 ug/L lead to highly desirable conditions (Figure 3).

Dissolved phosphorus is a subset of total phosphorus, and tends to be near the limit of detection in many samples, as algae readily take up this available P form. The focus of management is on total phosphorus as the primary indicator of algal bloom potential. Values in 2015 were low to moderate, indicative of less rainfall, active treatment, and effective detention in the north basin. Note that total phosphorus values in the dredged portion of the north basin (NB-1) are lower than those in the undredged portion (NB-2), and that values decline from the inlets to the beach area. The combination of weather, treatment and detention provided very desirable water quality conditions in 2015.

Nitrogen values tend to be low to moderate, with total Kjeldahl nitrogen (TKN) <1 mg/L and nitrate <0.5 mg/L. Values declined over the summer. Loss of nitrate can be a concern, as low available N:available P ratios favor cyanobacteria, but nitrate never completely disappeared and the low phosphorus levels helped with algae control overall.

There are periodic oxygen deficiencies in the deep hole area (MP-1), but not consistently. Low oxygen was observed in June and August, but oxygen was not completely depleted at the bottom on any sampling date in 2015. Conductivity is high in surface waters and very high in deeper water, indicating

Figure 2. Current system layout and water quality sampling sites in Morses Pond.

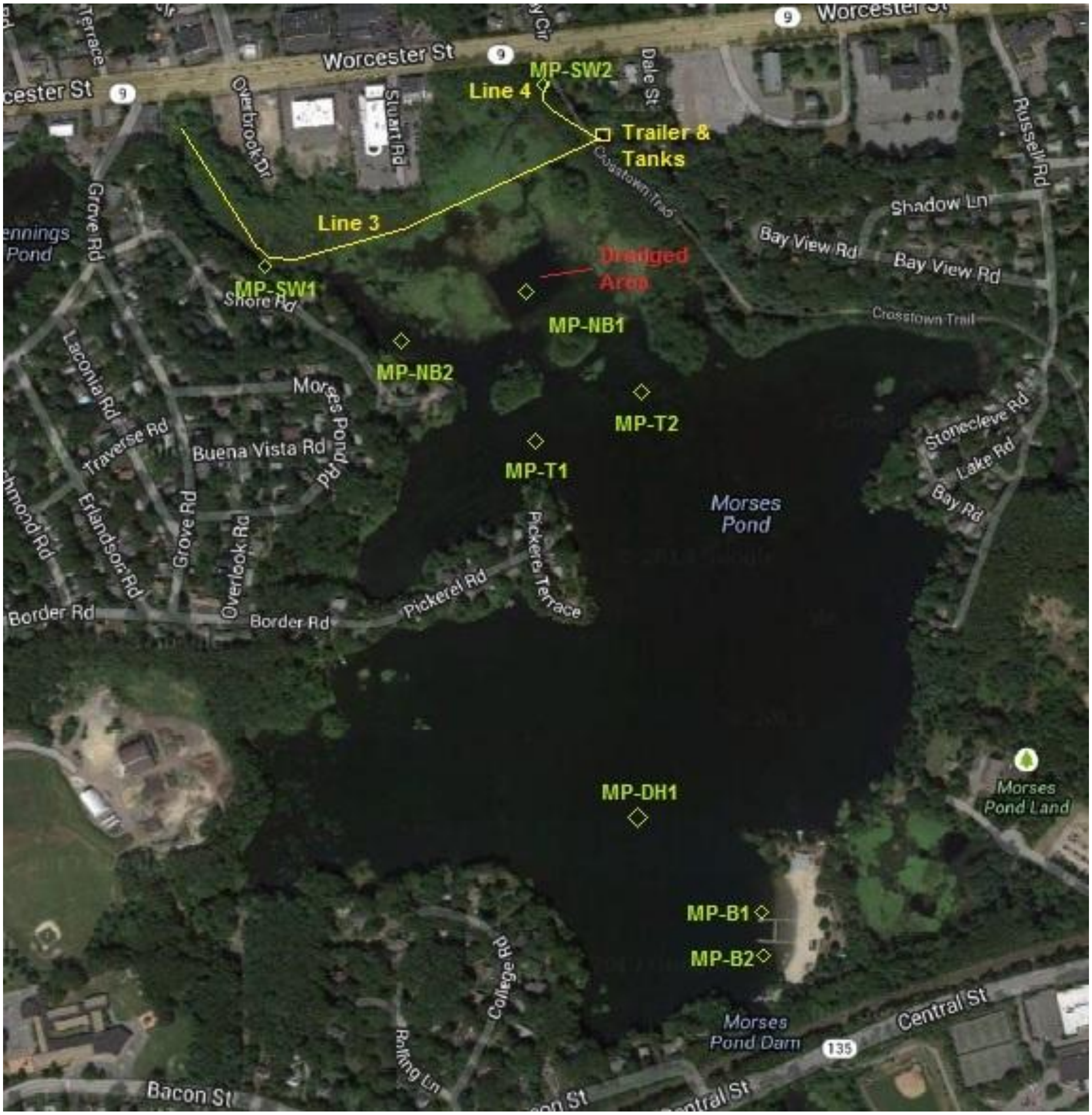


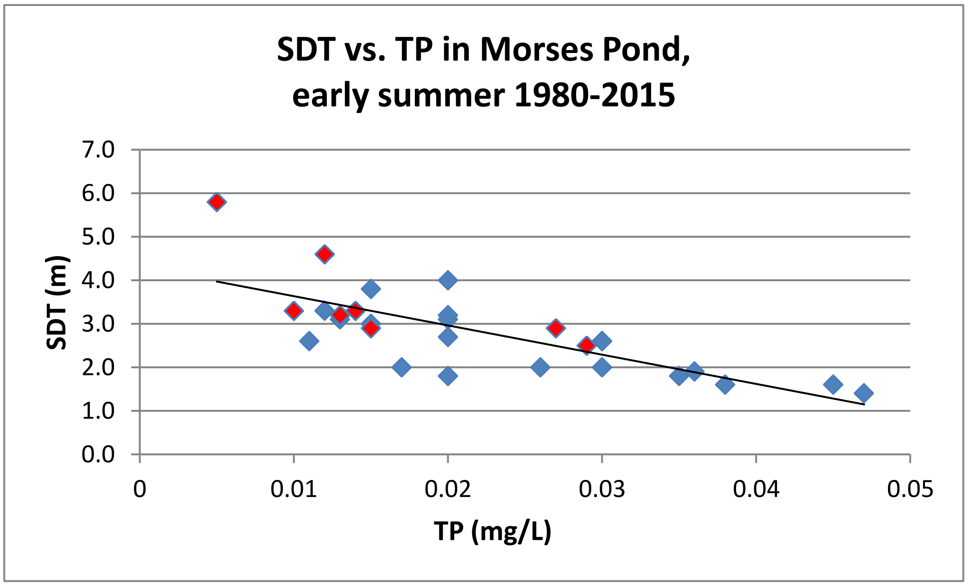
Table 3. Water quality record for Morses Pond in 2015.

	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														
5/31/15 13:25									0.120		1.20	0.40		
6/1/2015 8:05									0.061		0.71	0.32		
6/1/2015 14:15									0.049		0.60	0.33		
MP-SW-2 Boudler														
5/31/15 13:25									0.260		1.40	0.24		
6/1/2015 8:05									0.098		0.68	0.57		
6/1/2015 14:15									0.086		0.71	0.53		
5/14/2015														
North Basin														
MP-NB-1 (dredged)	0.2	18.5	6.9	75.1	471	7.3	2.7	75	0.013	0.005	0.73	0.34	3.1	
MP-NB-2	0.2	18.6	7.1	76.8	506	7.2	2.4		0.010	0.005	0.61	0.36		
Transition Zone														
MP-T-1	0.8	19.5	9.0	99.2	520	7.2	5.0		0.005	0.005	0.51	0.30		
MP-T-2	0.6	19.0	8.8	96.0	521	7.3	6.3		0.010	0.005	0.52	0.29		
South Basin														
MP-B-1														
MP-B-2														
MP-1 (MP -DH1)	0.3	20.0	9.7	108.6	522	7.8	2.7		0.005	0.005	0.45	0.31		
	1.0	19.9	9.9	110.3	522	7.8	3.1							
	2.0	19.7	9.9	109.3	522	7.9	2.7							
	3.0	15.6	10.4	106.3	507	7.9	1.7							
	4.1	11.1	9.5	87.9	550	7.8	1.9							
	5.1	7.0	3.9	32.9	735	7.5	4.1							
	6.0	6.3	2.0	16.0	747	7.4	4.7		0.059	0.005	0.65	0.32		
6/25/2015														
North Basin														
MP-NB-1 (dredged)	0.0	24.2	8.3	100.0	406	6.8	0.9		0.005	0.005	0.65	0.27		
	1.0	23.6	8.2	98.0	413	6.8	0.9							
	2.0	19.2	5.0	54.9	519	6.5	0.5							
	3.1	15.0	15.1	152.5	2022	6.5	2.6							
	3.5	14.0	13.4	132.8	2078	6.5	2.6							
MP-NB-2	0.1	23.1	7.7	91.4	478	6.9	1.8		0.028	0.014	0.57	0.30		
Transition Zone														
MP-T-1	0.1	25.0	9.3	113.7	456	7.2	1.4		0.018	0.005	0.43	0.23		
	1.0	24.2	8.6	104.4	463	7.2	1.4							
	2.1	21.2	3.5	40.3	367	7.1	1.4							
MP-T-2	0.1	24.8	8.8	107.5	446	7.1	1.5		0.011	0.005	0.43	0.22		
	1.0	24.5	8.7	105.1	445	7.2	1.6							
South Basin														
MP-B-1									0.005	0.005	0.48	0.23		
MP-B-2									0.005	0.005	0.54	0.22		
MP-1 (MP -DH1)	0.1	25.6	8.6	106.2	468	7.4	1.1	25	0.005	0.005	0.44	0.22	5.8	1.5
	1.1	25.2	8.5	104.9	465	7.4	1.1							
	2.0	24.9	8.3	101.7	465	7.4	1.1							
	3.0	21.9	6.0	69.6	465	7.4	1.2							
	4.0	15.4	4.0	40.9	522	7.3	1.5							
	5.0	11.2	3.3	30.6	655	7.2	1.7							
	5.4	9.8	0.8	7.2	669	7.0	4.4	47	0.031	0.005	0.56	0.08		
8/12/2015														
North Basin														
MP-NB-1 (dredged)	0.1	24.2	6.9	83.2	399	6.6	2.3		0.016	0.010	0.43	0.03		
	1.1	22.6	3.7	43.0	382	6.6	2.6							
	2.0	21.7	2.4	27.3	323	6.6	3.3							
	2.5	21.7	2.6	30.1	755	6.4	3.4							
	3.0	20.2	9.3	103.8	1346	6.3	5.1							
	3.5	18.3	4.3	46.2	1835	6.1	6.8							
MP-NB-2	0.1	23.9	7.5	89.9	384	6.6	2.9		0.030	0.015	0.52	0.25		
	0.5	22.7	7.4	86.7	390	6.6	2.9							
Transition Zone														
MP-T1	0.1	24.7	7.7	93.6	435	6.7	2.8		0.016	0.005	0.43	0.03		
	1.0	23.5	6.7	79.9	414	6.7	2.8							
	1.5	23.1	6.6	78.4	410	6.7	2.8							
	2.0	22.9	6.0	70.4	415	6.7	5.2							
MP-T2	0.1	25.1	7.8	95.8	441	6.3	1.9		0.012	0.005	0.42	0.03		
	0.8	24.1	7.8	94.5	441	6.5	2.3							
South Basin														
MP-B-1									0.015	0.014	0.43	0.03		
MP-B-2									0.013	0.023	0.44	0.03		
MP-1 (DH)	0.1	25.2	8.0	98.3	455	6.8	2.7	20	0.011	0.013	0.44	0.03	3.9	2.2
	1.0	24.9	8.0	97.6	453	6.9	2.7							
	2.1	24.5	7.9	96.0	454	6.9	2.8							
	3.0	24.2	7.3	88.8	454	6.9	3.0							
	4.0	23.6	4.9	58.0	472	6.8	2.7							
	5.1	16.8	1.0	9.9	620	6.7	4.7							
	5.4	14.7	0.7	6.6	653	6.6	7.2	44	0.020	0.012	0.72	0.06		

Table 4. Water Quality Testing Results Relating to the Phosphorus Inactivation System

Year	Location	Pre-Application TP (ug/L)	Early Summer TP (ug/L)	Late Summer TP (ug/L)	Algae Issues
2008	North Basin	28	18		Mats observed, some cloudiness, early summer is really July 23 at end of treatment
	Transition Zone	31	22		Some cloudiness, brownish color, early summer is really July 23 at end of treatment
	Swimming Area	21	12		Relatively clear, no blooms, early summer is really July 23 at end of treatment
2009	North Basin	35	40	63	Cloudy, some mats
	Transition Zone	35	39		Cloudy
	Swimming Area	15	10	27	Generally clear, no blooms
2010	North Basin	26	46	53	Cloudy, mats evident
	Transition Zone	28	21	32	Brownish color, minimally cloudy
	Swimming Area	19	15	43	Generally clear, no blooms until late August
2011	North Basin	53	33	130	Cloudy, mats evident
	Transition Zone	48	29	95	Slightly brownish
	Swimming Area	30	29	60	Clearest water in years in late June, but short-lived cyanobloom in early August
2012	North Basin	32	24	48	Very dense plant growth
	Transition Zone	28	37	28	Brownish most of summer
	Swimming Area	20	27	24	Had bloom in mid-July
2013	North Basin		47		Very wet June, system overwhelmed
	Transition Zone		78		
	Swimming Area	14 - 24	33	28	Continued treatment kept TP down, but not to target level
2014	North Basin	30	22		Dry May and June, wet July; dredged area trapping particulates fairly well
	Transition Zone	21	20		Dense plant growths, but water fairly clear
	Swimming Area	12	13	17	Water clear; best conditions in years
2015	North Basin	12	17	23	Very dry in May and June, fairly dry in July and August
	Transition Zone	8	15	14	
	Swimming Area	5	5	14	Clearest water in 20 years; better than 2014

Figure 3. Relationship between water clarity and total phosphorus in Morses Pond, 1980-2015.



Red diamonds indicate values for years in which P inactivation was practiced.

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, as are lawn fertilizers. 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 was moderate at all locations assessed in 2015.

Water clarity was as high in 2015 as we have observed in Morses Pond, with a new maximum record of 5.8 m (19.1 feet) achieved in late June. The Secchi measurement was still 3.9 m (12.9 feet) in mid-August. Corresponding chlorophyll-a levels, indicative of algae abundance, were low. Despite the urban nature of the watershed, water quality was very desirable in most parts of the lake during the summer of 2015. The dry weather, effective treatment in June, and improved detention through dredging in the north basin are all to be credited.

In 2014 we sampled upstream and downstream of the treatment point on Bogle and Boulder Brooks. Access downstream is limited, and reactions occur for minutes to hours, so this is not an ideal comparison, but an immediate decline in total phosphorus of 47 to 80% was evident. In 2015 we sampled the Bogle and Boulder Brook inlets three times over the course of one storm that lasted from May 31 through June 1 (Table 3). Values for total phosphorus and TKN were elevated, but were lower than many previous measurements going back two decades and well below what is considered typical for urban runoff. Value declined over the duration of the storm, indicative of wash out of pollutants. The removal of most phosphorus from fertilizers is expected to have an effect like that observed, but the lower TKN value is not explained. Some additional sampling in 2016 is warranted to assess inlet water quality.

From a longer term perspective (Table 4), while treatment in 2008 started late and was largely experimental, results for total phosphorus at the end of the initial treatment period for 2008 were <20 μg/L. Similar results were achieved in 2009 and 2010; throughout these three years values approached the ideal 10 μg/L level in early summer. Total phosphorus remained somewhat elevated in early summer of 2011; we do not know if there was some lab error associated with the 2011 early summer values, but the water was fairly clear at that time, so available phosphorus had to be very low, even if the total phosphorus was somewhat elevated.

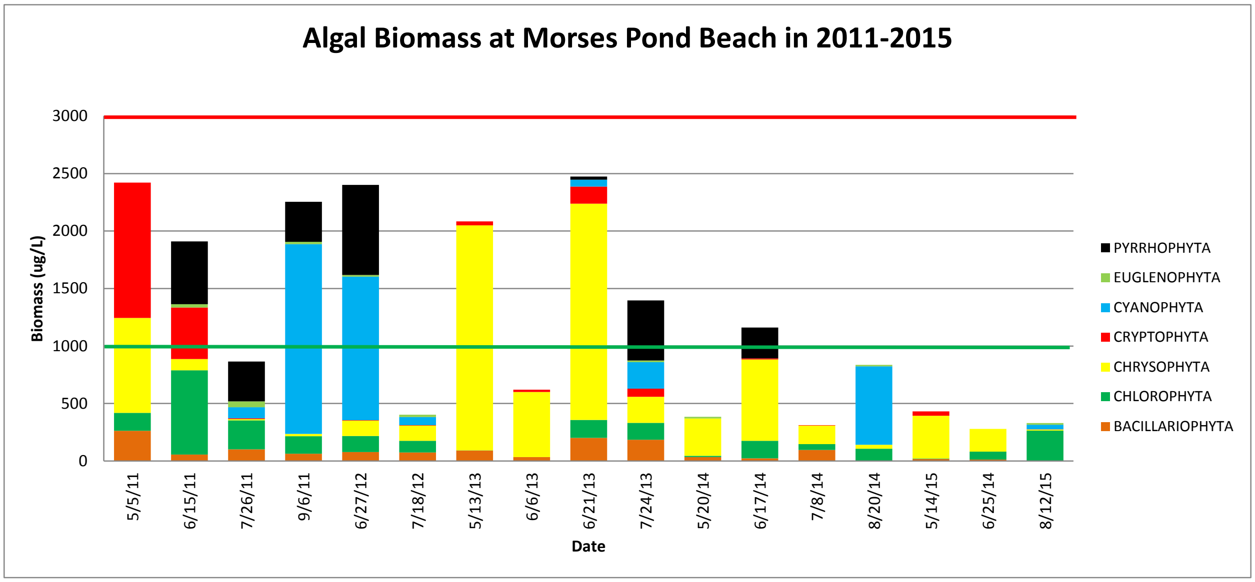
Treatment problems were encountered on most treatment days in 2012, and total phosphorus increased in early summer of 2012. Frequent and timely repairs kept the treatments going, but they were not as efficient and apparently not as effective as in the previous three years. Detention capacity of the north basin was limited by shallow depth resulting from years of sediment deposition; dredging was planned for fall 2012. Consequently, the combination of treatment and detention was insufficient to prevent a bloom from forming in mid-July, and the phosphorus level in the south basin was >20 ug/L. A copper treatment 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 in the summer of 2012.

System repairs by the Wellesley DPW and WRS Inc. made more effective treatment possible in 2013, but rain in June was about 2.5 times the long-term average, and not all incoming runoff could be treated. Phosphorus levels never reached the early summer target, although continued treatment kept values lower than they would have been through early August, when treatment was ceased. Fortunately, high runoff leads to a higher flushing rate, and no algal blooms occurred in 2013.

Conditions in 2014 and 2015 are a product of weather, effective treatment, and improved detention in the north basin. 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, and chemical costs were not elevated. The relationship depicted in Figure 3 has been upheld; maintenance of total phosphorus <20 ug/L minimizes bloom potential. It is possible to have higher phosphorus and no blooms if flushing is consistently high through the summer, but there is usually a dry period during which blooms use nutrients input in prior months unless treatment has occurred.

Algal data for 2011-2015 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. The record for Morses Pond phytoplankton over the last 5 years is varied, but

Figure 4. Algal Data for 2011-2015

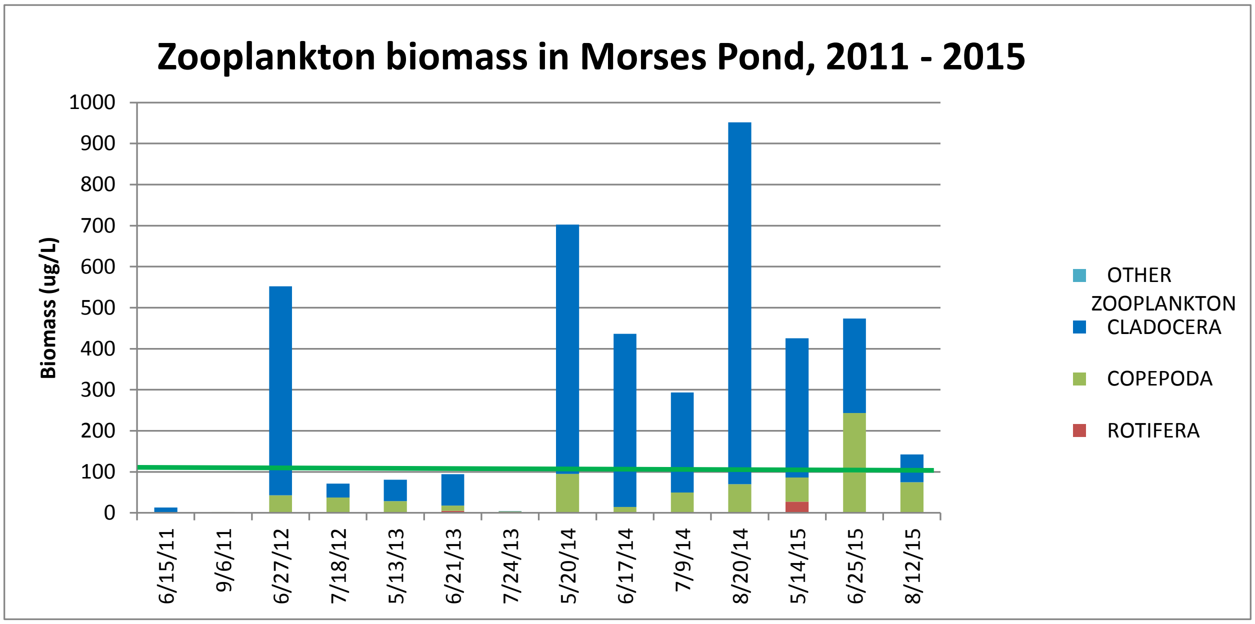


since spring phosphorus inactivation began, biomass values have not exceeded the general threshold of 3000 ug/L that signals low clarity (note that there is no official threshold for algae, but the red line in Figure 3 is a useful limit). Phytoplankton biomass has often been below the 1000 ug/L threshold indicative of low biomass, including 3 of 4 values for 2014. Cyanobacteria were moderately abundant in late summer 2011 and late spring 2012, but have not been common since then. The few cyanobacteria that were detected in August of 2014 were bloom forming species, but did not reach bloom proportions in 2014. Bloom forming cyanobacteria were observed in small clumps along the shoreline in late September of 2015, but were absent from plankton samples.

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; 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 tend 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 years, a good sign, and abundance was elevated in most of spring and summer of 2014 and 2015. The late summer zooplankton population was very low in 2011 and 2013, but was substantial in 2012 and hit an all-time record (for any lake on which we have worked) in 2014. Late summer biomass was also high in 2015, although much lower than in 2014. Variation does not appear to relate to aluminum treatments, which could be toxic at high concentration and high or low pH; the treatment protocols minimize this probability.

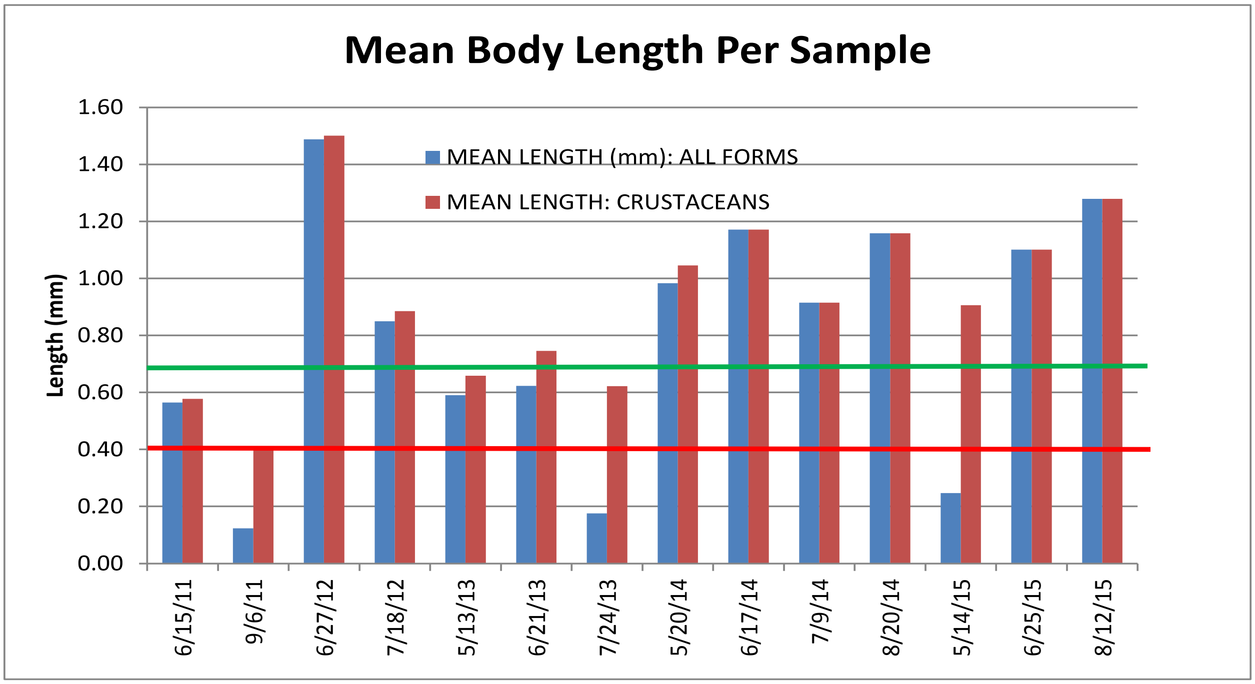
Figure 5. Zooplankton abundance for 2011-2015.



Variation in fish reproduction and predation and flushing rate may have considerable influence, but maintaining a desirable algae community is also important. Algae productivity may still be high in Morses Pond, but as long as the algae are edible and there are plenty of large grazing zooplankton, the standing crop of algae will be low.

The size distribution of zooplankton is important, as larger individuals are more effective grazers and represent better food for small fish. Mean lengths for at least crustacean zooplankton usually exceed the minimum desirable threshold, including for all samples from 2014 and 2015. The grazing capacity in 2014 and 2015 was very high, and undoubtedly contributed to low algae abundance and high clarity. As flows were not high in those years, the influence of fish predation is most critical. The mean length data suggest that there may actually be an overabundance of game fish depressing populations of small fish that eat zooplankton. This is consistent with angler observations of excellent fishing and with the weed harvesting program that removes refuges for small fish. Although too many gamefish for too many years can cause fishery problems, this tends to be a naturally mitigated situation; if food resources are inadequate, the feeders will decline and the food populations will increase. 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 6. Zooplankton mean length, 2011-2015.



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 refinement process was detailed in the 2010 annual report. The current approach is to harvest all areas by the end of June, sometimes using both 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 when the dredging was planned and avoidance pipeline clogging was desired. A second cutting occurs from August into October in areas 2, 3, 4 and 6, with some touch up around the shoreline perimeter of area 7.

The keys to successful harvesting include:

- Initiating harvesting by the Memorial Day weekend.
- 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 the 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 has been 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 has worked well.

A change was made in 2015, when a seasonal employee was hired and dedicated to the harvesting project. Concern over declining cutting hours per day and competing commitments for staff who normally provide harvesting effort prompted this shift in staffing. Cutting began in late May as usual, but continued through the summer until the seasonal employee returned to college in late August. Cutting by permanent staff was deferred until October. There was a two week period in mid- to late June when the large harvester was inoperative until parts were obtained for repairs, but overall harvesting results were very similar to past years.

Harvesting Record

Records provided by the Town of Wellesley indicate the harvesting effort expended on Morses Pond (Table 5). Although the record is not always complete, records have been kept since 2007. Between late May and late October, from 2007 through 2015, harvesting was conducted on a range of 43 to 76 days. This represents a range of 303 to 520 total hours devoted to some aspect of the harvesting program, and 223 to 335 hours of actual harvesting time. Total loads of aquatic plants harvested have ranged from 78 to 125 per harvesting season. 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, with larger weights in more recent years. There is speculation that this is a function of record keeping and not an actual increase in harvest weight, but we cannot be sure.

Between 6.4 and 7.7 hours are spent on a day when harvesting occurs, including transport to and from the pond, actual cutting, transport on the water, loading and unloading, and harvester maintenance. 2014 provided the second highest number of days when harvesting occurred, but the lowest average hours per day in the record. A range of 3.5 to 5.4 hours per day are spent on actual cutting, with a decline between 2009 and 2014. Data for 2012 may be different from those of other years, at least partly due to cutting in area 1 in preparation for dredging; plant density is very high in this section of the pond, which is not normally harvested, and resulted in faster load generation but more travel time, reducing hours spent actually cutting each day but raising the biomass removed. Yet the declining number of cutting hours was observed in all years since 2009 until 2015 (Figure 8), and appears related to increases in time for maintenance and travel. Beginning in 2014, records were kept for non-cutting hours in categories including transport time on the water, transport time on land, and maintenance. The 2015 record indicates that non-cutting time was roughly cut in half by having a staff member dedicated solely to the harvesting program. Continuation of the 2015 approach is recommended.

Figure 7. Plant Management Zones for Morses Pond.

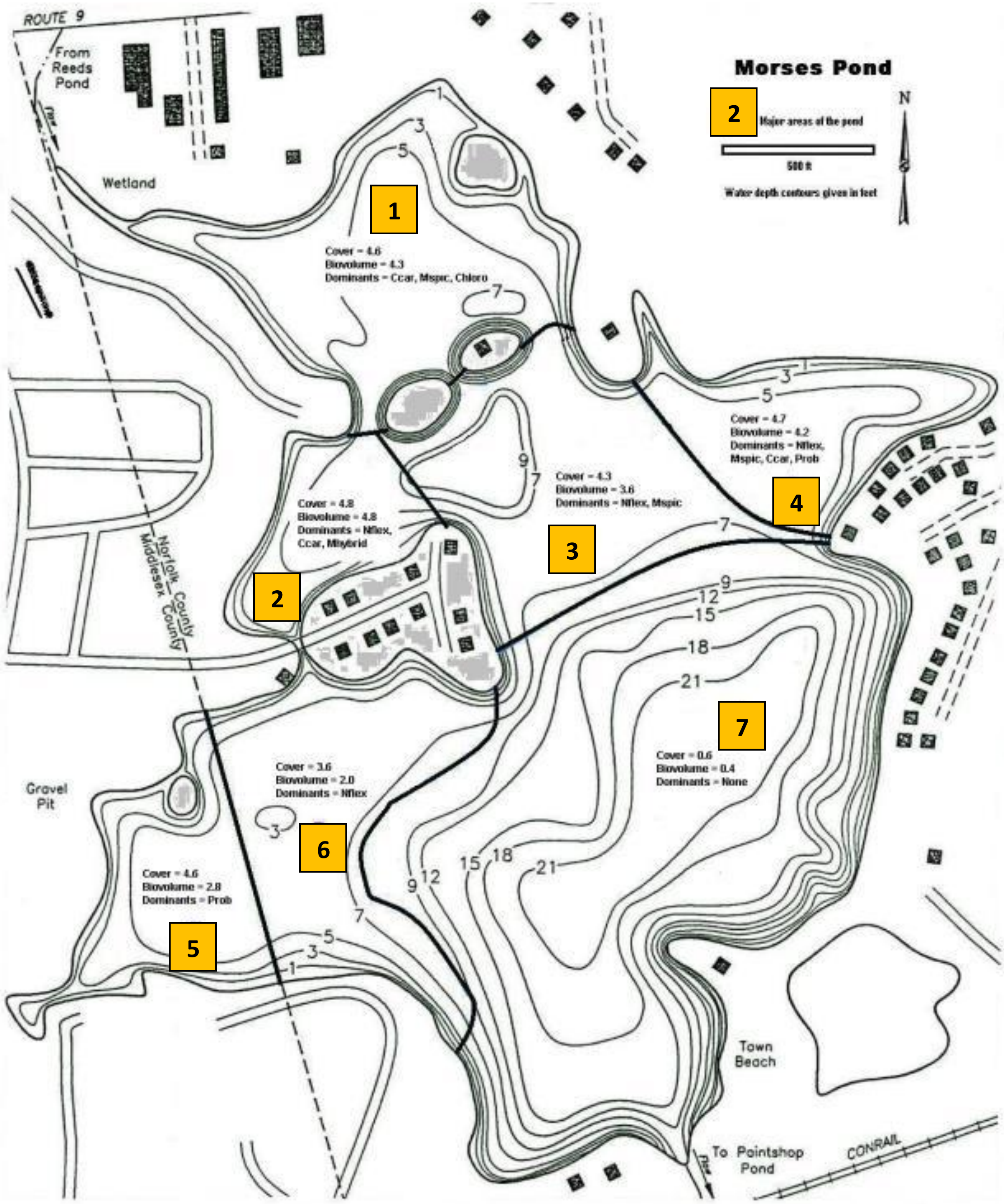
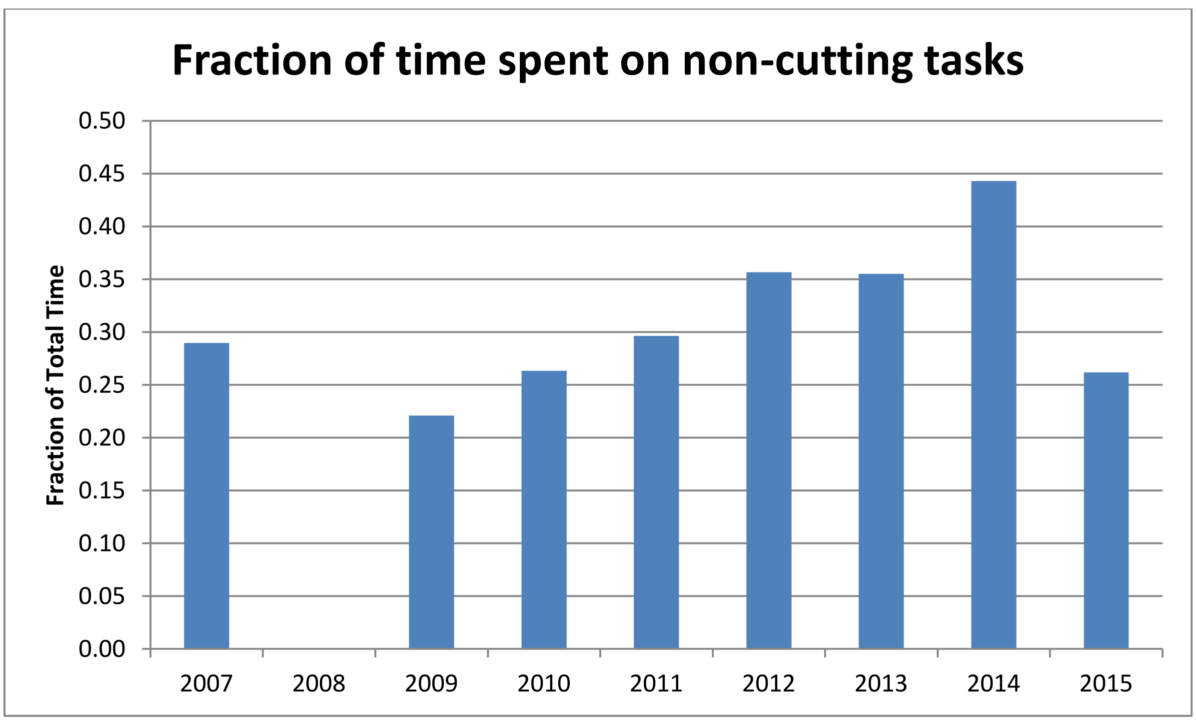


Table 5. Harvesting Record for Morses Pond.

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

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, harvesting includes Area 1, which had very dense plant growths and may account for additional weight removed.

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



Weight per day, per load, per total hour and per cutting hour vary considerably among years, and will vary substantially among days within years. Some periods are more productive than others, owing to areas of variable plant density and distance to the offloading area between the beach and outlet. Weight per cutting hour is viewed as highly relevant, and excluding early "training" years and 2012, ranges from 1000 to 1800 lbs/cutting hour. With a weight per load that is typically between 3000 and 5000 lbs, the operator is ideally cutting for between 2 and 3 hours, coming in to unload and get a break, and getting a second cutting session in the same day. This should result in about 5 hr of cutting per day; this target was met in the first 4 years with records but not been met in the next 3 years. The staffing adjustment of 2015 improved this metric, with 4.7 hours of cutting time achieved per day. The harvester has 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 necessary repairs and a delay in parts acquisition limited harvesting in the last half of June. Harvesting in 2015 continued through July, however, making it a more continuous process. August harvesting has also occurred as planned, and until 2015 harvesting continued into September. Staffing limitations pushed fall harvesting into October, and it will be interesting to see if any spring improvement is observed as a result.

We are missing plant weight data from 2007 and hourly activity data from 2008, and the identification of plants being targeted by harvesting is not always consistent with what has been observed by staff in the field. Robbins' pondweed, a desirable species, was the dominant plant harvested on 3 days early in the 2014 program, but is generally avoided. Two species of milfoil and fanwort are the primary targets of harvesting, amounting to more than ¾ of all biomass harvested based on 2014 and 2015 records. Some water lilies are also targeted to thin patches. There have been problems with plant fragment creation and accumulation along shorelines in some years. Some fragment release is unavoidable, but adjustments were made that greatly improved performance in recent years. There have been changes in personnel and procedures, so continued training should be emphasized. Overall, the plant harvesting program has been proceeding well, achieving desirable results, and being adjusted to enhance performance as warranted. Improved efficiency is the primary goal moving forward.

There have been some plant controls additional to mechanical harvesting with "standard" weed cutters. A benthic barrier was installed at the swimming beach in 2008 as a pilot study, but no further application occurred. The original benthic barrier is still in place, but is buried under sand. 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.

Hydroraking occurs annually if needed in the beach area, prior to setting up the ropes and docks. In 2013 there was no hydroraking, but dredging of sand deposits to deepen the north basin facilitated beach nourishment in the swimming area, and any plants in that area were buried by sand transported in the dredging pipeline. Hydroraking of the swimming area was conducted in 2014, with 6700 lbs of plants removed. Hydroraking of shallow areas was desired by many shoreline residents, and was planned for 2009. However, equipment problems precluded execution of hydroraking beyond the beach area that year. Hydroraking of peripheral areas was conducted in 2010, with residents paying for those services off their shoreline parcels. Hydroraking of the beach area and several peripheral areas subsidized by private citizens occurred in 2015 as well.

Plant Surveys

Plant surveys were conducted in early to mid-May of 2008, 2009, and 2010 prior to plant harvesting to determine the assemblage features and facilitate recommendation of any program adjustments. These surveys have helped to identify areas supporting very dense aquatic plant growths and helps set priorities for harvesting. Shoreline surveys were also performed to guide localized plant control by shoreline residents, including proposed hydroraking. In 2011, with the harvesting program protocols generally well known to the DPW staff involved in the project, we opted to survey the plants at selected stations during the harvesting, allowing some comparison among harvested areas as a consequence of harvesting. This process was repeated in 2012 and 2013 for continued comparison of harvested vs unharvested areas. In 2014 and 2015 we returned to a pre-harvesting survey to determine if there had been any cumulative impact of harvesting, as it is possible that repeated harvesting could shift the plant community to lower growing, more desirable forms.

Methods

Surveys applied the point-intercept method, resulting in 306 survey points on Morses Pond the same as utilized during the 2005 vegetation survey that set the stage for the comprehensive plan as relates to plant control in 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.

Shoreline surveys to support hydroraking were described in the 2010 annual report. No such surveys were conducted after 2010. The number of points surveyed has been reduced since 2011, based on statistical analysis of how many points are necessary to get an accurate appraisal of plant conditions, but the choice of points is randomized within each established zone each year, so the 306 point configuration remains valid and useful.

2015 Results

For the point-intercept surveys, 37 species are known from Morses Pond, with 23 plant species detected in 2005, 20 plant species encountered in the 2008 and 2009 surveys, 24 in 2010 and 2011, 25 species in 2012, 20 species in 2013, 18 species in 2014, and 25 species in 2015 (Table 6). Oscillations in species richness are largely a function of a few rare species being found or not found in any given year; the dominant suite of species remains the same. The four invasive submerged aquatic plant species encountered include:

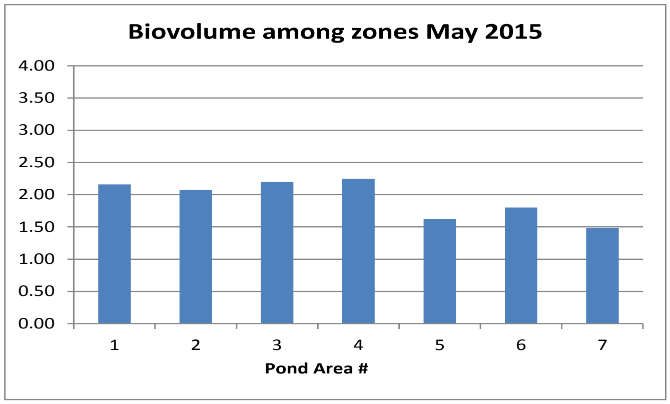
- *Cabomba caroliniana* (Fanwort)
- *Myriophyllum spicatum* (Eurasian watermilfoil)
- *Myriophyllum heterophyllum* (Variable watermilfoil)
- *Potamogeton crispus* (Curlyleaf pondweed)

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*

Table 6. Aquatic Plants in Morses Pond.

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

Figure 9. Biovolume of Plants in Areas of Morses Pond in 2015.



salicaria (Purple loosestrife) is a peripheral species that is abundant but not always picked up by our aquatic surveys.

Overall, Morses Pond exhibited moderate vegetation cover and biovolume prior to harvesting in 2015 (Figure 9). This is not appreciably different than other years. As the survey is usually in May, cover and biovolume have not reached maximum levels, and values are much higher for unharvested areas in summer. Dominant species 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. The harvesting operation accomplishes that goal in the target areas most of the time, but growth prior to harvesting in the spring can be substantial, and getting to all areas requires effort through June.

Multi-Year Results

One central question is whether or not the harvesting is making any longer term difference. It is possible that the twice per year cutting will favor low growing species over the invasive species that fill the water column over time, but no evidence has been obvious since the new harvesting program began in 2007. With start up and training, it was not until about 2011 that the program was running at full capacity; the 2010 plant survey occurred prior to harvesting and makes a good point of comparison for later data that are also collected prior to harvesting. Comparing 2015 data prior to any harvesting with data from 2010 prior to any harvesting, we do not see a decrease in the biovolume of plants coming into the harvesting season (Figure 10). In essence, the plant community grows back to its original biovolume status each year, despite harvesting in many (but not all) areas. Note that Area 5 is not harvested, Area 7 is minimally harvested, and Area 1 was only harvested twice, but part of it was dredged. Yet areas 2, 3, 4 and 6, which are harvested twice per year, show no indication of decreased biovolume the following spring after repeated years of harvest.

The frequency of the main invasive species, fanwort and two milfoil species, showed a decrease between 2010 and 2014, although only Eurasian watermifoil exhibits such a decrease in 2015 (Figures 11-13). However, the unharvested areas exhibit similar decrease. Two of the more desirable species, common naiad and Robbins' pondweed, showed even more pronounced decreases in 2014, even in unharvested areas. In 2015, common naiad was still scarce in most areas, but was much more abundant in area 6 than in recent years (Figure 14). Robbin's pondweed rebounded in 2015 and was more abundant (Figure 15) in many areas. The plant community is not especially stable, but there is no strong indication of a decrease in nuisance species or a steady increase in desirable species from harvesting.

Any decline in the frequency of invasive species in harvested areas may be a consequence of reduced species richness. There is a decline in the average number of species found at each survey station (Figure 16) for all pond areas except area 7, which receives very little harvesting. However, area 5 also receives minimal harvesting and exhibited a decline in species richness. Harvesting has not increased species richness, but it is not clear that it is responsible for any perceived decrease.

Figure 10. Biovolume Comparison, 2010 vs. 2015.

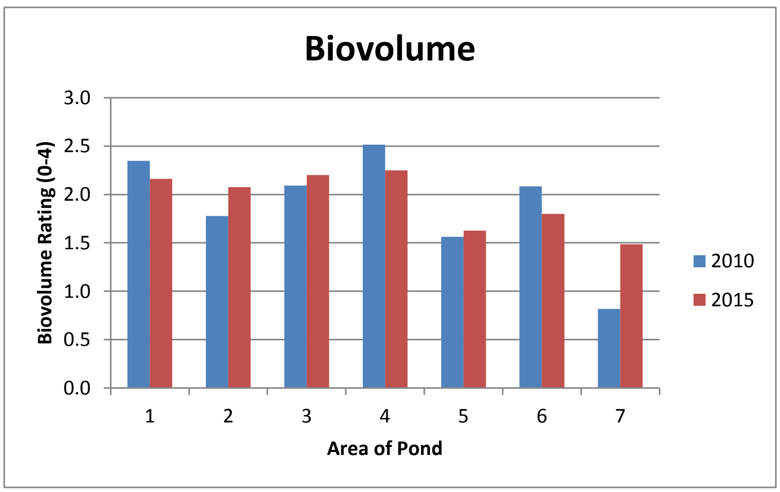


Figure 11. Fanwort Frequency Comparison, 2010 vs. 2015.

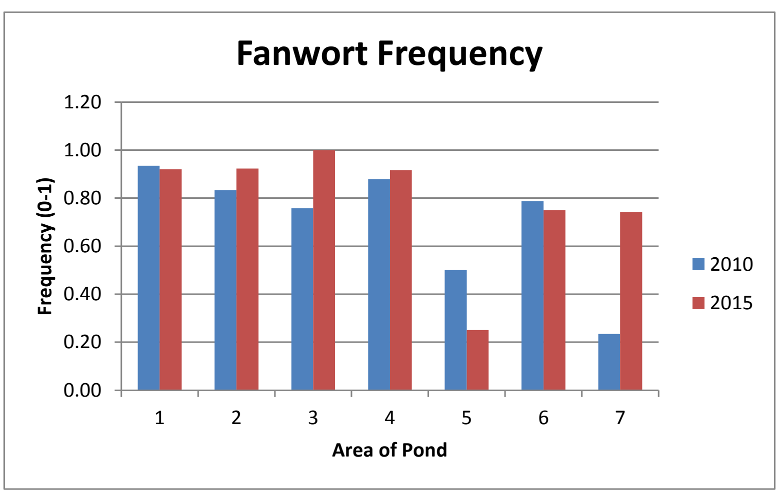


Figure 12. Variable Milfoil Frequency Comparison, 2010 vs. 2015.

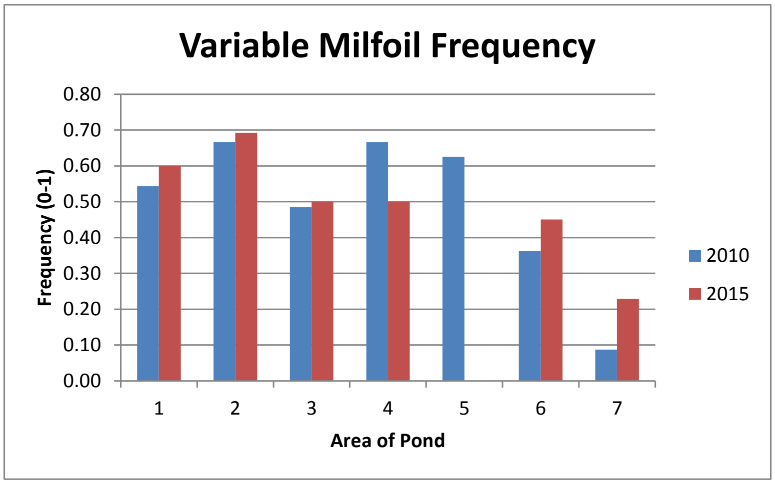


Figure 13. Eurasian Milfoil Frequency Comparison, 2010 vs. 2015.

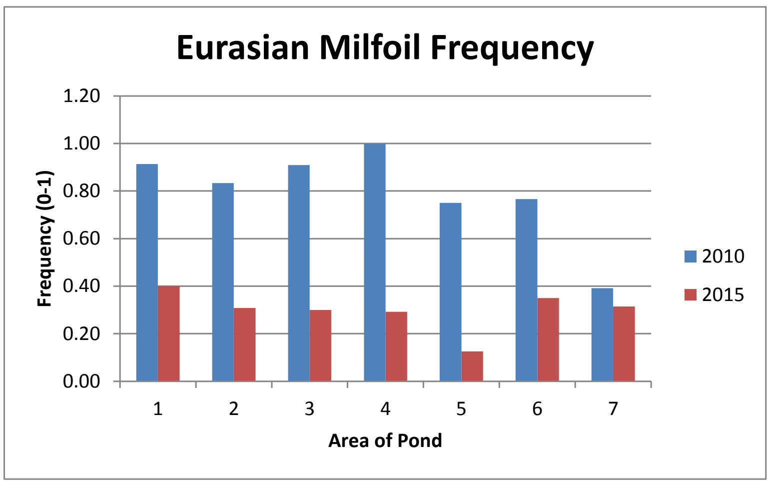


Figure 14. Common Naiad Frequency Comparison, 2010 vs. 2015.

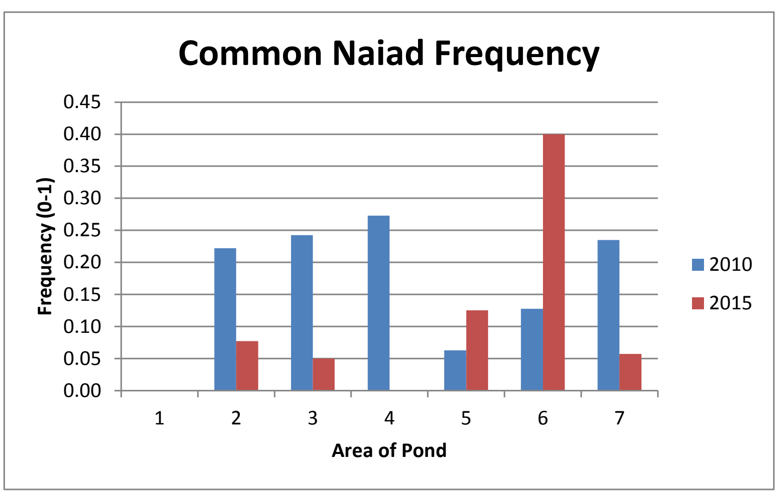


Figure 15. Robbins' Pondweed Frequency Comparison, 2010 vs. 2015.

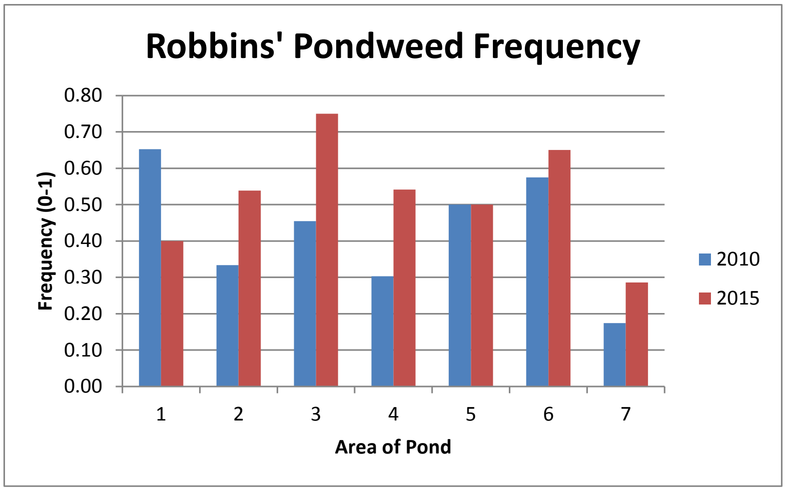
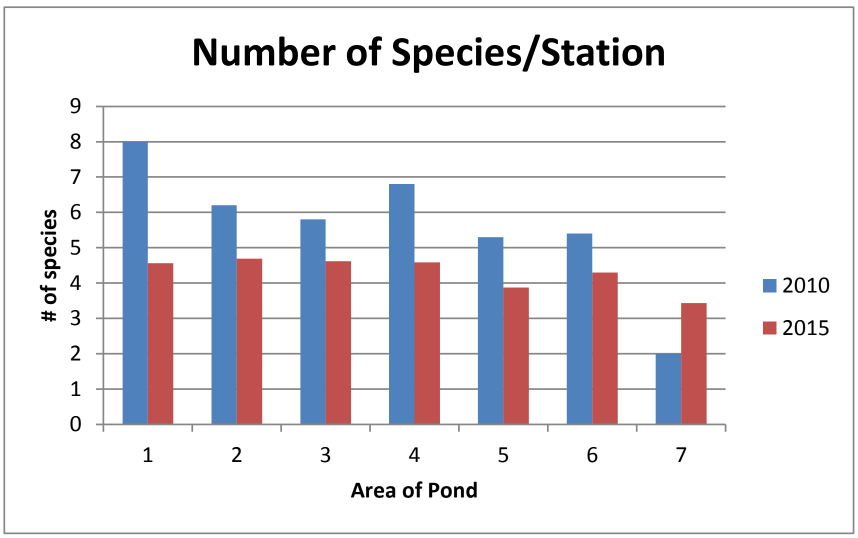


Figure 16. Comparison of Number of Species per Survey Station, 2010 vs. 2015.



Conclusions Relating to Plants and Mechanical Harvesting

The plant community of Morses Pond would still be too dense in most areas without harvesting and is dominated by invasive species. Harvesting with the newer, larger harvester and an adjusted approach appears to be controlling biomass and the portion of the water column filled, but shifts in species dominance are not extreme; invasive species have been reduced in frequency of occurrence in some years, but so have other species, and changes are not lasting or unidirectional. Harvesting keeps areas open for habitat and recreational use, but apparently must occur each year to maintain those gains. Harvesting is a reliable maintenance technique, but has not yet been demonstrated as a strong force in shaping the longer term plant community in Morses Pond.

Hand Harvesting

A group of volunteers within the Friends of Morses Pond has accepted responsibility for finding and pulling out water chestnut (*Trapa natans*) plants in Morses Pond each spring and summer. This group uses kayaks and manual removal to eradicate pioneer infestations before seeds can be formed and deposited. This effort continues to be very successful; no water chestnut has been recorded in any lakewide plant survey to date. Plants are typically encountered in peripheral areas with considerable emergent or surface vegetation and are attributed to seeds being transported to Morses Pond by waterfowl, a common dispersal method for this invasive species.

As a seed producing annual species, water chestnut is best controlled by plant removal prior to seed production. Once seeds have been produced and dropped by the plant, removal will not prevent recurrence the following year. Consequently, it is important to locate each new plant and pull it prior to seed release, usually by the end of July. The Morses Pond program concentrates on early detection and removal, and has been supported by the town through the provision of kayaks, but is otherwise a completely volunteer effort that has proven very effective.

Low Impact Development Demonstration

In the spring of 2008, AECOM evaluated public sites within the Morses Pond watershed for future application of Low Impact Development (LID) techniques. A desktop analysis was conducted on the approximately 60 parcels identified. Out of the 60 parcels, 13 locations were identified for further field investigation. Based on the field investigation, the Upham Elementary School and Bates Elementary School were chosen as the best properties for a LID demonstration.

The Upham Elementary School was selected for further design, and in 2009 preliminary design plans and specifications were prepared. The design included conversion of grassed islands and a portion of the paved play yard in front of the school to a series of water quality swales with added bioretention filtration of stormwater. The design also included a larger biorentention area behind the school by the ball field parking. AECOM worked with Wellesley DPW and the Natural Resource Commission (NRC) on fine tuning the design to provide a demonstration project that would provide water quality treatment with minimal maintenance requirements. In early 2011 the plans were rejected by the school board due to impacts to trees in the area. This was a surprising turn of events, and the NRC developed an alternative plan a LID demonstration project.

As an alternative, a demonstration project was completed in the Morses Pond beach complex area. This was viewed as a high visibility site during the beach season, and could be used to educate residents about the need for and potential of simple landscaping techniques in managing urban water quality. Two rain gardens were established and a roof drip line erosion control system was installed. This was meant as both a functioning system for the beach complex and as an educational tool. There has not been any follow up activity, however, and this sort of effort needs to be expanded within Wellesley.

Education

The Town of Wellesley produced an informative brochure on the importance of phosphorus control many years ago, and has expanded on this approach to resident education since then. Everyone interacting with the Natural Resources Commission is provided an educational packet which contains brochures and other materials under the theme of the Green Wellesley Campaign. The packet focuses on protecting the environment and living a more sustainable lifestyle as a resident of Wellesley, although the contents are applicable to almost any town in the area. 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.

The NRC has assembled an excellent suite of educational materials, and while it may take years to affect the cultural shift in our thinking and habits that protects and improves our environment, this is an important step in the right direction.

The Town also has bylaws relating to lawn watering and other residential activities that affect water quality in streams and lakes, including Morses Pond. The extent to which residents understand these regulations is uncertain, but the educational packet helps in this regard. The right messages are being sent, but reception and reaction have not been gauged recently.

In 2006 a survey was conducted by AECOM on behalf of the Town to assess resident awareness and practices. It appeared that more people handled their own lawn care than expected, and that most were anxious to learn about approaches that might have less impact on water quality. Most homeowners had little background knowledge of issues relating to fertilizer use and other residential management practices.

It was determined that a website would be a desirable additional means of communicating with residents on their role in protecting water quality through desirable residential practices. Morses Pond pages were constructed to be incorporated into the Town's website. Layout and content were adapted from existing materials and subject to review. Revision has been underway since summer of 2011, but town staff time for review and direction has been very limited. Expenditure of time and funds on the phosphorus inactivation system in 2012 - 2015 limited resources by the Pond Manager to devote to this effort as well. We need to revisit this resource, update and improve it, and perhaps resurvey the town population for environmental awareness and actions in 2016.

Dredging

The Town of Wellesley arranged for the North Basin to be dredged in the late 1970s; no dredging had been conducted since 1979, and both natural and anthropogenic sources of sediment have causes considerable infilling of the North Basin since that time. Dense growths of submergent and emergent vegetation limit recreational utility and habitat value in the North Basin, although some forms of water-dependent wildlife benefit from these conditions. While dense vegetation does provide some filtering capacity, the overall loss of depth limits detention time and facilitates resuspension during storms, threatening water quality in the main body of the pond. It was determined as part of the comprehensive planning process that the North Basin should be dredged again to restore detention capacity.

In 2009 the Town hired Apex Inc. to develop dredging plans and shepherd them through the dredging process. Sediment quantity and quality were assessed, plans were developed, and permits were secured. A number of complications arose, including the need to document yet again that Morses Pond was not a Great Pond under the laws of the Commonwealth and therefore not subject to Chapter 91, an additional regulatory process. That effort was ultimately successful.

More troublesome was the detection of metals and hydrocarbon contamination in the north basin, something not observed previously. However, dredging regulations and related contamination thresholds had changed since the previous sediment assessment in 2004, and not all the same tests were run in earlier sampling. The result was that the permitting process took longer than hoped and the cost to dispose of the sediment was considerably higher than initially expected. The targeted area was reduced to about two acres to both avoid areas of greater contamination and to attempt to keep the cost within the allocated amount.

An agreement was secured from the Catholic Diocese of Massachusetts to utilize the parking lot of the "closed" Catholic Church on Rt 9 as a dredged material processing area. However, material had to be removed by March of 2011, and delays in the permitting process caused bids to be secured for the work in September, with an anticipated starting date of early November 2010. Contractors were clearly uncertain about dredging in late autumn and achieving adequate dewatering over the winter to clear the parking area by spring. As a result, fewer contractors submitted bids, and the lowest bid was approximately twice the amount allocated for the dredging.

It was decided that no bid would be accepted and that the dredging project would be revisited in a year or two, when additional funds could be secured and when the timing of the project could be potentially made more advantageous. No further action occurred in 2011, but additional funds to pursue dredging were allocated in 2012 and the project was put out to bid successfully. Cashman Construction was the successful bidder, and Apex has acted as the Town's agent in the process. The Pond Manager had minimal involvement with the dredging project, but dredging has now been completed and summary information is available.

Soft sediment was dredged in the fall of 2012. Soft sediment was dried in geotubes on the adjacent property (former St. James parish, eventually to be a town facility) until spring 2013, when it was hauled away and the parking area was restored to its former condition. Additional dredging of coarser sediment (mostly sand) exposed by soft sediment removal was conducted in the spring of 2013 and used for beach nourishment in the town swimming area. Visual inspection of the swimming area during summer 2013 indicated that the added sand buried most plants and created a more favorable substrate for human uses. However, by mid-summer there were some milfoil and fanwort plants colonizing the deposition area. No nuisance conditions were observed, but the substrate appears hospitable for at least some plant growth. The swimming area was hydroraked in 2014 prior to opening for the season, with 6700 lbs of mostly invasive plants removed.

The reported sediment removal tally was 12,104 cubic yards (cy), with 6,383 cy of mainly muck sediments that was dried at the St. James site and disposed of in an approved landfill, and 5,721 cy of sandy material that was pumped to the beach area. The contract value was just under $820,000.

The dredging of the north basin was an expensive project and only a few acres of area have actually been dredged. Any sediment removal increases detention capacity of the north basin, however, an important settling and pollutant processing area within the pond, and is highly desirable. A smaller area was dredged to a deeper depth, expecting that other material will slough into the depression and result in a less topographically severe slope over time, but still providing increased detention time (about 20% more). It may be desirable to hydrorake a channel through the dense growths to direct inflow from Bogle Brook to the newly deepened area, but this may not be necessary. Evaluation of flow path in 2013 - 2015 indicated that most flow did move through the newly dredged area, maximizing detention.

The plant survey included some points in the dredging area, allowing comparison with non-dredged, unharvested areas. Cover and biovolume were both substantially reduced. However, invasive submergent species were the most common plants found in the dredged areas, albeit at low densities. Visual assessment indicated some accumulation of fine silt after only a month since dredging ended, but this sloughing of nearby organic matter into the new “hole” was expected. The substrate is mostly sandy, but plant growth can be expected in water <8 ft deep. A substantial portion of this area is deeper than 8 ft, however, so regrowth may be low as a function of light limitation.

Financial Summary

Not all of the allocation for FY15 was expended as of the end of June 2015 (Table 7), as not as much time had to be spent working with the P inactivation system; in essence, operations went better than expected, but as the treatment season largely coincides with the end of the fiscal year, and surplus can’t easily be spent in the remaining time. A total of $5971 from the Pond Manager Account of $51,020 was unspent. The full $7,140 under the Monitoring Account was expended. Sometimes funds from the Phosphorus Inactivation Account are allocated to WRS for additional labor as needed, but no funds were used by WRS in FY15. Rather, funds from that account were used for chemical supplies and system repairs by the DPW.

As of the last invoice, dated November 6, 2015, just under 15% of the FY16 allocation of $59,450 (between the Pond Manager and Monitoring Accounts) had been spent. This includes some summer treatment and monitoring, plus meetings and follow up work in fall 2015, and is typical of this time in the contract cycle. Most effort is expended in the spring during the P inactivation period, and funds have to be conserved to ensure that that element of this project is properly carried out. However, with the move to automation and remote control over the P inactivation system, we should realize significant savings that can go into other tasks like education that have received less attention in recent years.

Additional funds were available for the automation of the phosphorus inactivation system, which is in progress. The actual automation work is largely complete, but new pumps were needed and must be tied into the system. Some funds may have to come from the Pond Manager Account, so we can't know how to allocate funds for various tasks in 2016 until that work is complete, but we anticipate no shortfall overall, and hope to extend our efforts more deeply into other areas in the second half of FY16.

Table 7. FY2015 financial summary.

Account	Task	% complete as of this invoice	$ Invoiced by WRS	$ Allocated to WRS	% Allocation Expended	Notes
Pond Manager (FY15)	Support for Morses Pond Management	25%	$45,049.00	$51,020.00	88.3%	Had to treat inflow less than expected, so some $ left
Monitoring (FY15)	Water quality tracking	100%	$7,140.00	$7,140.00	100.0%	All FY15 sampling complete
P Inactivation (FY15)	Treatment at inlets to reduce phosphorus	0%	$0.00	$0.00	0.0%	No funds from this account used by WRS
		Total	$52,189.00	$58,160.00	89.7%	Total of $5971 from two accounts unspent