Western Basin of Monponsett Pond

Halifax and Hanson, Massachusetts

2015 Year-End Alum Treatment Report

Prepared for:
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Appendices

I. INTRODUCTION

Aquatic Control Technology (ACT) was contracted by the Town of Halifax to conduct a Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond. In accordance with this contract, the following document serves as a year-end report to summarize the tasks completed in the 2015 management season.

Image 1. 2015 Treatment Zones of the Western Basin of Monponsett Pond

II. PERMITTING

U.S. Environmental Protection Agency National Pollution Discharge Elimination System Permit

Lycott Environmental filed an electronic Notice of Intent (eNOI) under the U.S. Environmental Protection Agency Pesticide General Permit (PGP) for the application of pesticides to the Monponsett Ponds on behalf of the Town of Halifax on May 9, 2012. This application was signed and submitted by the Town of Halifax on May 19, 2013, which then received an active status ten days following its submission. The NOI remains valid until May of 2018.

Massachusetts Endangered Species Act Project Review

A 'REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond' was submitted to the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (NHESP) on March 31, 2015. The NHESP provided approval correspondence on May 14, 2015.

Order of Conditions

The Orders of Conditions (Halifax & Hanson) have been automatically extended by the Permit Extension Act and are therefore valid for an additional four years from the original date of expiration or until 2019.

Massachusetts Department of Environmental Protection License to Apply Chemicals

ACT prepared and filed for the required License to Apply Chemicals permit from MA DEP Office of Watershed Management; the approved license was issued on May 13, 2015 (#15139).

III. 2015 TREATMENT PROGRAM CHRONOLOGY

The tasks performed as part of the 2015 treatment program are outlined below.

- Received approved MA DEP License to Apply Chemicals 5/13/2015
- Received management plan approval from NHESP 5/14/2015
- Alum treatment #1 6/02/2015
- Alum treatment #2 6/30/2015
- Alum treatment #3 7/23/2015

*Note: Pre-treatment, 1- and 3-day post-treatment surveys and sampling were conducted after each treatment. Further, 7-day post-treatment surveys and sampling were only done after treatment #1 & 2.

IV. TREATMENT LOGISTICS

A total of three (3) buffered, low-dose alum applications were administered during the 2015 management season: June 2nd, June 30th and July 23rd. During each treatment event, one specially equipped treatment vessel was used to apply 3,000 gallons of aluminum sulfate and 1,500 gallons of sodium aluminate to areas greater than 4' in depth in the West Basin of Monponsett Pond, an area totaling 235 acres. The 235 acre treatment area

was further divided into three smaller pre-determined treatment zones ('**Image 1**') with relatively similar depth characteristics in order to ensure accurate dosing and a more uniform application of the alum and sodium aluminate. These smaller treatment zones were then treated evenly with an approximate 0.7 ppm of Al.

V. MONITORING PROGRAM

The following table outlines the major components of the monitoring program and their respective goals, as approved in the habitat management plan ('**Appendix A**').

Table 1. Monitoring program design

Monitoring component	Timing in relation to treatment	Location(s)	Goals
Water Quality	Before, during and after each application	1 established location within each treatment zone	Evaluate short and long-term effects on water quality
Measurement of flocculation	During	1 visual recording; 6 measurement locations	Assess the amount of floc accumulated on the sediment
Monitoring of state-listed species	Before, during and after one and five years following	5 paired plots	Evaluate short and long-term effects on these species identified by NHESP as potentially susceptible to the treatment

a. WATER QUALITY MONITORING

Baseline, required water quality parameters (i.e., pH, total and dissolved phosphorus, alkalinity and turbidity) were gathered at a pre-determined location within each treatment area. These data were collected during pre-treatment and 1- and 3-day post-treatment sampling efforts for each treatment event. Also, these data were collected during 7-day post-treatment sampling efforts, however, for the first and second treatment events only ('**Appendix B, Table 1**'). Additional *in situ* water quality parameters (i.e., temperature, dissolved oxygen and water clarity [via Secchi disk]) were collected at the same locations at 1- and 3-day post-treatment sampling efforts for each treatment ('**Appendix B, Table 2**').

Total Phosphorus Monitoring

A total phosphorus measurement was collected per treatment area per sampling event over the 2015 management season, for a total of 24 measurements overall. Phosphorus levels overall decreased following the first and second treatment events, with the exception of a temporary increase at Site B until the third pre-treatment sampling. Following the third treatment, phosphorus levels at all three sites rebounded to levels similar to that prior to the second treatment ('**Figure 1**'). Overall the results show a reduction in total phosphorus of nearly 50% (46 ppb June – 26 ppb July) during the course of the season.

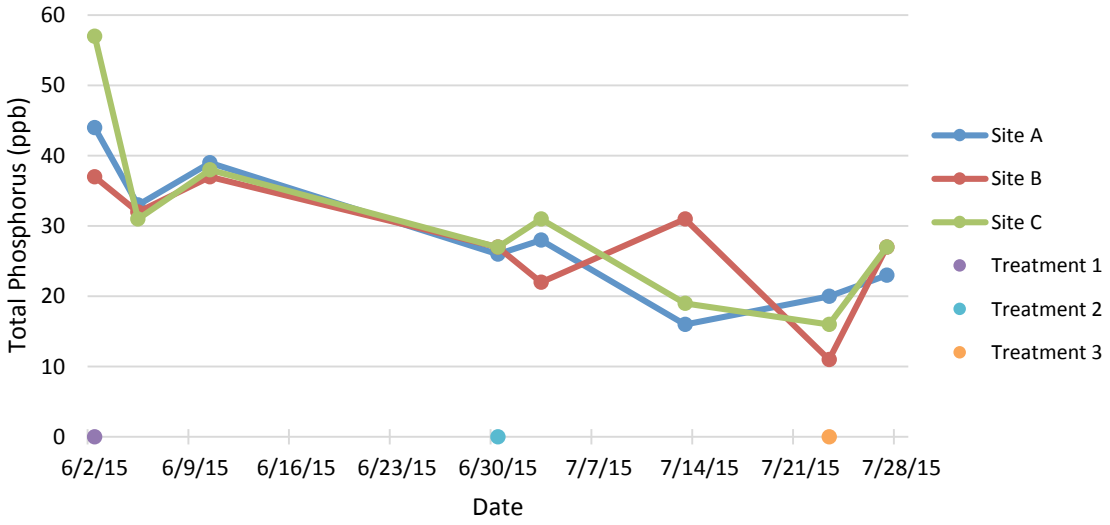

Figure 1. Comparison of total phosphorus (ppb) during pre- and post-treatment sampling within each treatment zone in the West Basin of Monponsett Pond, (June 2 to July 27, 2015).

Dissolved Oxygen Monitoring

A dissolved oxygen measurement was collected *in situ* per treatment area per sampling event throughout the season, totaling 73 measurements. Despite observed fish mortality at the time of the first buffered alum treatment, early morning and daytime dissolved oxygen levels recorded were sufficient to support a variety of fish species. A slight increase in dissolved oxygen was observed following the first treatment event; however, levels later decreased and remained stable ('**Figure 2**'). The dissolved oxygen measurements suggest that levels remained within desirable ranges (> 5 mg/l) for fish and wildlife populations throughout the course of the program and were not significantly impacted by the buffered alum treatments.

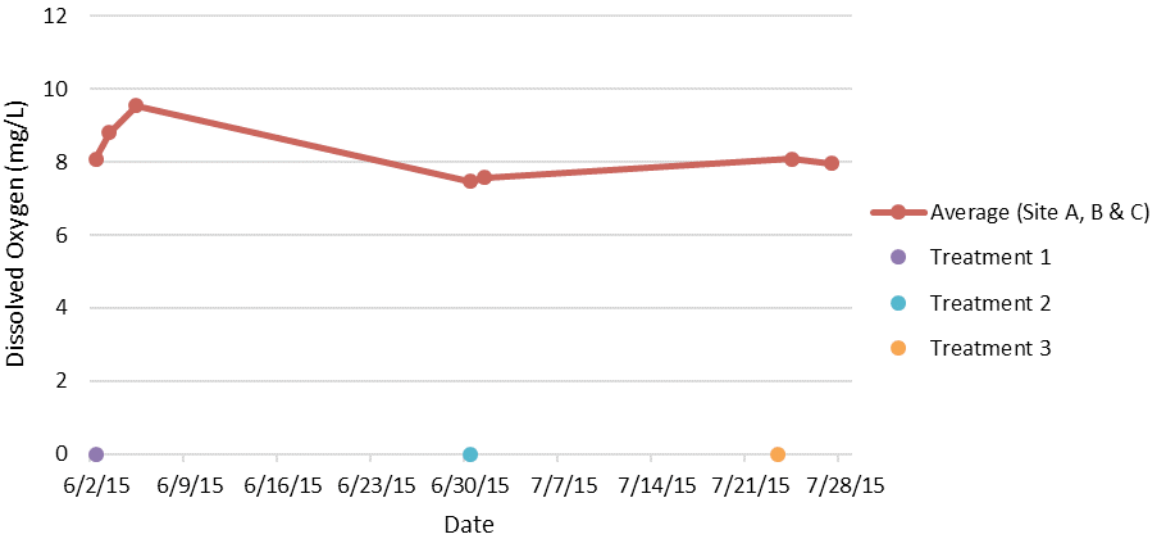

Figure 2. Average dissolved oxygen (mg/L) sampling results of all three treatment zones, (June 2 to July 27, 2015).

Water Clarity Monitoring (via Secchi Disk)

Water clarity was measured five (5) times per treatment zone, with the exception of Site C, which was measured an additional two (2) times, throughout the season. After the first treatment event, there was an increase in Secchi depth, which correlates to better water clarity. However, the depth decreased slightly throughout the remainder of the management season ('**Figure 3**'). Despite fairly consistent algal abundance recorded during our sampling, the Secchi depth measurements along with visual observations suggest a reduction in clarity due to increasing algal cell density.

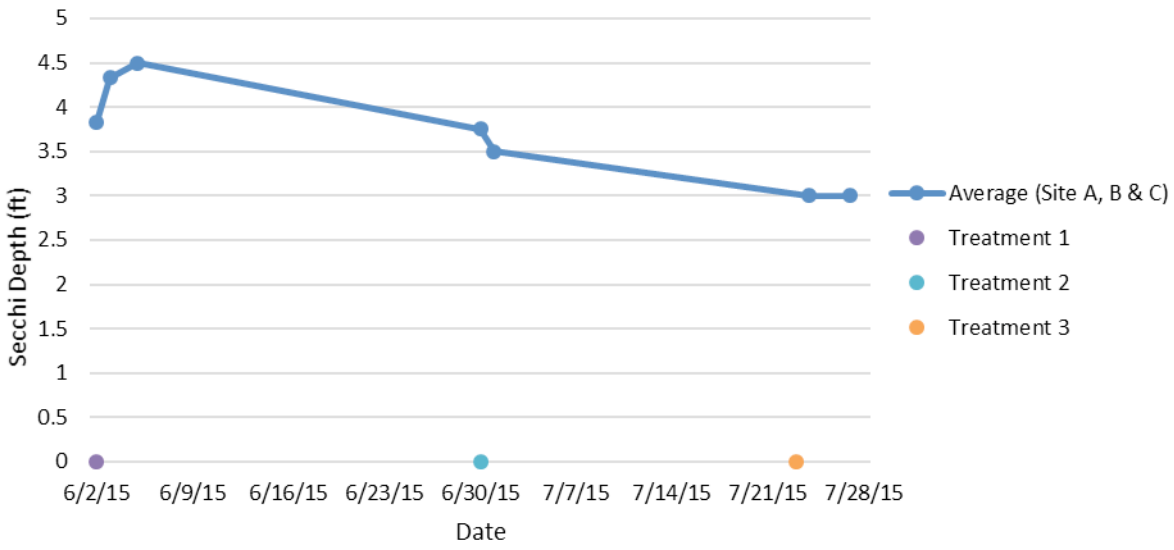

Figure 3. Average Secchi Disk depth (ft.) results of all three treatment zones during pre- and post-treatment sampling, (June 2 to July 27, 2015).

pH Monitoring

A pH measurement was collected per treatment area per sampling event over the 2015 management season, for a total of 24 measurements overall. pH levels remained fairly steady for the first and third treatment events and their post-treatment measurements. However, following the second treatment, there was a decrease and then sharp increase in pH levels, from approximately 6 to 8 ('**Figure 4**'). Overall the results show relatively constant pH levels throughout the management period. Although there was a significant pH drop immediately following the second buffered alum treatment, *in-situ* measurements performed during the course of the treatment indicated minimal pH fluctuations (7.25-6.75 SU) in response to the aluminum sulfate and sodium aluminate application. Despite the decline values remained within the range of 6.0-7.5 SU that is desirable for the aluminum - phosphorus reaction.

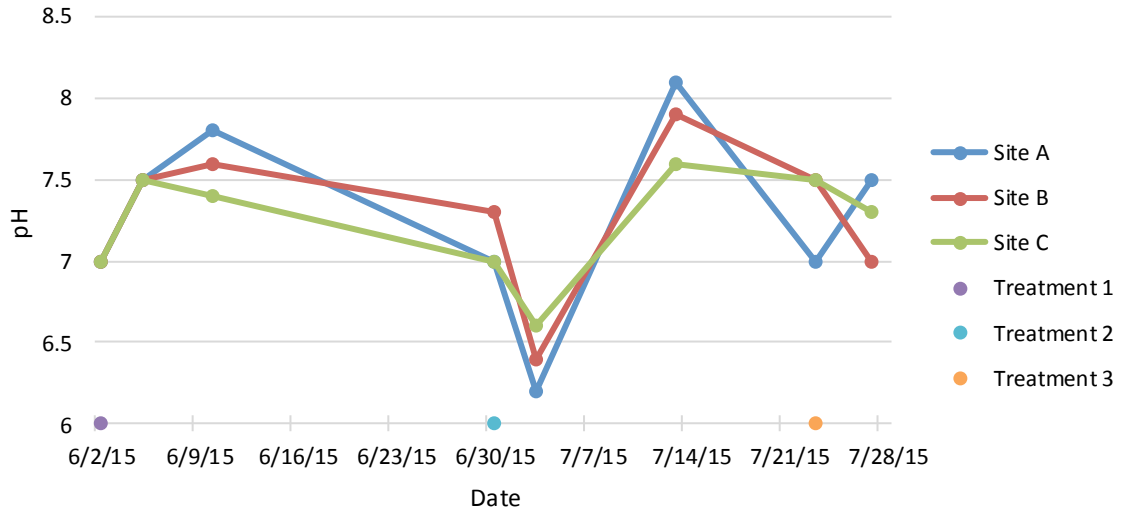

Figure 4. Comparison of pH during pre- and post-treatment sampling within each treatment zone (June 2 to July 27, 2015).

Total Alkalinity Monitoring

Total alkalinity was measured per treatment area per sampling event, for a total of 24 measurements overall during the 2015 management season. The total alkalinity measurements remained steadily between approximately 7 and 9 mg/L throughout the sampling program, with the exception of two non-detect measurements on June 5, 2015 at Site A and B ('**Figure 5**').

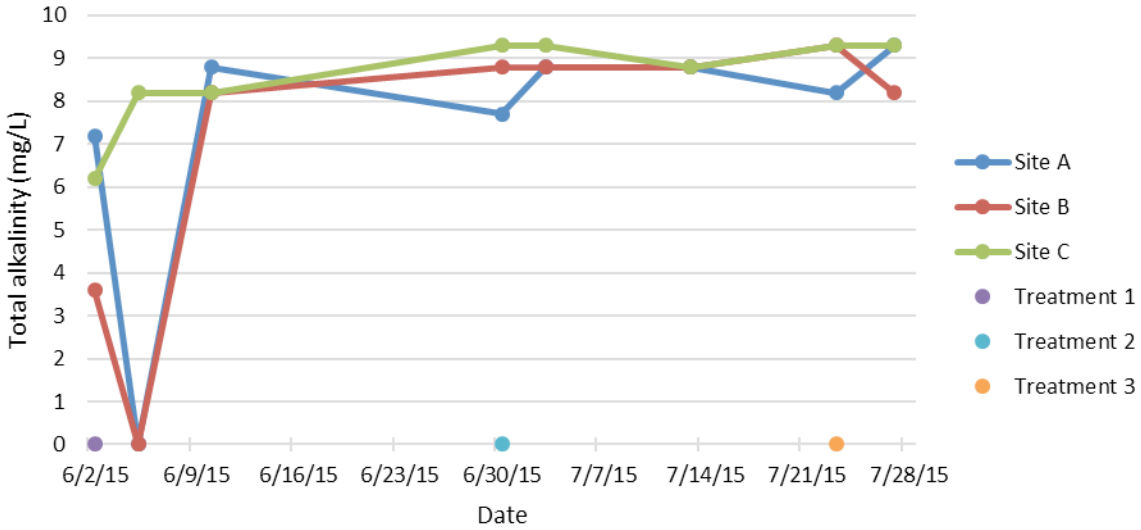

Figure 5. Comparison of total alkalinity (mg/L) measurements during pre- and post-treatment sampling within each treatment zone (June 2 to July 27, 2015).

b. ALGAE SAMPLING

A single monthly sample (April-September) was collected from Area B within the West Basin for algae species identification and evaluation of general species abundance/dominance. Based on the results of these samples the algae assemblage remained fairly uniform during the 2015 season. All samples indicated a blue-green dominant assemblage with high numbers of the filamentous blue-greens, *Planktolyngbya* and *Aphanizomenon*

present in both early and late season samples. The unicellular colonial blue-green *Microcystis* was also prevalent in all of the samples, but was generally less abundant than the filamentous blue-greens. Other background species consisted of predominantly diatoms (*Aulacoseira* and *Tabellaria*) and green species (*Akistrodesmus*, *Elakothrix*, and *Scenedesmus*) that appeared to increase in density during the course of the growing season. Although blue-green species dominated all of the samples the overall algae abundance increased during the course of the season.

c. IN SITU MEASUREMENT OF FLOCCULATION

Prior to treatment, five floc-collection devices were installed and situated in close proximity to the *in situ* mussel monitoring stations. The devices were installed from the surface (rather than in-water) due to unsafe cyanobacteria levels. Although the devices were weighted to remain upright during the at-surface installation, upon retrieval, complications such as partial lid closure and small losses in sample were noted. This likely offers an explanation for the decreased floc accumulation during the third treatment event. Average floc accumulation was less than 0.15 inches for each treatment event ('**Appendix B, Table 3**'). Overall floc measurement data from 2014 and 2015 suggest there is minimal floc accumulation associated with these lower dose treatments.

d. MUSSEL MONITORING

Although originally proposed in the habitat management plan, short-term mussel monitoring did not occur during the initial treatment event due to reduced water clarity and an ongoing fish kill. The monitoring occurred during the third treatment event; however, due to high cyanobacteria levels reported by the Town of Halifax's Board of Health (>70,000 cells/mL), in-water observations were replaced with at-surface observations. This methodology had complications, which led to collecting broader observations of mussels present (i.e., approximate density of live and recently spent mussels, and mussel behavior) at the monitoring stations utilized in 2013. Observations were done at 1 and 4 days following the third treatment ('**Appendix B, Table 4**'). Due to complications during mussel observation, conclusions on the short-term impacts on the state-listed mussels were difficult to draw; however, based on past monitoring at West Monponsett Pond and mussel monitoring conducted following other buffered alum treatments, the short-term impacts to state listed mussels appears to be minimal.

VI. DISCUSSION/CONCLUSION

Although West Monponsett Pond experienced periods of cyanobacteria growth with cell densities above the MA DPH threshold (70,000 cells/ml) in 2015, we feel based on the Secchi depths in late July and the incremental reduction of total phosphorus observed that the treatment program provided both short and long-term improvements. Despite a near 50% reduction in total phosphorus (TP) levels and an average TP concentration below 20 ppb in late July cyanobacteria densities continued to rise in late summer. Therefore, in an effort to better bind up available phosphorus and further reduce seasonal algae production we are proposing the following program modifications for 2016.

- Sampling results indicate that phosphorus levels were at their highest during the early season (6/2/15 mean TP – 46 ppb) and that cyanobacteria growth was already well established at the time of the initial alum treatment. Therefore we feel that beginning the treatment program earlier in the growing season will help mitigate phosphorus levels before the onset of widespread cyanobacteria growth. By reducing phosphorus earlier in the season we can perhaps better prevent the establishment of problematic cyanobacteria and improve our ability to maintain desirable conditions throughout the remainder of the growing season. We recommend moving the initial treatment up to early May.

- In addition to starting the multi alum treatment program earlier in the growing season, we also feel that increasing the initial aluminum dose will improve the phosphorus reduction at this critical time of algae

development in West Monponsett Pond. The Phosphorus sampling indicates that the initial alum treatment provided an approximate 30% reduction in total phosphorus; however, the remaining phosphorus levels in early June were still above excessive phosphorus threshold of 30 ppb (mean TP 32 ppb). We therefore are recommending that this initial aluminum dose be increased from 0.7 ppm to 1.4 ppm. We feel that doubling the initial dose will effectively reduce phosphorus concentration below the 30 ppb threshold in the early season, which will better prevent the establishment of problematic cyanobacteria growth. Also by more aggressively reducing phosphorus in the early season it is more likely that subsequent lower dose treatments will be effective at maintaining concentrations or further reducing TP levels.

We feel that these proposed program modifications are necessary for the long-term maintenance of West Monponsett. If you have any questions about the 2015 program or our 2016 management recommendations please do not hesitate to contact our office.

Appendix A

REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond

REVISED Habitat Management Plan for Phosphorus Inactivation in the Western Basin of Monponsett Pond

Applicant: Town of Halifax
499 Plymouth Street
Halifax, MA 02338

Representative: Aquatic Control Technology
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Spencer, MA 01562

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ATTACHMENTS

REVISED Habitat Management Plan for Phosphorus Inactivation in the West Basin of Monponsett Pond Halifax/Hanson, Massachusetts 2015

SITE DESCRIPTION & BACKGROUND

Monponsett Pond, located in the towns of Halifax and Hanson, Massachusetts, is a significant ecological, historical, and recreational resource as well as an important supplementary water supply for the nearby City of Brockton. The 528-acre pond is bisected by Route 58 which splits the water body into two basins - east and west - directly connected only by a small culvert in the southern portion of the pond. Both basins are highly developed with residential homes and receive inputs from a suburban watershed of approximately 6 mi^2.

As a whole, Monponsett Pond has been heavily impacted by use of its waters and watershed, and both basins have been placed on the Massachusetts Integrated List of Waters (303(d) list). As of 2010, the eastern basin was categorized as a 4c water body for presence of exotic species and a Total Maximum Daily Load (TMDL) was published in 2007 for high concentrations of mercury. The western basin appears on the 2010 303(d) list as a category 5 water body for nutrients, noxious aquatic plants, turbidity, and exotic species. The presence of two exotic aquatic vegetation species; Fanwort (*Cabomba caroliniana*) and Variable Milfoil (*Myriophyllum heterophyllum*), have been recorded recently in the eastern basin, while presence of Fanwort was noted in the western basin.

Both basins have also been subject to algae blooms in the past several years; however, the western basin has undergone extensive algae blooms for the past 25 years. During the summers of 2010 and 2011 these blooms prompted the closure of the western basin to swimming and boating for much of the summer. Algae testing has been carried out both by the Massachusetts Department of Public Health (MA DPH) and Massachusetts Department of Environmental Protection (MA DEP) throughout the summer months. MA DPH also conducted analysis of water quality, including total phosphorus. These results show a definite association between concentration of total phosphorus and total cell count in the western basin throughout the summer.

Despite these water quality challenges, the western basin has been identified as an area of priority habitat by the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (NHESP). The presence of the following three state-listed species of special concern has been confirmed as recently as June 2011: Tidewater Mucket (*Leptodea ochracea*), Eastern Pondmussel (*Ligumia nasuta*), and Umber Shadowdragon (*Neurocordulia obsoleta*).

PROPOSED PHOSPHORUS INACTIVATION PROGRAM

During the summer of 2013, Lycott Environmental conducted a low-dose buffered alum treatment of the West Basin of Monponsett Pond in accordance with the NHESP letter (09-27490) dated June 6, 2012 and the submitted Habitat Management Plan. As outlined in our recent report (Lycott – Low-Dose Alum Treatment Monitoring Report – Novemeber 14, 2014) the treatment program was performed without incident or observed short or long-term impacts to the rare species. Although this treatment approach was successful at reducing the internal total phosphorus concentration without impacting rare species, the phosphorus reduction was relatively short-lived. Post-treatment phosphorus testing indicated that phosphorus concentrations had returned to near pre-treatment levels within a month following the alum treatment. Therefore, in an effort to maintain a reduced phosphorus concentration at least throughout

the peak growing season (May-August), we are proposing the following modifications to the treatment program for your review and approval.

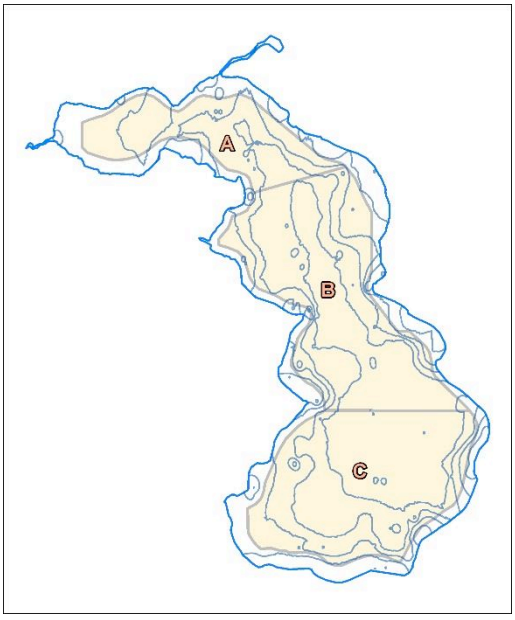
Aluminum Dose Modification

Although jar testing and the results of the 2013 treatment program indicate that a 3 ppm aluminum dose can remove a high percentage of available phosphorus, it may likely be better in-terms of seasonal cyanobacteria bloom prevention to reduce this dose and preform more treatment events. For this reason we are proposing an individual treatment dose of approximately 0.7 ppm of aluminum. Despite this reduced aluminum dose, the buffering capacity associated with this system (alkalinity has been estimated at 11.5 mg/L $CaCO_3$) will continue to require the application of sodium aluminate as a buffer. An aluminum sulfate to sodium aluminate ratio of 2:1 represents the theoretical balance point for pH in poorly buffered lakes such as Monponsett Pond, and therefore, the planned individual treatment dose is 3000 gallons of aluminum sulfate and 1500 gallons of sodium aluminate.

We anticipate performing a total of three treatments at this dose for a total dose of approximately 2.1 ppm of aluminum. We feel that by spacing this reduced overall dose over three individual treatments that we will not only extend the duration of phosphorus reduction, but also reduce the potential risk to resident rare species associated with the low-dose alum treatment.

Treatment Area Modification

No change to the overall extent of the treatment area is proposed. As with the 2013 treatment program, the aluminum sulfate and sodium aluminate will be applied to areas of the West Basin that are deeper than four (4) feet – a total treatment area of approximately 235 acres. However, rather than split this overall treatment area into 2.77 acre treatment sectors, as was done in 2013, we are proposing to divide the overall treatment area into three zones with relatively uniform depth characteristics (Zone A – 45 acres; Zone B – 98 acres; Zone C – 92 acres). This approach will enable accurate dosing and more uniform application without increasing the risk to rare species.



Application Methodology Changes

Treatment will be conducted with our specially equipped treatment vessel. The treatment vessel will be equipped with a fathometer and speedometer. The use of the speedometer enables us to prepare a

calibration table for chemical delivery (gal.) versus vessel speed (mph) which will insure even distribution of the alum and sodium aluminate. Suitable in-line pressure gauges and flowmeters to measure chemical delivery rates will also be used.

The treatment vessel will be equipped with 2 translucent polyethylene tanks with a combined capacity of 450 gallons. These tanks are also graduations on the outside, which allow our operators to visually monitor chemical delivery to insure the desired volumetric ratio is met.

Since the two chemicals cannot be tank-mixed prior to application, there are two separate pumping systems for each product including individual spray lines and drop-hoses. The chemical delivery spray boom will be mounted on the stern of the boat where the drop-hoses will emit the chemicals into the propwash of the outboard motor. Dispersing the chemicals into the propwash promotes flash mixing of the two products and ultimately excellent floc formation. Through our extensive prior alum/aluminate treatment experience, we have found that the use of this arrangement and application methodology provides the best results.

The treatment will be guided with an on-board differential GPS. The treatment vessel will be equipped with a field portable laptop connected to a Trimble XT GPS receiver. The laptop screen will show the pond and treatment area and treatment sector boundaries. The system logs the path of the treatment vessel with an accuracy of ± 1 meter. Each load of chemical will be logged and monitored.

A maximum of three low-dose buffered alum treatments will be performed, as described, during the course of the growing season. We anticipate that the treatments will be performed approximately four weeks apart beginning at the onset of active algae growth (i.e. May, June, and July). Each treatment is expected to be completed in one day.

MONITORING PROGRAM

The table below outlines the components of the monitoring program and the goals of each. Details are provided in the following sections.

Table 1: Monitoring Program Design

Monitoring Component	Timing in relation to treatment	Location(s)	Goal
Water quality	Before, during, and after each application	3 established locations within each treatment zone	Evaluate short and long-term effects on water quality
Measurement of flocculation	During	1 visual recording; 6 measurement locations	Assess the amount of floc accumulated on the sediments
Monitoring of state-listed species	Before, during, and after One and five years following	5 paired plots	Evaluate short and long-term effects on these species identified by NHESP as potentially susceptible to the treatment

Chemical and Physical Assessment of Treatment

Water Quality Monitoring

The water quality monitoring plan for West Monponsett Pond will include sampling at a single location within each of the three treatment zones. Sampling collection will occur immediately prior to each treatment and several days following each treatment. In addition to the sample collection basic *in situ* testing will be performed throughout each alum application.

Each pre and post-treatment water quality sample will be analyzed for the following parameters.

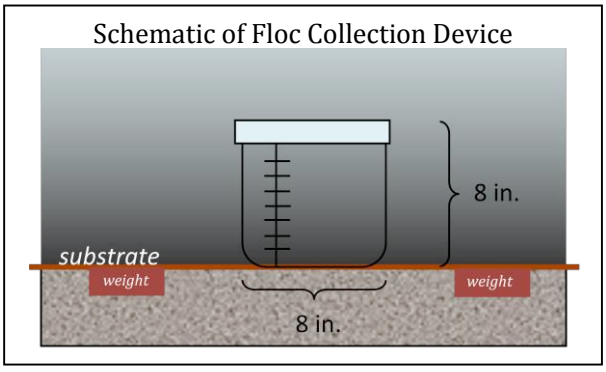
- pH
- Alkalinity
- Total Phosphorus
- Dissolved Phosphorus

The *in situ* testing that will be performed during treatment will include the following.

- Secchi depth
- Dissolved oxygen
- pH
- Alkalinity

Measurement of Floc Deposition

In order to measure the amount of floc deposition occurring during the treatment, five floc-collection devices will be installed prior to the treatment and will be situated in close proximity to the *in situ* mussel monitoring stations (**Figure 1**). These devices will be designed to capture floc as it precipitates to the pond's bottom. Two graduated (in inches) floc-collection devices will be installed on weighted pieces of plywood or similar material that will be placed on the substrate. The depth of floc in each device will be measured by an underwater observer the day following treatment. Images of the devices and floc will be recorded during each observation period.



In an effort to observe flocculation as it occurs, an underwater video camera will be set up in a shallow treatment location where water clarity will allow visual observation.

Monitoring of State-Listed Mussel Species

Long-term Mussel Monitoring Program: Pre- and Post-Treatment Mussel Monitoring

Since the submission of the original 'Habitat Management Plan' in May 2012, the pre-treatment and one year following the initial 2013 alum treatment long-term mussel monitoring event have been performed. Minor modifications to the proposed long-term mussel monitoring provided in the original 'Habitat Management Plan' were made by the NHESP-approved biologist performing these surveys. In order to maintain comparability with the five years post-alum treatment long-term mussel monitoring event, the modified survey methodology will be implemented at this time. This methodology was provided to the NHESP in a report titled, "Monitoring the Effects of Low-Dose Alum Treatment on *Leptodea ochracea*, *L. nasuta*, and *Neurocordulia obsolete* in the Western Basin of Monponsett Pond (Halifax, Massachusetts)" and the relevant excerpt is copied below. Per a recent conversation with the NHESP, additional revisions to this methodology is indicated below in **bold** text.

> *A third survey is planned for May 2018. The basic sampling unit [will be] a 1 x 1 meter (1m^2) quadrat bounded by a frame, with two centerlines that [divide] the quadrat into four 0.5 x 0.5 meter sections. The centerlines facilitated more careful searching in the low-visibility environment. Quadrat locations [will be] marked with underwater markers and recorded with GPS to enable the precise area of each to be resurveyed. Five quadrats [will be] established at 10 sites (50 quadrats total); the 10 sites [will be] paired (one shallow, one deep) at five locations in the pond (Figure 1). The quadrats [will be] arranged in a consistent pattern at each site (Figure 2). For each quadrat, biologists [will] first [conduct] a visual and tactile search to count the number of mussels (all species) occurring at or near the surface. The biologists then [will excavate] and [sieve] sediment from within one-fourth (0.25m^2) of the quadrat area to find buried mussels. Surface counts and buried counts [will be] recorded for each species, and shell length* ***and shell condition*** *[will be] recorded for L. ochracea and L. nasuta. Once these two steps [are] completed, all mussels [will be] placed back within the confines of the each quadrat. The following habitat information [will be] recorded for each quadrat: water depth, spatial extent of each substrate type, and percent cover of macrophytes. During the two post-treatment surveys, biologists [will] also [count]* ***and note shell condition of*** *freshly dead shells in addition to the steps described above.*

Figure 1 & 2. Mussel and Dragonfly monitoring stations (**Figure 1**) and quadrat arrange (**Figure 2**) derived from Biodrawversity's 2014 report, "Monitoring the Effects of Low-Dose Alum Treatment *Leptodea ochracea*, *Ligumia nasuta*, and *Neurocordulia obsolete* in Monponsett Pond."

Figure 1. Locations of mussel monitoring sites (Sites 1-5, including shallow and deep plots at each site) and dragonfly survey sites (E-1, E-2, and W-1 to W-7) in West and East Monponsett Pond in Halifax, MA.

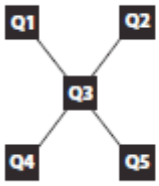


Figure 2. Spatial array of 5 1.0 m^2 quadrats (Q) at each site. Bricks were left on the lake bottom at Q1, Q2, Q4, and Q5; these were connected by strings and the intersection of the two strings marked the location of Q3. These were easily installed in 2013 and found again in 2014.

<u>*In situ* Mussel Monitoring: Behavioral Responses of Mussels to a Buffered Low-Dose Alum Treatment</u>

The *in situ* monitoring program aims to investigate mussel behavioral responses of the two state-listed species mussel species, *L. ochracea* and *L. nasuta*, to the modified low-dose alum treatment approached proposed in this document. *In situ* monitoring will be carried out in the initial year (i.e., 2015) of the modified low-dose alum treatment and in the last year (2018) proposed under this habitat management plan. In these years, *in situ* monitoring will be conducted during the first of the three 0.7 ppm alum treatment events, when water clarity is at its best in the West Basin of Monponsett Pond.

A total of three locations will be selected for *in situ* monitoring of state-listed mussel species. *In situ* monitoring will be performed within the long-term monitoring stations (refer to map for **Figure 1**). *In situ* monitoring site locations will be selected based upon two criteria:

- At depths >4 ft. deep to correspond with the treatment area
- At locations with known presence of the two state-listed mussel species

Prior to treatment, the observer will visit the three *in situ* monitoring stations. At this time, the observer will place a drilled, PVC 1-m^2 quadrat and place it over a mussel bed containing at least three individuals. Each mussel will be plucked, identified to the species-level, measured, photographed, and returned to the substrate (not seeded). A fluorescent, 15" marker flag with a unique identification number will be placed

near each mussel, and all mussels will be allowed to acclimate for five minutes. Following the acclimation period, mussel behavior — pumping activity (active vs. inactive), valve activity (open vs. closed), positioning (upright vs. dislodged), foot activity (protracted vs. retracted) — will be qualitatively measured for a 30 minute period. This 30 minute time period will be further divided into 10 minute intervals assessing the mussel behavior of each of the 3 mussels (i.e., each mussel will be monitored for 10 minutes). This information will be necessary to establish a baseline for natural mussel activity in the absence of an alum treatment (*i.e.*, control). Under optimal conditions, natural mussel activity is generally characterized by upright, prolonged active filtering interrupted by brief valve closures. Observations will be recorded in a waterproof field notebook.

It is anticipated that the modified alum treatment will require a full day to conducted treatment activities; therefore, performing *in situ* monitoring in the same day following treatment will not be possible. As such, mussel behavior will be again assessed one and three days following the treatment activities. *In situ* mussel behavior monitoring will be perform utilizing the same methodology prior to treatment. In the event that the quadrat has moved, the closest three mussels will be monitored utilizing the aforementioned *in situ* monitoring methods. Additionally, freshly dead mussel shells in or within close proximity to the quadrat will be counted, identified to the species-level, measured for shell length and erosion, photographed, and returned to the sediment.

Monitoring of State-Listed Dragonfly Species

Long-term Dragonfly Monitoring Program: Pre- and Post-Treatment Dragonfly Monitoring

As stated above, since the submission of the original 'Habitat Management Plan' in May 2012, the pre-treatment and one year following the initial 2013 alum treatment long-term dragon-fly monitoring event have been performed. Minor modifications to the proposed long-term mussel monitoring were made by the NHESP-approved biologist performing these surveys. In order to maintain comparability during the five years post long-term mussel monitoring event scheduled for 2018, the modified survey methodology will be implemented at this time. This methodology was provided to the NHESP in a report titled, "Monitoring the Effects of Low-Dose Alum Treatment on *Leptodea ochracea*, *L. nasuta*, and *Neurocordulia obsolete* in the Western Basin of Monponsett Pond (Halifax, Massachusetts)" and the relevant excerpt is copied below. No additional revisions were requested during our recent conversations with the NHESP.

> *Dragonfly surveys, focusing on N. obsoleta … [is scheduled to be completed in 2018]. Survey timing… [will]… accommodate weather conditions during the emergence period to ensure that surveys [are] conducted under the best possible conditions. Qualitative surveys of larvae, exuviae, and tenerals [will be conducted] using a combination of aquatic D-net sweeps in or near aquatic vegetation and other submerged structure, snorkeling in shallow water to hand-pick larvae, and walking along the shoreline to look for exuviae and tenerals on the lakeshore (especially rocks, bridge abutments, and trees). The causeway between the West and East basins [will be] surveyed most intensively, but several other locations in West and East Monponsett Pond [will] also [be] assessed and surveyed (Figure 1[see above]). Specimens [will be] collected, preserved in alcohol, and identified under a dissecting microscope*.

Monitoring of Fish and Wildlife Response to Treatment

As in 2013, *in situ* in-water and shoreline monitoring will investigate mortality of fish and other wildlife as a consequence of the buffered low-dose alum treatment. During the buffered low-dose alum treatment, *in situ* in-water and shoreline monitoring for fish and/or other wildlife mortalities will be conducted by three parties: a treatment team and a survey team. *In situ* in-water and shoreline monitoring will proceed as follows:

- **Treatment team**

    - Licensed applicator and assistant(s) will actively monitor the immediate treatment area for fish and/or wildlife mortality during application

- **Survey team**

    - Hourly follow-up inspections of the treatment areas will be conducted in conjunction with water quality testing and floc measurements

    - Quick (in-boat) visual inspection of pond's perimeter for fish and/or wildlife mortality following daily treatment activities

Any deceased fish and/or wildlife encountered during *in situ* in-water monitoring will be documented. Documentation will include: written observations regarding the counts (by species), time observed, and photographs of each specimen. All information pertaining to a fish and/or wildlife kill event will be immediately provided to the Division of Fisheries and Wildlife—Southeast (DFW-SE).

Appendix B

Treatment Monitoring Program at the West Basin of Monponsett Pond Raw Data (Table 1-4)

Table 1. Pre- and post-treatment baseline water quality sampling results

Date	Treatment and Timing	Site ID	pH	TP (ppb)	DP (ppb)	TAlk (mg/L)	Turbidity (NTU)
6/2/15	1st - Pre	A	7.0	44	27	7.2	X
		B	7.0	37	19	3.6	X
		C	7.0	57	29	6.2	X
6/5/15	1st – 3-day post	A	7.5	33	21	ND	X
		B	7.5	32	18	ND	X
		C	7.5	31	15	8.2	X
6/10/15	1st – 1-week post	A	7.8	39	X	8.8	4
		B	7.6	37	X	8.2	4
		C	7.4	38	X	8.2	3.7
6/30/15	2nd – Pre	A	7.0	26	ND	7.7	X
		B	7.3	27	ND	8.8	X
		C	7.0	27	ND	9.3	X
7/3/15	2nd – 3-day post	A	6.2	28	ND	8.8	X
		B	6.4	22	ND	8.8	X
		C	6.6	31	ND	9.3	X
7/13/15	2nd – 1-week post	A	8.1	16	ND	8.8	5
		B	7.9	31	10	8.8	5.6
		C	7.6	19	ND	8.8	6.2
7/23/15	3rd - Pre	A	7.0	20	ND	8.2	X
		B	7.5	11	ND	9.3	X
		C	7.5	16	ND	9.3	X
7/27/15	3rd – 3-day post	A	7.5	23	ND	9.3	X
		B	7.0	27	ND	8.2	X
		C	7.3	27	ND	9.3	X

Table 2. Pre- and post-treatment additional water quality sampling results

Date	Treatment and Timing	Site ID	Depth	T (°C)	DO (mg/L)	DO (% saturation)	Secchi (ft)
6/2/15	1st - Pre	A	Near Surface	17.7	8.02	84.2	4
		B	Near Surface	18.8	8.06	86.5	4
		C	Near Surface	18.4	8.14	86.7	3.5
			3 feet	18.4	8.14	86.7	
			4 feet	18.4	8.14	86.6	
			5 feet	18.4	8.13	86.6	
			6 feet	18.3	8.14	86.6	
			7 feet	18.3	8.15	86.6	
			8 feet	18.3	8.16	86.1	
			9 feet	18.3	8.17	86.8	
			10 feet	18.3	8.18	86.9	
6/3/15	1st – 1-day post	A	Near Surface	17.8	8.82	92.9	4
		B	Near Surface	17.3	8.88	98.6	5
		C	Near Surface	17.8	8.82	92.9	4
			3 feet	17.7	8.84	92.7	
			4 feet	17.7	8.82	92.6	
			5 feet	17.7	8.81	92.4	
			6 feet	17.7	8.79	92.2	
			7 feet	17.6	8.76	91.7	
			8 feet	17.6	8.71	91.2	
			9 feet	17.5	8.57	88.9	
			10 feet	17.5	8.38	87.6	
6/5/15	1st – 3-day post	A	Near Surface	20.6	9.63	107.1	4.5
		B	Near Surface	20.1	9.65	106	4.5
		C	Near Surface	19.2	9.68	104.8	4.5
			3 feet	19	9.67	104.3	
			4 feet	18.8	9.67	103.8	
			5 feet	18.6	9.67	103.4	
			6 feet	18.2	9.63	102.2	
			7 feet	18.2	9.47	100.2	
			8 feet	17.9	9.41	99.6	
			9 feet	17.7	8.50	89.2	
			10 feet	17.8	8.52	89.3	
6/30/15	2nd – Pre	A	Near Surface	22.2	7.95	91.3	4
		B	Near Surface	22.1	7.60	87.3	3.75
		C	Near Surface	22.7	7.40	85.5	3.5
			2 feet	22.4	7.40	85.5	
			3 feet	22.1	7.33	84.7	
			4 feet	21.9	7.20	81.9	
			5 feet	21.8	6.96	79.3	
			6 feet	21.8	6.81	77.6	
			7 feet	21.8	6.63	75.4	
			8 feet	21.8	6.32	72	

Date	Treatment and Timing	Site ID	Depth	T (°C)	DO (mg/L)	DO (% saturation)	Secchi (ft)
			9 feet	21.8	6.95	68.8	
			10 feet	21.8	5.65	64.1	
7/1/15	2nd – 1-day post	C	Near Surface	23.1	7.57	88.4	3.5
			4 feet	23.1	7.54	88.1	
			5 feet	23.1	7.57	88.6	
			6 feet	23	7.61	88.7	
			7 feet	23	7.58	88.3	
			8 feet	23	7.57	88.2	
			9 feet	23	7.51	87.5	
			10 feet	22.9	7.43	85.7	
			11 feet	22.2	7.74	55.1	
7/24/15	3rd – 1-day post	C	Near Surface	27.2	8.39	105.7	3
			3 feet	27.2	8.36	105.3	
			4 feet	27.2	8.35	105.2	
			5 feet	27.1	8.35	105	
			6 feet	27.1	8.32	104.6	
			7 feet	27.1	8.30	104.5	
			8 feet	27.1	8.30	104.4	
			9 feet	27	8.14	102.5	
			10 feet	26.3	6.20	76.7	
7/27/15	3rd – 3-day post	A	Near Surface	X	X	X	3
		B	Near Surface	25.1	8.15	98.7	3
		C	Near Surface	25.2	8.01	97.2	3
			3 feet	25.1	7.98	96.7	
			4 feet	25	7.92	95.9	
			5 feet	25	7.9	95.6	
			6 feet	25	7.87	95.2	
			7 feet	25	7.83	94.8	
			8 feet	25	7.79	94.1	
			9 feet	24.9	7.72	93.4	
			10 feet	24.8	6.94	83.6	

Table 3. *In situ* flocculation measurement data

Date	Treatment and Timing	Mussel Monitoring Station	Floc Deposition (in)
6/4/15	1st – 1-day post	1B	0.150
		2B	0.057
		3B	0.117
		4B	0.150
		5B	0.233
7/1/15	2nd – 1-day post	1B	0.083
		2B	0.067
		3B	0.027
		4B	0.167
		5B	0.127
7/23/15	3rd – 1-day post	1B	0.05
		2B	0.04
		3B	0.06
		4B	0.04
		5B	0.10

*Note: Devices were installed from the surface (rather than in-water) due to unsafe cyanobacteria levels. Additional complications offer an explanation for the decreased floc accumulation during the third alum application event.

Table 4. Summary of mussel monitoring observations

Site ID	Mussel Density* (m^{-2})	General Mussel Observations		
		Pre	1-Day Post***	4-Day Post***
1B	High (9 – 15 mussels m^{-2})	Mussels deeply to partially burrowed (~25-50% exposed), upright, and actively filtering with intermittent, brief aperture closures	Majority of mussels deeply to partially burrowed (~25-50% exposed), upright, and actively filtering with intermittent, brief aperture closures; 3 mussels dislodged**	Mussels partially burrowed (~50% exposed), upright, and actively filtering; 2 mussels dislodged**
2B	Medium (4 – 8 mussels m^{-2})	Mussels partially burrowed (50% exposed), upright, actively filtering with intermittent, brief aperture closures	Majority of mussels deeply to partially burrowed (~25 - 50% exposed), upright, actively filtering with intermittent, brief aperture closures; 2 mussels dislodged**	Mussels deeply to partially burrowed (~25 - 50% exposed), upright, actively filtering with intermittent, brief aperture closures; 1 mussels dislodged**
4B	Low (1 – 3 mussels m^{-2})	Mussels deeply burrowed (~25% exposed), upright, and actively filtering	1 mussel partially burrowed (50% exposed) upright, active filtering; 1 mussel dislodged**	1 mussel deeply burrowed (25% exposed) upright, actively filtering with several brief aperture closures; 1 mussel partially burrowed (50% exposed), upright, actively filtering

* Repeated movement of the boat from wave/wind action (despite securely anchoring and tying off to the shore) likely resulted in monitoring both within and immediately outside the 1-m^2 area. Therefore, precise density counts were not possible. Alternatively, each site was assigned a density category based on the approximated mussel abundance within the 1-m^2.

** Dislodged mussels were likely caused by collision with the stability rod during monitoring.

*** No freshly spent mussels were noted during the 1-day and 4-day post short-term mussel monitoring.