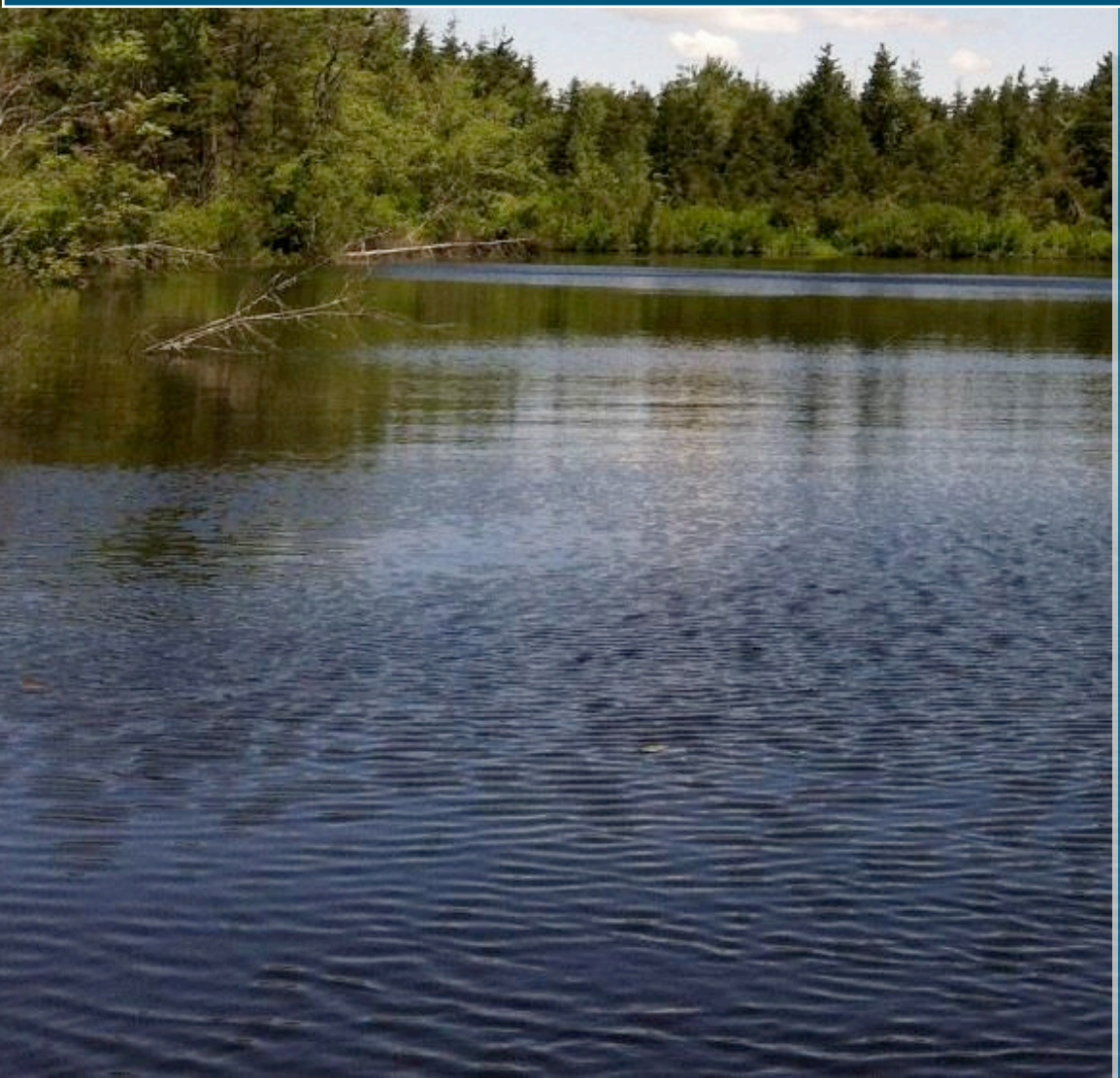
LYCOTT

Low-Dose Alum Treatment Monitoring Report

West Basin of the Monponsett Ponds

Halifax/Hanson, Massachusetts



Submitted: November 9, 2014

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1.0 INTRODUCTION

1.1 Background

Monponsett Ponds, located in the towns of Halifax and Hanson, Massachusetts, are 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 Ponds have 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 2012, the eastern basin was categorized as a 4a water body for presence of non-native species and a Total Maximum Daily Load (TMDL) was published in 2007 for high concentrations of mercury. The west basin appears on the 2012 303(d) list as a category 5 water body for non-native aquatic plants, excess algal growth, total phosphorus, and Secchi disk transparency. The presence of three exotic aquatic vegetation species; Fanwort (*Cabomba caroliniana*), Variable Milfoil (*Myriophyllum heterophyllum*), and Eurasian Milfoil (*Myriophyllum spicatum*) have been recently recorded (2013) in the eastern basin, while presence of solely Fanwort was noted in the west basin.

Both basins have also been subject to algae blooms in the past several years; however, the west basin has undergone consistent extensive algae blooms for the past 25 years (**Image 1**). During the summers of 2010 and 2011 these blooms prompted the closure of the west basin to swimming and boating for much of the summer. Algae testing has been carried out both by the Massachusetts Department of Public Health (MDPH) and Massachusetts Department of Environmental Protection (MassDEP) throughout the summer months. MDPH also conducted analysis of water quality, including total phosphorus. These results showed a definite association between concentration of total phosphorus and total cell count in the west basin throughout the summer.

Image 1. Historical imagery gathered in July 2, 2008 illustrates the western basin undergoing an extensive microscopic algal boom, as depicted by the vivid green water color.

Despite these water quality challenges, Monponsett Ponds have been identified as an area of Priority Habitat for Rare Species and Estimated Habitat for Rare Wildlife by the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (the NHESP). Presence of the following three state-listed species of special concern; Tidewater Mucket (*Leptodea ochracea*), Eastern Pondmussel (*Ligumia nasuta*), and Umber Shadowdragon (*Neurocordulia obsoleta*), are also known at this location.

1.2 Monponsett Pond Remediation Plan

For the past several years, the Town of Halifax has led a concerted effort with the municipalities; Hanson, Pembroke, and Brockton, and landowners within the watershed to implement an adaptive

watershed management plan to restore the ecological and recreational functioning of the Monponsett Ponds. In short, the adaptive watershed management plan primarily focuses on reducing phosphorus loading in the Monponsett Ponds and watershed, and secondarily on controlling invasive species within the eastern basin.

As part of this adaptive watershed management plan, the Town of Halifax contracted with Lycott Environmental (Lycott) to conduct aluminum sulfate (herein referred to as 'alum') treatments to reduce phosphorus and subsequently preclude the development of detrimental algal blooms in the Monponsett Ponds. Given the poorly buffered nature of the Monponsett Ponds and the presence of several state-listed species, Lycott recommended utilizing multiple, buffered low-dose (3 ppm) alum treatments to remove a phosphorus from the water column. A more detailed explanation of this treatment design is provided in **Appendix A**.

1.3 Low-Dose Alum Treatment Permitting

Several layers of permitting were necessary to implement a buffered low-dose alum treatment program in the west basin of the Monponsett Ponds. These permitting requirements are described below:

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

Lycott 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 19, 2013. This permit application received an active status ten days following its submission.

Massachusetts Endangered Species Act Project Review

As stated above, the Monponsett Ponds historically and presently are designated by the Massachusetts Division of Fisheries and Wildlife (DF&W) – NHESP as Priority Habitat for Rare Species and Estimated Habitat for Rare Wildlife. Based on the goal of the project to restore the west basin as an ecologically functional water body, it was evaluated by the NHESP as 'management of State-Listed Species Habitat' per 321 CMR 10.14 Exemptions from Review for Projects or Activities in Priority Habitat in accordance with the following:

> *The following Projects and Activities shall be exempt from the requirements of 321 CMR 10.18 through 10.23: 15. the active management of State-listed Species habitat, including but not limited to mowing, cutting, burning, or pruning of vegetation, or removing exotic or invasive species, for the purpose of maintaining or enhancing the habitat for the benefit of rare species, provided that the management is carried out in accordance with a habitat management plan approved in writing by the Division…*

A 'Habitat Management Plan for Phosphorus Inactivation in the West Basin of Monponsett Pond' was submitted to the NHESP on May 17, 2012. The NHESP provided Lycott with a determination letter approving the aforementioned plan on June 6, 2012.

Order of Conditions

On November 19, 2009, Lycott submitted a Notice of Intent (NOI) to the Halifax and Hanson Conservation Commissions. The Halifax and Hanson Conservation Commissions voted to approve the NOI and additional documents (i.e., the abovementioned 'Habitat Management Plan'), and Orders of Conditions (OOCs), DEP File #s SE 171-0412 (Halifax) and SE 175-0580 (Hanson) were received from these Commissions in 2012.

Massachusetts Department of Environmental Protection License to Apply Chemicals

A MassDEP Application to Apply Herbicide(s) to the Waters of the Commonwealth (BRP WM 04 Application) was submitted by Lycott on April 22, 2013. Lycott received the approved permit on May 22, 2013.

1.4 **Objective**

In accordance with the approved habitat management plan, Lycott must submit results/analysis of the monitoring program implemented in conjunction with the buffered, low-dose alum treatment at the west basin of the Monponsett Ponds. Upon review, the NHESP will determine if buffered, low-dose alum treatments do not have an adverse impact the state-listed species and therefore, that buffered, low-dose alum treatments may be applied in subsequent management years under the associated OOCs, DEP File #s. SE 171-0412 (Halifax) and SE 175-0580 (Hanson).

2.0 **MONITORING PROGRAM**

The following table summarizes the major components of the monitoring program and the goals of each in the approved Habitat Management Plan (refer to **Appendix A** for the original, detailed methodology pertaining to each monitoring component):

Monitoring Component	Timing in relation to treatment	Location(s)	Goal
Large-scale jar test	2 weeks prior	Treatment staging area	Verify that pH in the treatment area will remain within the target range of 6.5 and 7.5
Water quality	Before, during, and after months and years following	10 established locations; multiple locations during treatment	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[1]	Before, during, and after 1 and 5 years following	5 paired plots	Evaluate short and long-term effects on these species identified by NHESP as potentially susceptible to the treatment
Sediment cores	Before and after 1 month, 1 and 5 years following	3 established locations	Assess changes in |AL| and sediment P

[1] A subcontractor, Biodrawversity, was contracted by Lycott to perform the long-term state-listed species monitoring and assessment. A report of these findings is provided as a standalone document.

The remainder of the document will focus on providing brief methodology (if needed) and results of each monitoring program component (refer to **Appendix B** for raw data). Although not included in the above table, a general summary of the treatment logistics and activities and observations of fish/wildlife during the treatment will also be included in this report. Lastly, Lycott will discuss the impacts of the buffered low-dose alum treatment based on the overall results of the monitoring program.

2.1 **Large-Scale Jar Testing**

A large-scale jar test was conducted on May 23, 2013 to illustrate that pH remained within the target range of 6.5 and 7.5 during the proposed buffered low-dose (3 ppm) alum treatment at the west basin of the Monponsett Ponds. At this time, a buffered (2:1 ratio of aluminum sulfate to sodium aluminate) low-dose (3 ppm) application utilizing 4.197 milliliters of alum and 2.098 millimeters of sodium aluminate was applied to 50 gallons of pond water (**Image 2**). Over the 24-hour duration of this experiment, pH remained within the target pH range of 6.5 and 7.5 with a 1.5% and 0.29% percent change after 1-hour and 24-hour time intervals (**Figure 1**). Total alkalinity was also measured during the jar test experiment; these values did not exceed 9.5 mg/L of $CaCO_3$.

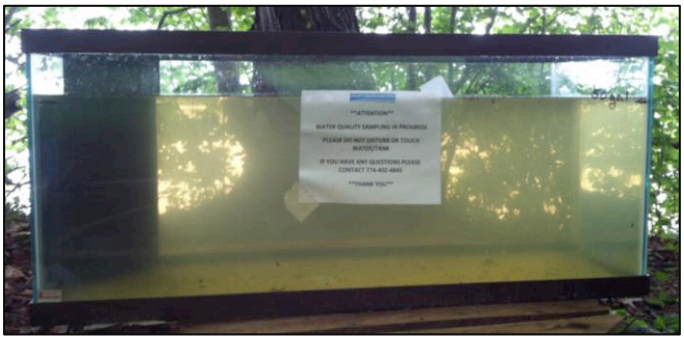
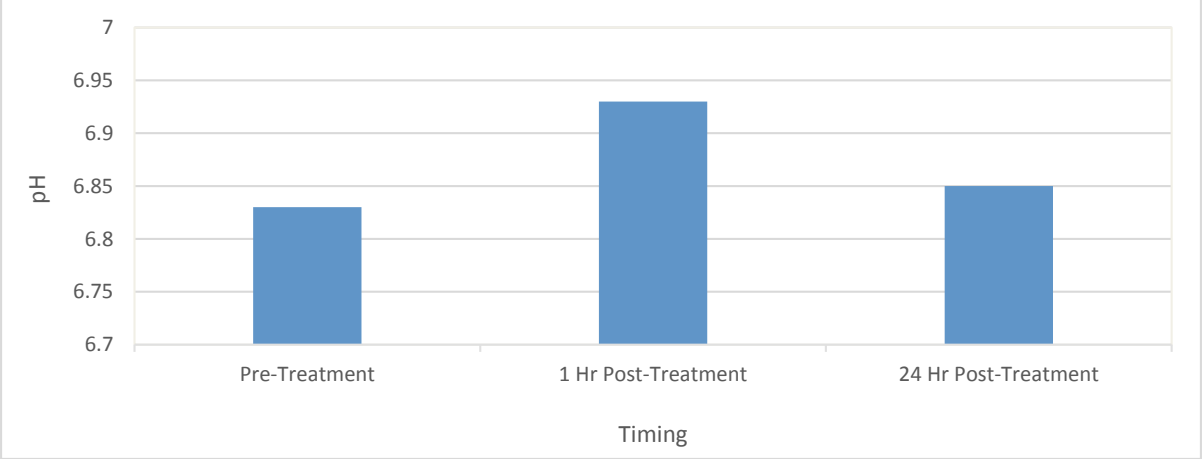


Image 2. May 23, 2013 large-scale jar testing station.

Figure 1. Comparison of (mean) pH measured during a large-scale jar test over a 24-hour period, west basin of the Monponsett Ponds, MA.



2.2 **Treatment Logistics and Application**

Two treatment vessels were used to apply 13,000 gallons of aluminum sulfate and 6,500 gallons of sodium aluminate to treat ~235 acres at Monponsett Pond (i.e., areas > 4' in depth) over a 4-day period. A summarization of the amounts of aluminum sulfate and sodium aluminate applied per treatment day is provided in the table below. A map of the daily treatment activities is provided in Appendix **C.**

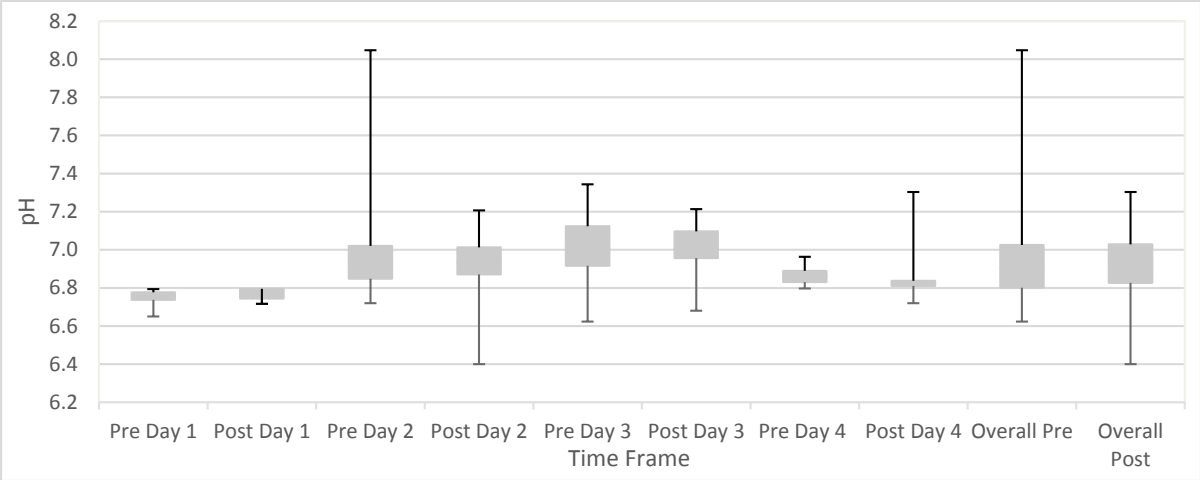
Timing	Amount of aluminum sulfate (gal.)	Amount of sodium aluminate (gal.)
6/4/2013 (Day 1)[1]	1700	850
6/5/2013 (Day 2)	5000	2500
6/6/2013 (Day 3)	4000	2000
6/7/2013 (Day 4)	2300	1150
[1] Equipment malfunction results in a half-day of treatment		

2.3 **Water Quality Monitoring**

In Situ Treatment Sector pH and Dissolved Oxygen Monitoring

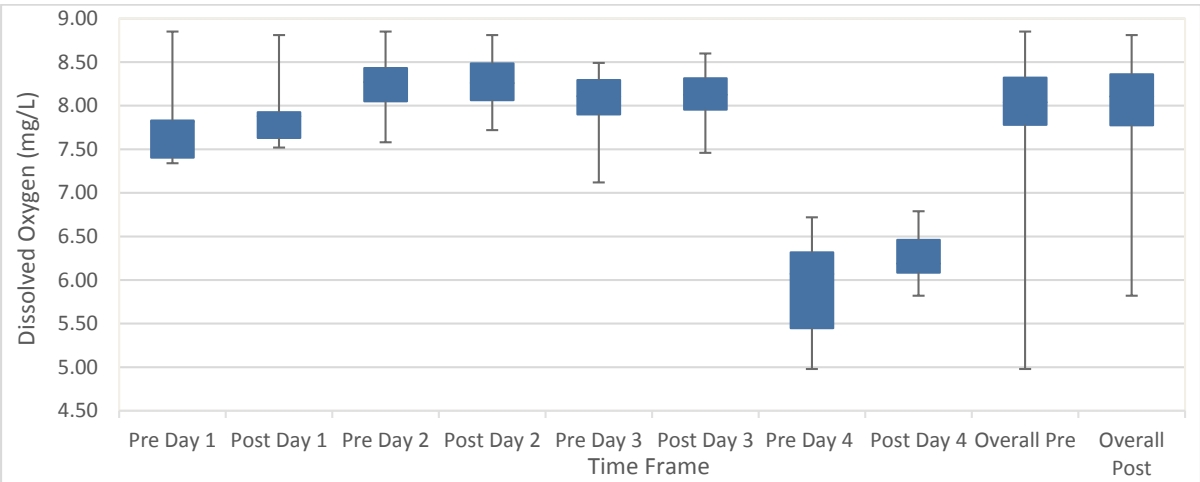
A total of 255 (i.e., 83 measurements with two duplicates) pH were collected at one sampling location within each treatment sector before and one-hour post-treatment. The majority (96%) of the pH measurements fell within the target range of 6.5 to 7.5. Changes in the daily and overall pre and post pH data were minute and not significant over the duration of the low-dose alum treatment (i.e., daily and overall) (**Figure 2**).

Figure 2. Comparison of pH pre- and post-application within treatment sectors, west basin of the Monponsett Ponds, MA.



Dissolved oxygen was also collected in conjunction with pH; values ranged between 4.98 and 8.85 mg/L and 5.82 and 8.81 mg/L for the pre- and post-treatment measurements, respectively. Changes in the daily and overall pre- and post-treatment dissolved oxygen data were relatively consistent during the first 3 days of treatment and then decreased in the fourth day of treatment. Comparisons of the daily and overall pre- and post-treatment dissolved oxygen data did not indicate significant differences.

Figure 3. Comparison of dissolved oxygen pre- and post-application within treatment sectors, west basin of the Monponsett Ponds, MA.



Long-Term Baseline Water Quality Monitoring

Baseline water quality parameters, pH, dissolved oxygen, total phosphorus, alkalinity, water clarity (via Secchi disk), temperature, and conductivity, were gathered at ten pre-established locations before (i.e., 5/23/13, 6/3/13, & 6/4/13 AM), during (i.e., 6/4/13 PM, 6/5/13, 6/6/13, & 6/7/13), and following (i.e., 7/12/13 & 7/18/14) the low-dose alum treatment. Results of the long-term baseline water quality monitoring program are summarized in the following table:

Parameter	Summary of Results
pH	• Majority of pH values (96%) within target range of 6.5 to 7.5 throughout monitoring program • Mean pH values relatively consistent before and during treatment; minute change in mean pH in one-month post and one-year post-treatment sampling event • Mean pH values consistent with typical diurnal patterns (i.e., lower in the morning before treatment than the evening following treatment)
Dissolved Oxygen	• Dissolved oxygen ranges between 5.46 and 9.18 mg/L throughout monitoring program • Mean dissolved oxygen consistent throughout monitoring program • Mean dissolved oxygen values consistent with diurnal fluctuations (i.e., generally lower in the morning before treatment than the evening following treatment)
Total phosphorus	• Total phosphorus ranges between 0.019 and 0.18 mg/L (i.e., 19 to 180 parts per billion) throughout monitoring program • Total phosphorus high (180 ppb) two weeks prior to treatment; during the treatment mean total phosphorus was relative consistent (range: 50 to 58 ppb) with no discernable patterns in total phosphorous between the AM and PM sampling events; one month post-treatment (mean) total phosphorus exhibits -32% percent change, and one-year post-treatment, total phosphorus similar to pre-treatment levels
Total Alkalinity	• Total alkalinity ranges between 5.43 and 14.4 (mg/L of $CaCO_3$) throughout treatment program • Mean total alkalinity values relatively consistent during sampling events before and during treatment; however, increase in mean total alkalinity during the one-month and one-year post-treatment sampling events
Water Clarity	• Secchi disk readings ranged from 0.3 m to 1.1 m (i.e., low water clarity) throughout the monitoring program • Secchi disk readings were nearly double during the pre-treatment sampling event than in the one-month and one-year post-treatment sampling events
Temperature	• Values recorded consistent with diurnal and seasonal fluctuations (range: 20.16 °C to 28.13 °C)
Conductivity	• Conductivity ranged between 213 and 251 µS, and no discernable trends detected over the course of the monitoring program.

2.4 **In Situ Measurement of Flocculation**

Height (in inches) of the accumulated floc in the six-paired floc devices were minimal and ranged from 0.04 inches (at site 1) to 0.38 inches (at site 3). In general, floc devices measured on the day of treatment accumulated less flocculent than devices measured following all treatment activities. Visual recordings of the flocculation at the 'deep hole' also noted minute amounts of floc throughout the water column. In several recordings, *Lepomis* spp. (various species) were documented swimming uninhibited by the floc. Representative images of the floc devices and flocculation captured during the buffered low-dose alum treatment are shown, as follows:

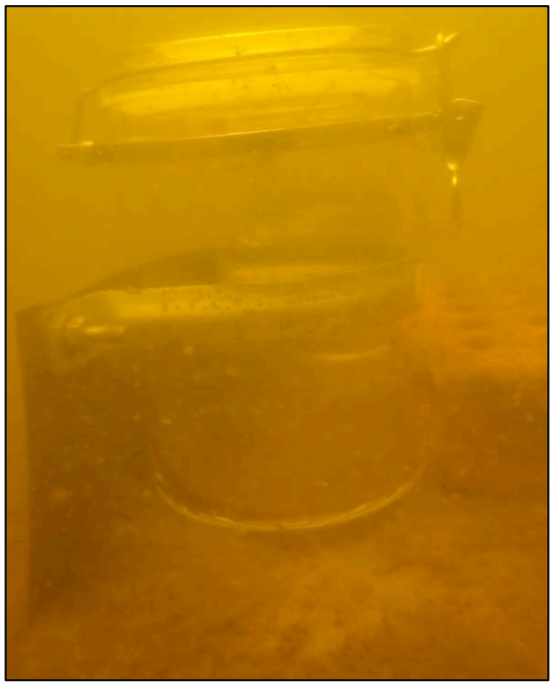


Image 3. Floc device sealed after day of treatment.

Image 4. Retrieval to floc device to the surface for measurement on the last day of the alum treatment.

Image 5. Visual recordings at the deep hole indicated minute amounts of floc throughout the water column. This image also captured several *Lepomis* spp. swimming through the floc uninhibited.

2.5 In Situ Monitoring of Fish and Wildlife Response to Treatment

The following table summarizes fish/wildlife documented during the 2013 buffered low-dose alum treatment:

Date	Day of Treatment	Survey, Treatment, & Shoreline Team Fish/Wildlife Observations
6/4/13	1	• 4 moderate to severely decomposed *Lepomis* spp. (various species) observed at state boat ramp • 2 live *Chrysemys picta* swimming underwater
6/5/13	2	• 3 dead fish; 2 *Perca flavescens* and 1 *Lepomis* sp. exhibiting minimal decay at boat ramp • 1 severely injured (i.e., burn mark) *Perca flavescens* near town beach • 1 dead *Lepomis* sp. exhibiting minimal decay on opposite shoreline of state boat ramp • 1 live turtle (species unknown) swimming beneath the surface • 30 live *Lepomis* spp. (various species) observed swimming underwater in conjunction with video recording of flocculation at the deep hole
6/6/13	3	• No fish or wildlife mortality observed • 1 fish (unknown species) feeding at surface • 1 *Pandion haliaetus* feeding on fish (unknown species) • Family (adult and six juveniles) of *Branta canadensis* swimming along shore
6/7/13	4	• no fish or wildlife mortality observed

2.6 **Short-Term Monitoring of State-Listed Mussels**

In situ mussel monitoring occurred at four 1 m^2 quadrats (herein referred to as 'mussel monitoring stations'). Each quadrat was incorporated into a single day of the four-day buffered low-dose alum treatment (e.g., day 1 of treatment incorporated mussel monitoring station #1, day 2 of treatment incorporated mussel monitoring station #2, day 3 of treatment incorporated mussel monitoring station #3, and day 4 of treatment incorporated mussel monitoring station #4). The following table summarized the mussel behavior observed at each monitoring station during the 2013 low-dose alum treatment (refer to **Appendix C** for 'mussel monitoring stations' locations). Representative photographs captured during the *in situ* mussel monitoring are also provide below:

Monitoring Station ID	Summary of Observations
#1	During setup, 4 mussels in quadrat; all deeply burrowed, upright/stable, and filtering 1 of 4 mussels (LEOC[1]) within underwater camera view frame for monitoring: ○ Pre-application: filtering majority of time (74%), brief valve closures, intermittent burrowing and repositioning ○ Immediately post-application: filtering majority of time (88%), brief valve closures, intermittent repositioning ○ 2 to 3 hours post-application: filtering majority of time (67 – 75%), brief and slightly prolonged valve closures, intermittent burrowing ○ 4 and 6 hours post-application: filtering majority of time (73 – 88%), brief valve closures; intermittent burrowing and repositioning ○ Next morning: minimal floc accumulation ≤0.25; quadrat shifted and 2 mussels (LEOCs) remain inside and all filtering, stable/upright, burrowed, displaying a protracted foot; 4 mussels (3 LEOC, 1 ELCO) noted directly outside quadrat also exhibiting same behavior ○ Day after entire (4-day) treatment: ~10 mussels observed within/near quadrat (primarily LEOCs; 1 juvenile, 1.25" in length); all partially/deeply burrowed (0.25 – 0.5" exposed), filtering, stable/upright, protracted foot; single spent mussel with adductor muscles attached and remaining soft tissues missing

Monitoring Station ID	Summary of Observations (continued)
#2	During setup, 5 mussels (1 juvenile) in quadrat; upright/stable, burrowed (1" exposed), filtering 1 of 5 mussels (LEOC) within underwater camera view frame for monitoring: ○ Pre-application: filtering majority of time (71%), brief valve closures, intermittent burrowing and repositioning ○ Immediately post-application: filtering majority of time (90%), brief valve and siphon closures ○ 2 and 4 hours post-application: filtering majority of time (87 – 94%), brief valve and siphon closures, intermittent repositioning ○ Next morning: minimal floc accumulation ≤0.25"; quadrat shifted and 3 living and 1 dead mussel (LEOCs) inside; dead mussel severely decomposed/dead for several days; all filtering, partially and deeply burrowed (0.25 to 1" exposed), upright, protracted foot; nearby quadrat, 4 mussels (LEOC, ELCO, LINA), exhibiting similar behavior ○ Day after entire (4-day) treatment: minimal overall floc accumulation ≤0.25"; 4 mussels observed within/near quadrat; all filtering, upright, partially and deeply burrowed (0.25" to 1.5" exposed); single spent mussel with adductor muscles attached and remaining soft tissues missing
#3	During setup, 6 mussels in quadrat; 4 deeply burrowed, stable, filtering and 2 dislodged; nearby quadrat several ELCO dislodged (not dead) 2 of 5 mussels (LEOC, LINA) within underwater camera view frame for monitoring: ○ Pre-application: LEOC filtering majority of time (74%), intermittent repositioning; LINA consistent burrowing/repositioning ○ Immediately post-application: LINA repositioned and angle of valves to camera inhibits monitoring; LEOC filtering 42% of the time, intermittent repositioning, minute siphoning of floc, intermittent deep siphoning; visible floc encroachment ○ 2 to 4 hours post-application: difficult to determine behavior due to substantial floc encroachment; apparent unblocked (floc-free) channel where LEOC siphons; intermittent deep siphoning noted; LINA out of view frame ○ Next morning: (relatively) moderate floc (1 -2" layer present); 6 mussels in quadrat (LEOC, LINA, ELCO), all mussels partially exposed, filtering, upright/stable; near quadrat, 17+ mussels (primarily ELCOs) deeply burrowed, filtering, upright/stable Day after entire (4-day) treatment: (relatively) moderate floc (1 -2" layer present); 8 mussels within/near quadrat, all partially burrowed (0.25 – 0.75" exposed), upright, filtering; lots of spent shells, very deteriorated
#4	During setup, 14 mussels in quadrat and all upright/stable, filtering, burrowed 1 mussel (LEOC) within underwater camera view frame for monitoring: ○ Pre-application: filtering majority of time (98%) and very intermittent valve closures ○ Immediately post-application: filtering majority of time (80%), brief valve closures, intermittent forceful siphoning ○ 2 to 4 hours post-application: filtering majority of time (89 – 91%), intermittent forceful siphoning and siphon closre ○ Next morning/day after entire (4-day) treatment: minimal floc accumulation (0.5"); 15 mussels within/nearby quadrat (LEOC, LINA, ELCO, PYCA); filtering, deeply burrowed (0.25 – 0.5" exposed), upright
Note: ELCO = *Elliptio complanta*, LINA = Ligumia nasuta , LEOC = *Leptodea ochracea*, PYCA = *Pyganodon cataracta*	


Image 6 - 7. Mussel monitoring station #1: floc accumulation miniscule, and mussels were partially/deeply burrrowed and actively filtering following treatment activities.

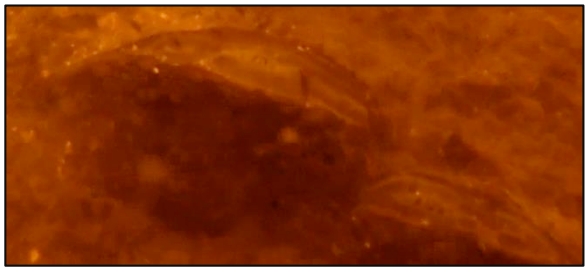



Image 8 – 9. Mussel monitoring station #2**:** floc accumulation minimal (≤0.25”), and mussels were partially/deeply burrrowed and actively filtering following treatment activities (shown left). A single spent mussel with adductor muscles attached and remaining soft tissues missing was also observed near this location following treatment activities (shown right).

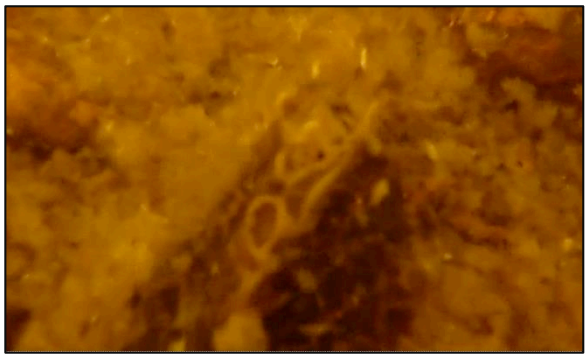


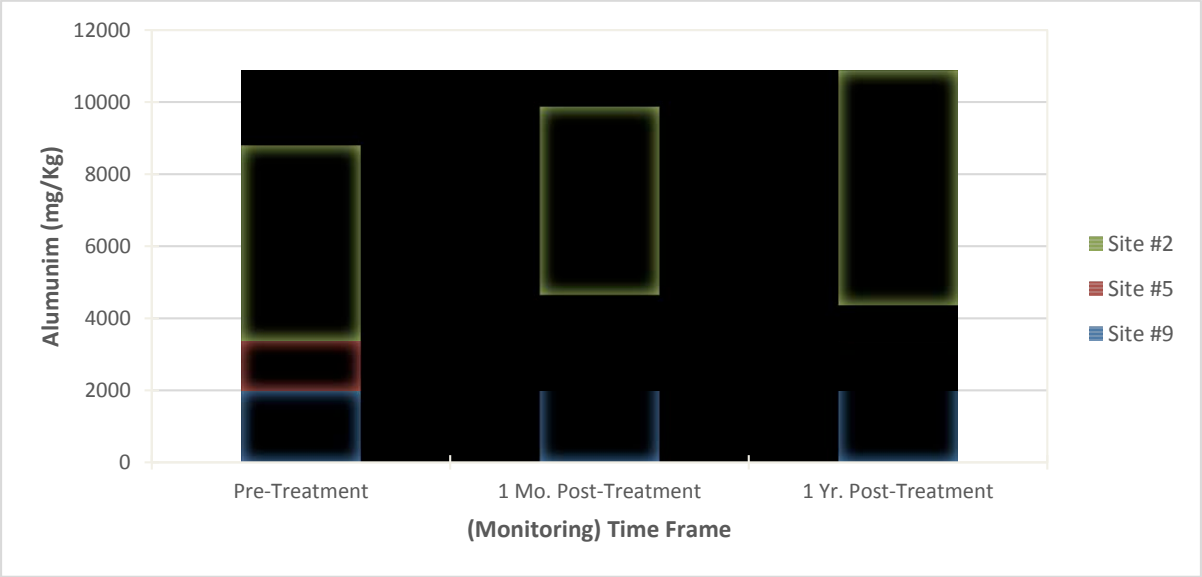

Image 8 – 9. Mussel monitoring station #3**:** floc accumulation (relatively) moderate (1 – 2”), and mussels were partially burrrowed and actively filtering following treatment activities (shown left). During *in situ* monitoring floc encroachment was most substantial at this location; however, it appeared siphoning creating an unblocked (floc-free) channel for the observed mussel.


Image 9 – 10. Mussel monitoring station #4**:** floc accumulation minimal (≤0.5”) (shown in both images), and mussels were deeply burrrowed and actively filtering following treatment activities (shown left).

2.7 **Sediment Cores**

Sediment cores were gathered from a subset of the ten pre-determined locations; site #2, #5, and #9, on June 3, 2013 (i.e., pre-treatment), July 12, 2013 (i.e., one-month post-treatment), and July 18, 2014 (one-year post-treatment). Results of the sediment core analysis indicated that the overall amount of aluminum slightly increased following the treatment. Aluminum values were highly variable between sites (**Figure 4**). Total phosphorus remained relative unchanged one-month following treatment and decreased one-year following the treatment. Total phosphorus values were highly variable overall – both between sites and over the course of the monitoring program.

Figure 4. Comparison of the sum of aluminum (mg/Kg) in the sediments over the course of the monitoring program, west basin of the Monponsett Ponds, Halifax/Hanson, MA.



3.0 **DISCUSSION/CONCLUSION**

Results of the monitoring program indicated that the 2013 buffered, low-dose alum treatment did not adversely impact the state-listed species or water quality in the west basin of Monponsett Pond. A major concern associated with the use of alum treatments in poorly buffered systems, such as the Monponsett Ponds, is that it may result in unintended ecologically detrimental fluctuations in water chemistry, especially pH. Incorporation of a buffering solution (i.e., sodium aluminate) can improve the water's buffering capacity, and subsequently prevent large pH fluctuations during treatment. Results of the monitoring program reflect this sentiment, and the majority of pH values (96%) measured *in situ* in the treatment sector and at the ten pre-established monitoring locations did not fall outside the target range of 6.5 and 7.5. Additionally, no discernable trends or significant changes to pH were identified in the long-term or short-term datasets, respectively.

Floc, a by-product of alum treatments, may also pose an issue for benthic organisms via the suffocation under accumulated floc or the clogging of gills. Implementation of low-dose alum treatment limits the amount of floc produced during each treatment and subsequently reduces the risk of benthic invertebrate mortality. Results of the *in situ* measurements of flocculation indicated the amount of floc produced as a consequence of the treatment was minimal – height of accumulated floc within collection devices did not exceed 0.38 inches. *In situ* monitoring of mussels during and immediately following (i.e., one-day direct application and one-day following entire treatment) indicate that, in general, mussels continued to respond normally to alum treatments, and in areas that collected

atypically high amount of floc (as with mussel monitoring station #3), mussels could reposition to continue unobstructed filtering.

Overall, Lycott believes the monitoring program indicates that low-dose alum treatments can be applied as management tool to reduce phosphorus in water bodies while having minimal impacts to highly sensitive habitats, such as the Monponsett Ponds. In highly eutrophic water bodies, repeated low-dose applications will be needed to effectively reduce the total phosphorus to a level which will reduce the frequency of detrimental cyanobacteria/algal blooms within this water body. Reduction of total phosphorus in the west basin from the low-dose alum treatment was (atypically) short-lived and by 2014, total phosphorus had reached pre-treatment levels. Additional factors, such as external phosphorus loading from the watershed and internal phosphorus loading from sediments warrant investigation and remediation to ensure the efficacy of future low-dose alum treatments.

Appendix A

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

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

Representative: Lycott Environmental, Inc.
21 West Main Street
Spencer, MA 01562

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NHESP APPROVAL PAGE

INSERT IMAGE OF APPROVAL LETTER OR SIMILAR

SHOWING DIVISION APPROVAL PER 321 CMR 10.14

Habitat Management Plan for Phosphorus Inactivation in the West Basin of Monponsett Pond Halifax/Hanson, Massachusetts 2012

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*).

PHOSPHORUS REDUCTION GOALS FOR THE MONPONSETT WATERSHED

The Town of Halifax is working towards developing a Watershed Management Plan for the Monponsett Ponds. Since the large watershed lies not only within Halifax, but also Hanson and Pembroke, coordination between each municipality and the land owners within the watershed is of the upmost importance. The following is an outline of goals developed by Halifax Town Officials:

1. Work with the newly established Monponsett Pond Watershed Association (organized by the Halifax Board of Health with a first meeting of March 15, 2012)
2. Start a monitoring program to determine phosphorus levels

3. Work to determine sources and amounts from the following:
    a. Storm sewers
    b. Septic systems
    c. Run-off from cranberry bogs and other upstream sources
    d. Fertilizer use around the ponds
4. Develop a filtering system for storm water management
5. Continue to monitor septic system use around the Ponds and work with property owners to repair and replace systems
6. Work with cranberry bog owners to utilize Best Management Practices and reduce phosphorus loads in the bogs
7. Encourage use of non-phosphorus fertilizers for lawn/plant care around the ponds

PROPOSED PHOSPHORUS INACTIVATION PROGRAM

The on-going effort to improve water quality in Monponsett Pond and thereby its ability to support aquatic life, recreation, aesthetics, and use as a water supply has recently focused on reduction of phosphorus in the western basin. A phosphorus inactivation program has been proposed including the use of aluminum as a flocculant. The presence of three state-listed species of special concern has prompted NHESP to require analysis of the reaction of these species and monitoring of water quality before, during, and after the proposed treatment. The following sections of this treatment and monitoring plan provide details on the development of the treatment and monitoring activities that will take place as a result.

PERMITTING

Several layers of permitting – federal, state, and local – exist for the management program proposed for the western basin of Monponsett Pond. The permitting requirements are described here in progressive order.

❖ Orders of Conditions

The Halifax and Hanson Conservation Commissions have issued Orders of Conditions OOCs), DEP File #s_____ and _____ respectively. These OOCs are valid for ___ years or until ____ and ____. Copies are attached to this document.

❖ Massachusetts Endangered Species Act

Both basins of Monponsett Pond have been designated by the Massachusetts Division of Fisheries and Wildlife (DF&W) Natural Heritage and Endangered Species Review Program (NHESP) as Priority Habitat for Rare Species and Estimated Habitat for Rare Wildlife. The proposed project occurs within the mapped habitat of the following state-listed species:

Scientific Name	Common Name	Taxonomic Group	MA Status
Leptodea ochracea	Tidewater Mucket	Freshwater Mussel	Special Concern
Ligumia nasuta	Eastern Pondmussel	Freshwater Mussel	Special Concern
Neurocordulia obsolete	Umber Shadowdragon	Dragonfly	Special Concern

Based on the goal of the project to restore the western basin as an ecologically functional water body it will be evaluated as 'management of State-listed Species habitat' per 321 CMR 10.14

Exemptions from Review for Projects or Activities in Priority Habitat in accordance with the following:

> *The following Projects and Activities shall be exempt from the requirements of 321 CMR 10.18 through 10.23: 15. the active management of State-listed Species habitat, including but not limited to mowing, cutting, burning, or pruning of vegetation, or removing exotic or invasive species, for the purpose of maintaining or enhancing the habitat for the benefit of rare species, provided that the management is carried out in accordance with a habitat management plan approved in writing by the Division…*

This document serves as the habitat management plan and has been approved by DF&W as described above (NHESP Approval Page, page 2).

- **U.S. EPA National Pollution Discharge Elimination System Permit**

  In accordance with the U.S. Environmental Protection Agency's (EPA) National Pollution Discharge Elimination System (NPDES) permit, a Notice of Intent (NOI) of Coverage Under the Pesticide General Permit (PGP) for Discharges from the Application of Pesticides will be filed prior to the treatment of the western basin of Monposnett Pond. This permit is expected to be valid for five (5) years.

- **Massachusetts License to Apply Chemicals**

  A 'License to Apply Chemicals' will be obtained from the Massachusetts Department of Environmental Protection, Office of Watershed Management for each year a treatment is conducted.

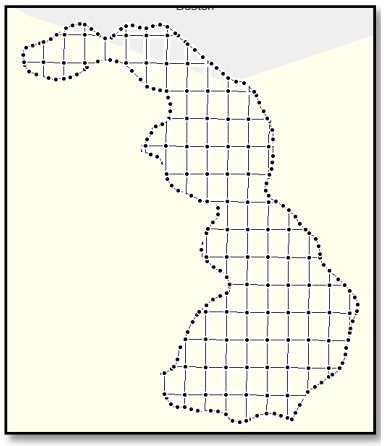
TREATMENT DESIGN

Although referred to as a 'whole-lake' treatment, the aluminum sulfate and sodium aluminate will be applied to areas of the lake that are deeper than four (4) feet – a total of approximately 235 acres, or 83% of the basin. Treatment of areas less than four feet in depth is not considered advantageous in large water bodies due to the disruption of this shallow area by wind and wave action.

Based on jar testing, an in-water aluminum concentration of 3 ppm is anticipated to remove a large percentage of phosphorus from the water column. Typically, aluminum is added to the water column through an aqueous application of aluminum sulfate ($Al_2(SO_4)_3$) . Data collected from the western basin indicates that the water body has poor buffering capacity (alkalinity has been estimated at 11.5 mg/L $CaCO_3$) and therefore simultaneous application of sodium aluminate is recommended. 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 dose for treatment of the western basin of Monponsett Pond is 12,732.56 gallons of aluminum sulfate and 6,366.28 gallons of sodium aluminate.

In order to reduce the potential impact on fauna present within the pond and to accommodate application logistics, the 235-acre treatment area will be broken into sections which will further be divided into 2.77-acre sectors. Each day of treatment will focus upon one of the sections with each sector within that section treated in a pattern such that no two connecting sectors receive treatment sequentially. Each of these sectors will be treated with 150 gallons of aluminum sulfate and 75 gallons of sodium aluminate – the capacity of the treatment vessel. It is anticipated that alum application will last approximately thirty minutes and application of the entire treatment area will span a one-week period.

Liquid aluminum sulfate and sodium aluminate will be applied to the lake surface simultaneously from a moving treatment vessel. The boat's operator will follow a pre-established path through each sector by carefully monitoring the boat's position via a hand-held GPS unit. The boat's path and speed will be recorded with the same GPS unit for future analysis.



Example of GPS tracks used for guidance during treatment

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
Large-scale jar test	2 weeks prior	Treatment staging area	Verify that pH in the treatment area will remain within the target range of 6.5 and 7.5
Water quality	Before, during, and after months and years following	10 established locations; multiple locations during treatment	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
Sediment cores	Before and after One month, one and five years following	3 established locations	Assess changes in |AL| and sediment P

Chemical and Physical Assessment of Treatment

Jar Test

A large-scale jar test will be conducted at the treatment staging area approximately 14 days prior to the scheduled treatment to verify that pH in the treatment area will remain between 6.5 and 7.5 at present water quality conditions. Water will be transferred directly from the subject water body to a 55 gallon glass tank and allowed to settle. Analysis of pH and alkalinity will be conducted and the planned concentration of aluminum will be added, with the planned ratio of aluminum sulfate to sodium aluminate, and applied to the collected water. Alkalinity and pH will be assessed one hour following treatment and again the following morning.

If results of this jar test indicate that pH will fall outside of the 6.5 to 7.5 range, the application rate and ratio will be reassessed and adjusted if necessary. An additional jar test will be carried out as described above to confirm that the adjustments produce the desired results. The treatment will not proceed until the application rate is confirmed to have limited effect on pH.

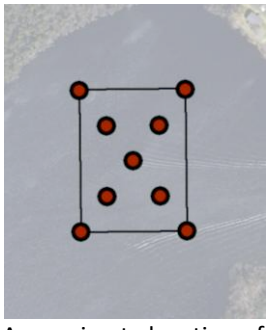
Water Quality Monitoring

The water quality monitoring plan for Monponsett Pond will include sampling at a total of ten (10) locations (see map of **Sample Locations for Chemical and Physical Assessment**). These locations have been selected based on their varying depths and proximity to the treatment area – both inside and out.

The following parameters will be evaluated at each of the 10 sampling locations twice daily on days that treatment takes place. Samples will be collected in the morning before treatment begins and in the evening when treatment has ended for the day.

- Secchi depth
- Dissolved oxygen
- Conductivity
- Total Phosphorus (three locations, mornings following treatment)
- Temperature
- pH
- Alkalinity

Analysis of pH and alkalinity will be conducted *in situ* on an hourly basis. Sampling will occur within the area that was treated one hour previous to the sample collection to allow for stabilization of water conditions and settling of alum through the water column. Following each hour of treatment, 9 locations within the area that has just been treated will be sampled for pH, dissolved oxygen, and alkalinity (see image at right). GPS locations of each sample point will also be recorded with a Garmin GPSMAP 60CSx as samples are taken. Observations of the treatment procedures, floc formation, and any fish and wildlife interactions will be made throughout the treatment and recorded along with all water quality data in a weatherproof field notebook.



Approximate location of sample locations within treatment sectors

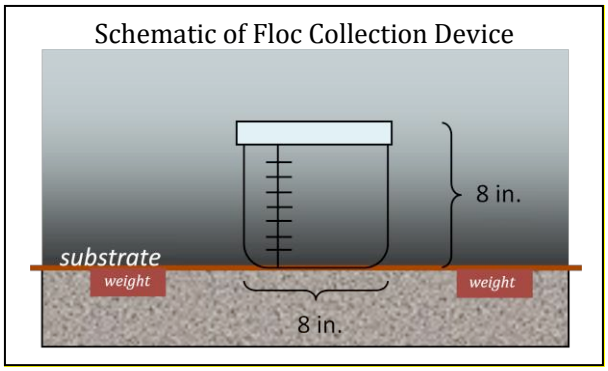
If pH consistently falls outside of the 6.5 to 7.5 range during these sampling events, the results will be verified with duplicate samples. If pH outside of the prescribed range persists, treatment will be suspended. Additional monitoring will be conducted and NHESP/DEP will be contacted to determine when the treatment may resume.

A sampling program for the parameters listed above will continue in the months and years following the

initial treatment in conjunction with additional treatments and/or state-listed species monitoring.

Measurement of Flocculation

In order to measure the amount of flocculation occurring during the treatment, six pairs of floc-collection devices will be installed prior to the treatment. These devices will be designed to capture floc as it precipitates to the pond's bottom. Five of the six measurement stations will be situated in close proximity to the paired plots that will be monitored for state-listed mussels (state-listed species section below), while the sixth will be placed at the pond's deep hole. 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 morning following treatment of the section in which it is located and all devices will be measured the morning following the last day of 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. A floc-collection device will be installed at this location so that measurement of floc may be conducted as well.

It should be noted that the western basin of Monponsett Pond is generally extremely turbid with secchi depths of less than one foot common throughout the summer and fall. Clarity may therefore inhibit this visual observation. Should low clarity persist during treatment, rendering the underwater recording of floc depth impossible, floc-collection devices will be covered with a water-tight lid and brought to the surface by a diver. The device will be transported to shore where it will be allowed to settle for measurement.

Sediment Sampling

Three locations have been selected for sediment core sampling to assess changes in aluminum and phosphorus concentrations (see map of **Sample Locations for Chemical and Physical Assessment**). Samples will be collected utilizing an AMS 2" x 4' Soft Sediment Core Sampler with samples collected in an acrylic Plexiglas tube.

Site	Location relative to treatment area	Water depth (ft.)
5	Outside	1
9	Inside	5
1	Inside	10

Sediment cores will be collected from these locations one day prior to treatment and one month following the completion of treatment. Additional cores will be collected one and five years following

treatment in conjunction with state-listed species monitoring.

Monitoring of State-Listed Mussel Species

Several monitoring procedures will be conducted prior to, during, and following the initial buffered low-dose alum treatment of the western basin of Monponsett Pond. These monitoring events will allow for an assessment of the mussel populations, including the two state-listed species, in the pond and their reaction to the treatment. Based on the limited visibility present in the western basin of Monponsett Pond, monitoring procedures have been developed such that the lack of visual contact does not inhibit the production of valid results.

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

The monitoring conducted prior to the buffered low-dose alum treatment will be a repeatable event using semi-quantitative methods to investigate the abundances, catch-per-unit-effort, demographics (*i.e.,* size structure), shell conditions, distributions, and habitat of the mussel species in the western basin of Monponsett Pond. Comparison of the baseline survey with follow-up surveys (*i.e.* one and five years following the first treatment) will allow for assessment of the long-term effects of a buffered low-dose alum treatment on individual mussel populations in the west basin of Monponsett Pond.

A total of five-paired plots will be surveyed to gather baseline information on the mussel species in the western basin. In order to reduce sampling costs, plot locations will be situated in areas with known mussel beds (see map for **Mussel Monitoring Stations**) (GZA Environmental, 2011). At each site, two 25-m^2 quadrats will be established; one quadrat will be situated in shallow water (1-4 feet) while the other will be placed in deeper water (>4 feet). The precise location of each plot will be recorded using a hand-held GPS device. Additionally, the boundary of each plot will be delineated by installing markers (concrete bricks painted with Sea Hawk Smart Solution Metal Free Bottom Paint) at two-foot intervals directly outside the sampling frame. Due to the characteristic poor visibility in the western basin, sampling bias will be an obvious concern at the time of the survey. Sampling bias will be accounted for by implementing a modified 25-m^2 quadrat. The modified sampling apparatus will be rectangular (12.5 x 2 m in size) and equipped with a center guideline.

At each quadrat, a diver will employ visual and tactile search methods to collect mussels within the sampling frame. Searches will initiate from a random start point (*i.e.*, either end of the sampling frame) and will continue for 30 minutes. In addition to gathering mussels, the diver will record three habitat features, percent substrate composition, percent cover of rooted aquatic macrophytes, and depth (ft.). Water visibility, time spent for visual versus tactile search methods, and proportion of quadrat sampled at stoppage time will also be measured to account for inter-observer variability. In scenarios where searches are completed prior to the 30-minute stop time; the diver will also take note of amount of time needed to search the entire quadrat.

Upon search completion, gathered mussels will be placed into a mesh bag. The mesh bag will be attached to a surveying vessel by a rope and a series of tugs will alert a topside observer to surface the gathered mussels for examination. Once surfaced, gathered mussels will be identified to the species-level, counted, and measured for shell length (anterior-posterior dimension across the valves to the nearest 0.1 mm). The topside observer will also assess the degree of shell erosion according to the following rank system:

Rank	Erosion Type
0	no erosion
1	erosion limited to the umbo
2	erosion of the umbo and partial erosion of valves
3	complete or nearly complete erosion of both umbo and valves

At this time, the diver will excavate 1% of the quadrat area. Excavations will involve the removal of all substrate from the 1% area to a depth of 10 to 15 cm, and transport of the material to a mesh bag where it can be examined at the surface. At the surface, excavated material will be sifted through a set of sieves (smallest size 4 mm) to detect smaller mussels. Again, all mussels discovered during this process will be identified, counted, and measured for length. Following measurements, a representative individual from each species collected will be documented by photograph. All substrate and mussels will be returned to their original location in filtering position. Simultaneously, the diver will utilize fluorescently painted washers tied to a surface float to designate locations with high abundances of state-listed species within the long-term monitoring station. This process will help facilitate site selection for *in situ* mussel monitoring (as detailed below). Markers will be removed during the follow-up long-term monitoring survey.

In situ Mussel Monitoring: Behavioral Responses of Mussels to a Buffered Low-Dose Alum Treatment

The *in situ* monitoring program aims to investigate mussel behavioral responses of two-state listed species, Tidewater Mucket (*Leptodea ochracea*) and Eastern Pondmussel (*Ligumia nasuta*), to a buffered low-dose alum treatment in the western basin of Monponsett Pond.

A total of five locations will be selected for *in situ* monitoring of state-listed mussel species, Tidewater Mucket and Eastern Pondmussel. In order to reduce sampling costs, *in situ* monitoring will be performed within the long-term monitoring stations (*i.e.*, five-paired plots; refer to map for **Mussel Monitoring Stations**). *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

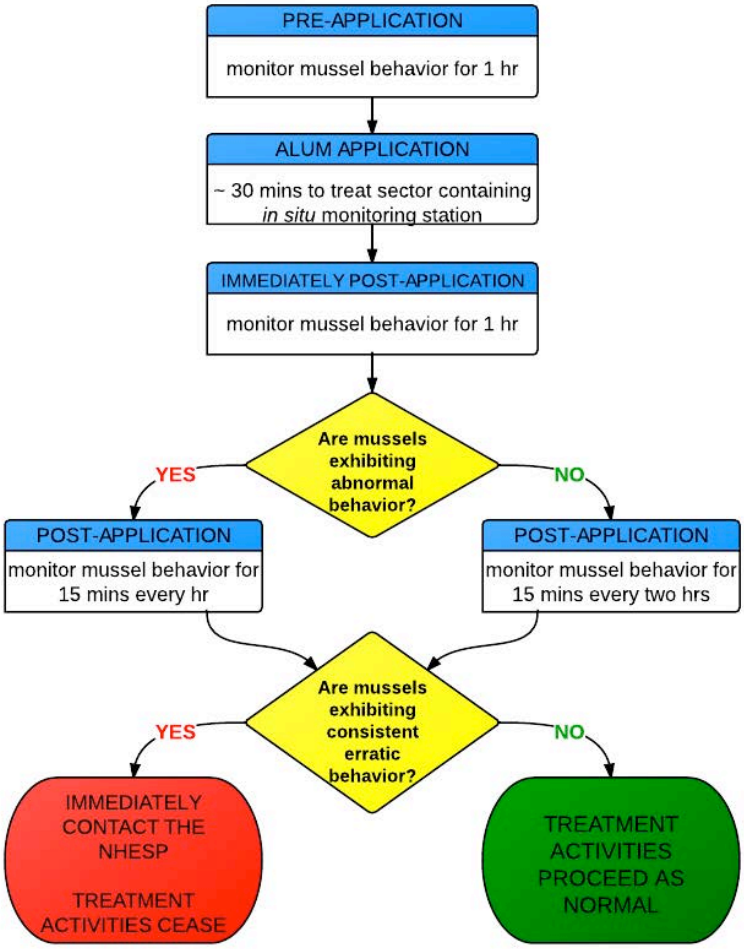
The five *in situ* monitoring locations are intended to assess mussel behavioral responses during the entire buffered low-dose alum treatment. As previously mentioned in the **treatment design**, it is anticipated that total treatment duration will span one work week or five days. Prior to application, the five individual (treatment) sectors containing the *in situ* monitoring stations will be assigned to a separate section (*i.e.,* one day of treatment) so that behavioral responses of mussels may be observed during the entire treatment period. During application, the day's treatment activities will commence in the individual sector enclosing the *in situ* monitoring station.

One-hour prior to the first day of treatment, the observer will visit the corresponding *in situ* monitoring station included in the day's treatment activities. At this time, the observer will lower an underwater camera until mussels are within the monitor's view frame. At the surface, the underwater camera will be attached to a monitor and powered with a portable battery. The monitor and portable battery will be placed into a waterproof case and situated inside a buoy for easy accessibility. Mutual concession between the number of individuals within the view frame and adequate mussel behavior assessment will ultimately determine the underwater camera's distance from the pond's bottom. Once the appropriate adjustments have been made, the observer will record the number of mussels within the view frame.

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 one hour period prior to the day's treatment activities. 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. Immediately following an application of the individual sector containing the *in situ* monitoring station, the observer will monitor mussel behavior for a one-hour time period (*i.e.*, treatment).

Mussel monitoring will proceed until one-hour following the day's treatment activities. Monitoring will be conducted utilizing the aforementioned methodology; however, monitoring duration will be limited to a 15 minute time period. Furthermore, sampling effort will be contingent on the mussel behavior observed during the one-hour treatment period. For instance, under a scenario in which signs of stress or mortality (*e.g.*, extended valve closure, dislodgement/disequilibrium, prolonged gaping with inactive filtering, and foot retraction) are detected, a higher sampling effort (15 min duration/per hr) will be performed for the remainder of the daily treatment activities. Conversely, less sampling effort (15 min duration/per two hrs) will be needed in the event that no adverse changes in mussel behavior are detected during the one-hour treatment period.

Upon monitoring completion, consistent erratic behavior (as detailed above) will be immediately reported to the NHESP, and future treatment activities will cease unless otherwise directed by the NHESP. However, if no significant changes are detected, the second day of treatment and *in situ* mussel monitoring will proceed in a similar manner as described above (and so on for treatments conducted on days 3 – 5). A schematic illustrating the *in situ* methodology is shown below:



Monitoring of State-Listed Dragonfly Species

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

A baseline survey will be designed as a repeatable event investigating the distribution, abundances and CPUE of the state-listed dragonfly species, *Neurocordulia obsoleta*. Comparing baseline survey information with follow-up surveys will allow for assessment of the long-term effects of a buffered low-dose alum treatment in west basin of Monponsett Pond on the aforementioned species.

A total of six plots (strip transects 105 m x 9 m in size) will be distributed in suitable habitat throughout the perimeter of the west basin of Monponsett Pond. Historically, *N. obsoleta* have been reported along the RT-58 causeway in the west basin of Monponsett Pond (GZA, 2011; personal communication the NHESP). As such, a higher sampling effort (four of the six plots) will be allotted to this particular portion of the water body. The remaining plots will be established in suitable habitat throughout the remainder of the west basin of Monponsett Pond. Determination of the exact location of these plots will be contingent on findings from a cursory survey of the perimeter of the west basin of Monponsett Pond. During the cursory survey, GPS coordinates (x, y), field notes, and photographs will document suitable habitat outside the RT-58 causeway area (see map for **Dragonfly Cursory Survey and Potential Monitoring Locations**).

At each plot, an observer will utilize an aquatic d-frame net (mesh size: 0.5 mm) to gather larval invertebrates within the sampling area. Searches will initiate from a random start point and will continue for 45 minutes. For the duration of the search, the observer will drag an aquatic net across the pond's bottom (to include ~2 cm depth) to gather larval invertebrates from key habitat features: substrate (≥ 32 mm in size), woody debris, and rooted vascular plants. Species within *Neurocordulia* are classified as 'climbers/clingers', and are generally not found within fine substrate. If necessary, the observer may incorporate hand-shoveling to facilitate the collection of bottom substrate and debris into the net. Periodically, the observer will carefully empty the net's contents into a 5-gallon holding bucket filled with nearby pond water.

It is likely that the baseline survey will be conducted prior to the *N. obsoleta's* emergence; *N. obsoleta* are generally on the wing from late-May to early-August. Therefore, it is anticipated that only *N. obsoleta* nymphs (*i.e.*, larval stage) will be present at the time of the baseline survey. If the baseline and followup surveys are conducted within the on the wing time period, survey methods will be carried out in a similar manner as detail above; however, following each 45 minute timed search an additional 15 minute timed search will be allotted to examine emergent features (*e.g.,* partially submerged substrate, emergent vegetation, and manmade structures) for *N. obsoleta* exuviae. Given the crepuscular nature of *N. obsoleta*, adults are not practical to observe in surveys conducted during the on the wing period.

Upon search completion, sample processing will be conducted on-shore nearby the sampling location. Gathered material will be transferred from the holding bucket(s) to a plastic dish tub for sorting. Using forceps, gathered invertebrates will be separated by family. *N. obsoleta* nymphs observed at this time will be counted. Accurate field identification of larvae is a difficult task; therefore, a subsample of *N. obsoleta* (n ≤ 5 *N. obsoleta* for all plots sampled per survey) will be preserved in a Whirl-Pak in 70% ethanol, labeled, and returned to the laboratory to verify field identifications. Surveys conducted during the 'on flight' period will also record the number of *N. obsoleta* exuviae collected during the 15 minute timed search. A subsample of *N. obsoleta* exuviae (n ≤ 15 *N. obsoleta* exuviae for all plots sampled per survey) will be preserved using the aforementioned methods, and returned to the laboratory to verify field identifications. Following sampling, removed material and invertebrates will be carefully returned to their original location.

Monitoring of Fish and Wildlife Response to Treatment

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, a survey team, and a shoreline observer. *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
- **Shoreline observer**
    - Shoreline inspections (with binoculars) for fish and/or wildlife mortality from accessible lookout points; accessible lookout points will be evenly distributed throughout the pond's perimeter

Any deceased fish and/or wildlife encountered during *in situ* in-water and shoreline 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), and next-day treatment activities will cease unless otherwise directed by the DFW-SE. In a scenario where no fish and/or wildlife mortality is detected, the second day of treatment and *in situ* in-water and shoreline monitoring will proceed in a similar manner as described above (and so on for treatments conducted on days 3 – 5).

REPORTING

Several reports will be generated as a result of this Habitat Management Plan. These reports will be submitted to NHESP and other interested parties (*i.e.* the Client and Conservation Commissions).

<table>
<tr><th>Approximate Timing For Report Submission</th><th colspan="2">Description of Report and Information Contained Therein</th></tr>
<tr><td>Prior to treatment</td><td colspan="2">Results of the jar test and final treatment ratios, general information on treatment date and logistics</td></tr>
<tr><td rowspan="3">1 week following treatment</td><td colspan="2">General summary report on treatment activities including observations during treatment and raw data from sampling events</td></tr>
<tr><td colspan="2">A summary report of the results from the baseline mussel and dragonfly surveys. Results to be included:</td></tr>
<tr><td><u>Mussels</u>
➢ % rooted macrophytes, % substrate composition, species richness, abundance, CPUE, size structure, shell erosion
➢ Aforementioned variables reported per plot, per depth category (shallow/deep), and cumulatively (pond-wide)
➢ Descriptive statistics computed for qualitative data
➢ Size structure, abundance, and CPUE reported for each species
➢ Abundance and CPUE reported for the mussel community
➢ GIS-based map of precise locations of the mussel monitoring stations (i.e., five-paired plots)
➢ Copies of field notes, photographs, and the NHESP rare species data observation forms</td><td><u>Dragonfly</u>
➢ Abundance and CPUE for N. obsoleta
➢ Abundance and CPUE reported for each life stage
➢ All the aforementioned variables reported per plot and cumulatively (pond-wide)
➢ Descriptive statistics computed for qualitative data
➢ GIS-based maps of the precise locations of six plots and the additional suitable habitat locations
➢ Written description of the location and habitat features of the additional suitable habitat locations
➢ Copies of field notes, photographs, preserved specimens, and the NHESP rare species data observation forms</td></tr>
<tr><td>2-3 months following treatment</td><td colspan="2">Year-end report including data analysis for chemical and physical assessments before, during, and after treatment</td></tr>
<tr><td rowspan="2">1 year after treatment</td><td colspan="2">Final Report including all data collected for this Habitat Management Plan</td></tr>
<tr><td colspan="2">An in-depth report discussing the long-term effects of the treatment on the mussel populations and N. obsoleta in Monponsett Pond. Information to be included:
• Results of the baseline mussel and dragonfly surveys (as specified in ‘1-week following treatment’)
• Results of the 1-year post-treatment mussel and dragonfly surveys (as specified in ‘1-week following treatment’)
• Data analysis of the two datasets to detect changes from pre- to post-treatment</td></tr>
<tr><td>5 years after treatment</td><td colspan="2">Update the 1-year after treatment in-depth report discussing the long-term effects of the treatment on the mussel populations and N. obsoleta in Monponsett Pond. Information to be included:
• Results of the baseline mussel and dragonfly surveys (as specified in ‘1-week following treatment’)
• Results of the 1-year post-treatment mussel and dragonfly surveys (as specified in ‘1-week following treatment’)
• Results of the 5-year post-treatment mussel and dragonfly surveys (as specified in’1 week following treatment’
• Data analysis of the three datasets to detect changes from pre- to post-treatment</td></tr>
</table>

Sample Locations for Chemical and Physical Assessment

Legend

- Water Samples
- Sediment Cores, Water Samples

N

0 350 700 1,400

Feet

MassGIS Color Ortho Imagery

Monponsett Pond -Western Basin
Halifax & Hanson
Massachusetts

Lycott Environmental, Inc.

21 West Main Street
Spencer, MA 01562
508-885-0101
www.lycott.com
info@lycott.com

Mussel Monitoring Stations

Legend

- Individual (Mussel) Monitoring Station

N

0 500 1,000 1,500

Feet

1:11,000

Data Source(s):

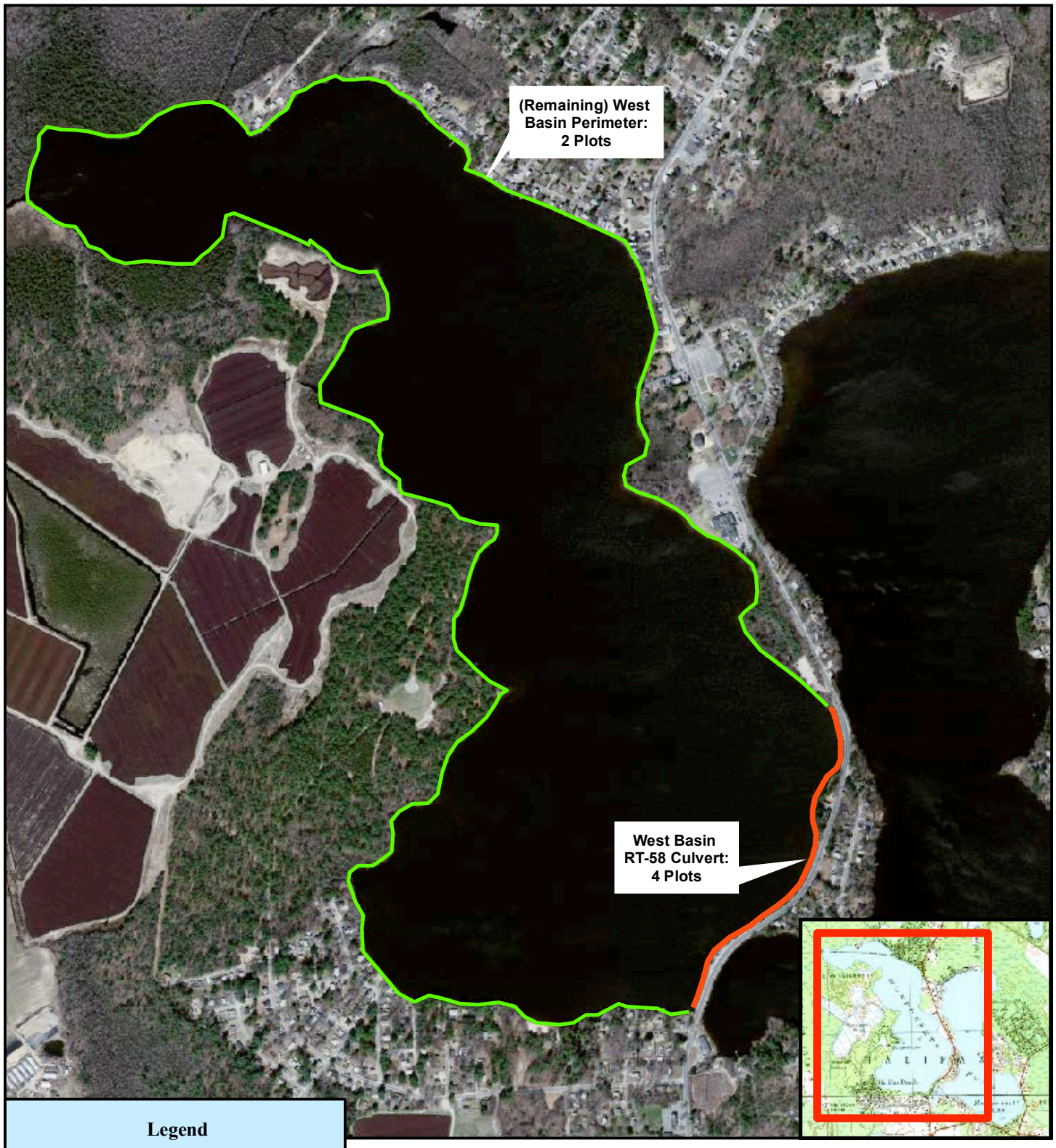
MassGIS: USGS Topo Quad revised 01'
MassGIS: USGS Color Orthoimagery (30 cm) revised 08'-09'

Monponsett Pond
Halifax& Hanson
Massachusetts

Lycott Environmental, Inc.

21 West Main Street
Southbridge, MA 01562
508-885-0101
www.lycott.com
info@lycott.com

Dragonfly Cursory Survey and Potential Monitoring Locations



Legend

- Historical N. obsoleta Observations
- Cursory Survey

N

0 525 1,050 1,575

Feet

1:11,000

Data Source(s):

MassGIS: USGS Topo Quad revised 01'
MassGIS: USGS Color Orthoimagery (30 cm) revised 08'-09'

Monponsett Pond
Halifax/Hanson
Massachusetts

Lycott Environmental, Inc.

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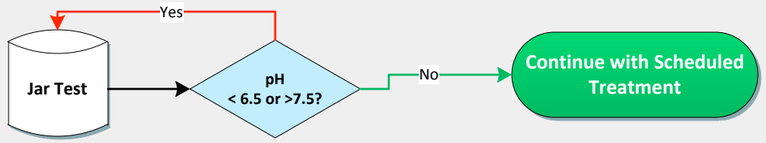
info@lycott.com

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

Chemical & Physical Assessment

Fauna Monitoring

14 Days Before Treatment



Conduct Baseline Survey for State-Listed Species
Tidewater Mucket (*Leptodea ochracea*), Eastern Pondmussel (*Ligumia nasuta*), & Umber Shadowdragon (*Neurocordulia obsoleta*)
(May 15-June 1)

Water Quality | Sediment Cores | Floc Collection | Fish & Wildlife Monitoring | Mussel Monitoring

1 Day Before Treatment

Baseline Water Quality
10 locations
Secchi, Temperature, pH, Dissolved Oxygen, Alkalinity, Total Phosphorus

Collect Sediment Cores
3 locations

Install Floc Collectors
6 collection devices
1 video camera

Install Monitoring Stations
5 locations
1 video camera

Ea. Treatment Morning

Water Quality
10 locations
Secchi, Temp, pH, DO, Alkalinity

Shoreline Inspection
Record #s of dead fish, wildlife, etc.

Monitor Mussel Behavior
1 hour

During Treatment

Water Quality
1hr. After treatment
9 locations in each sector
pH, DO, Alkalinity

pH
< 6.5 or >7.5?

Yes

No

Treatment Area Inspections
During by treatment team & 1 hr after by sampling team

Shoreline Inspections

greater # dead organisms than obs. before?

Yes

No

Monitor Mussel Behavior
immediately post-treatment (1 hr)

Monitor Mussel Behavior
15 mins every hour

Yes

Are mussels exhibiting abnormal behavior?

No

Monitor Mussel Behavior
15 mins every 2 hours

Are mussels exhibiting consistent erratic behavior?

Yes

No

STOP

CONTINUE

Ea. Treatment Evening

Water Quality
10 locations
Secchi, Temp, pH, DO, Alkalinity

Collect/Measure Floc Collectors
6 collection devices

30 Days After Treatment

Baseline Water Quality
10 locations
Secchi, Temperature, pH, Dissolved Oxygen, Alkalinity, Total Phosphorus

Collect Sediment Cores
3 locations

1 Year After Treatment

Baseline Water Quality
10 locations
Secchi, Temperature, pH, Dissolved Oxygen, Alkalinity, Total Phosphorus

Collect Sediment Cores
3 locations

Conduct State-Listed Species Surveys
(May 15-June 1)

LYCOTT

Appendix B

info@lycott.com
(508) 885-0101
21 West Main St (Route 9)
Spencer, MA 01562

Table 1. 2013 Large-Scale Jar Testing Raw Data, West Basin of the Monponsett Ponds, Halifax/Hanson, MA.

SITE	(Monitoring) Time Frame	Date	pH			Dissolved Oxygen (mg/L)	Temperature (°C)	Alkalinity (mg/L of CaCO3)	Total Phosphorus (mg/L)			Conductivity (µS)
			Measurement #1	Measurement #2	Mean				Measurement #1	Measurement #2	Mean	
Tank	Pre-Treatment	5/23/2013	6.80	6.86	6.83	7.1	20.8	8.57	0.142	0.150	0.146	227
Pump-Site	Pre-Treatment	5/23/2013	6.80	x	6.80	7.58	21.5	8.68	0.134	x	x	228
Tank	1-hr Post-Treatment	5/23/2013	6.93	6.93	6.93	6.9	21	x	0.158	0.168	0.163	243
Tank	24-hr Post-Treatment	5/24/2013	6.85	6.85	6.85	7.17	18.6	9.5	0.166	0.186	0.176	236
Pump-Site	24-hr Post-Treatment	5/24/2013	6.78	x	6.78	7.45	20.4	8.67	0.176	x	x	225

Table 2. 2013 – 2014 *In Situ* Treatment Sector pH and Dissolved Oxygen Monitoring Raw Data, West Basin of Monponsett Ponds, Halifax/Hanson, MA

Treatment Sector ID	Day of Treatment	Size (acres)	Amt of Aluminum Sulfate (gal.)	Amt of Sodium Aluminate (gal.)	Treatment		Sampling Event		pH								Dissolved Oxygen (mg/L)	
					Start Time	End Time	Start Time	End Time	Pre-#1	Pre-#2	Pre-#3	Mean (of Pre-#1-#3)	Post-#1	Post-#2	Post-#3	Mean (of Post-#1-#3)	Pre-	Post-
1	1	3.5	200.35	100.18	9:43	10:03	9:30	10:30	6.82	6.73	6.80	6.78	7.00	6.83	6.90	6.91	8.04	7.62
2	1	3.5	200.35	100.18	10:15	10:35	10:07	11:09	6.80	6.75	6.80	6.78	6.85	6.66	6.70	6.74	7.45	7.52
3	1	3.5	200.35	100.18	10:44	11:00	10:36		6.74	6.66	6.80	6.73	6.79	6.66	6.70	6.72	7.34	7.66
4	1	1.01	58.03	29.01	11:20	11:25	11:16	12:20	6.91	6.67	6.80	6.79	6.84	6.76	6.70	6.77	7.35	8.15
5	1	3.5	200.35	100.18	11:55	12:10	11:40	12:41	6.62	6.63	6.80	6.68	6.93	6.69	6.80	6.81	7.83	7.88
6	1	1.67	95.52	47.76	11:28	11:36	11:26	12:28	6.82	6.63	6.80	6.75	6.87	6.62	6.70	6.73	7.36	7.62
7	1	0.76	43.23	21.61	11:40	11:44	11:32	12:39	6.80	6.75	6.80	6.78	7.05	6.80	6.80	6.88	7.96	8.25
8	1	3.5	200.35	100.18	12:22	12:43	12:23	12:25	6.44	6.71	6.80	6.65	7.03	6.79	7.00	6.94	8.04	8.14
9	1	3.5	200.35	100.18	12:55	1:10	12:47	1:05	6.87	6.64	6.80	6.77	6.89	6.74	6.80	6.81	7.94	7.97
10	1	1.57	89.97	44.99	1:20	1:30	1:10	1:15	6.89	6.67	6.80	6.79	6.91	6.64	6.80	6.78	7.80	7.98
11	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12	1	2.2	125.96	62.98	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13	1	3.08	176.2	88.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
14	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
15	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
16	1	1.57	89.96	44.98	x	x	x	x	x	x	x	x	x	x	x	x	x	x
17	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
18	1	3.48	199.1	99.55	x	x	x	x	x	x	x	x	x	x	x	x	x	x
19	1	0.54	30.99	15.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x
20	1	3.34	190.97	95.48	x	x	x	x	x	x	x	x	x	x	x	x	x	x
21	1	3.5	200.35	100.18	x	4:30	3:28	5:30	6.93	6.76	x	x	x	x	x	x	8.30	x
22	1	0.77	43.83	21.91	x	x	x	x	x	x	x	x	x	x	x	x	x	x
23	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
24	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
25	1	3.5	200.35	100.18	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12	2	3.5	200.35	100.18	9:52	10:03	9:34	10:53	6.76	6.78	6.80	6.78	6.86	6.95	6.80	6.87	8.05	7.77
13	2	3.5	200.35	100.18	10:15	10:21	10:05	11:14	6.90	6.73	6.80	6.81	6.94	6.72	6.80	6.82	8.00	8.10
14	2	3.5	200.35	100.18	10:40	10:50	10:17	11:42	6.90	6.77	6.80	6.82	7.02	6.96	6.80	6.93	8.40	8.23
15	2	1.55	88.47	44.23	11:04	11:04	10:36	12:05	6.89	6.75	6.80	6.81	7.03	6.67	6.80	6.83	8.32	8.05
16	2	1.03	59.08	29.54	11:08	11:11	10:42	12:08	6.88	6.71	6.80	6.80	6.85	6.76	6.80	6.80	8.21	7.83
17	2	0.54	30.99	15.5	11:16	11:20	10:50	12:14	6.95	6.85	6.80	6.87	6.99	6.88	6.80	6.89	8.01	8.04
18	2	2.86	163.72	81.86	11:33	11:39	10:58	12:33	6.84	6.69	6.80	6.78	7.00	6.85	6.80	6.88	7.58	7.86
19	2	2.17	123.97	61.98	11:55	12:00	11:18	12:55	6.96	6.85	6.80	6.87	6.98	6.86	6.80	6.88	7.84	8.04
20	2	3.5	200.35	100.18	12:12	12:22	11:24	1:15	6.95	6.85	6.80	6.87	7.01	7.02	7.00	7.01	8.85	8.46
21	2	3.48	199.1	99.55	12:35	12:46	11:47	1:32	6.96	6.85	6.80	6.87	7.04	6.94	6.80	6.93	8.14	8.26
22	2	3.5	200.35	100.18	1:02	1:12	12:26	2:00	6.94	6.90	6.80	6.88	7.24	6.80	7.00	7.01	8.01	8.24
23	2	1.83	104.73	52.36	1:26	1:31	12:47	2:23	7.01	6.91	6.80	6.91	7.11	6.75	7.00	6.95	8.05	8.81
24	2	3.08	176.2	88.1	1:41	1:50	1:22	2:40	7.11	6.25	6.80	6.72	7.06	6.87	6.80	6.91	8.15	8.53

Treatment Sector ID	Day of Treatment	Size (acres)	Amt of Aluminum Sulfate (gal.)	Amt of Sodium Aluminate (gal.)	Treatment		Sampling Event		pH								Dissolved Oxygen (mg/L)	
					Start Time	End Time	Start Time	End Time	Pre-#1	Pre-#2	Pre-#3	Mean (of Pre-#1-#3)	Post-#1	Post-#2	Post-#3	Mean (of Post-#1-#3)	Pre-	Post-
25	2	3.5	200.35	100.18	2:03	2:13	1:52	2:57	7.00	6.86	7.00	6.95	6.90	6.73	6.80	6.81	8.35	8.46
26	2	2.92	167.06	83.53	2:28	2:36	2:06	3:20	7.14	6.78	7.00	6.97	7.22	6.87	6.80	6.96	8.53	8.49
27	2	3.04	173.98	86.99	2:50	2:55	2:15	3:50	7.11	6.65	6.80	6.85	7.11	6.87	7.00	6.99	8.33	8.55
28	2	0.77	43.83	21.91	3:19	3:23	2:45	4:20	7.08	6.92	7.00	7.00	7.04	6.72	6.80	6.85	8.18	8.66
29	2	1.57	89.96	44.98	3:25	3:30	2:50	4:28	7.13	6.84	7.00	6.99	6.96	6.89	7.00	6.95	8.61	8.38
30	2	3.5	200.35	100.18	3:42	3:53	3:01	4:42	7.22	9.92	7.00	8.05	7.12	6.90	7.00	7.01	8.08	8.29
31	2	3.5	200.35	100.18	4:06	4:17	3:44	5:07	7.15	6.76	7.00	6.97	7.13	6.95	7.00	7.03	8.45	8.58
32	2	3.38	193.46	96.73	4:32	4:44	3:54	5:33	7.01	7.06	6.80	6.96	6.30	6.40	6.50	6.40	8.50	8.25
33	2	3.5	200.35	100.18	5:06	5:12	4:27	6:06	7.09	6.89	7.00	6.99	7.08	6.94	7.00	7.01	8.38	8.39
34	2	1.42	81.15	40.57	5:34	5:38	8:24	6:34	7.17	7.05	7.00	7.07	6.70	6.69	6.80	6.73	8.67	8.44
35	2	0.41	23.61	11.8	5:16	5:18	4:39	6:10	7.17	7.03	7.00	7.07	7.24	7.38	7.00	7.21	8.41	8.76
35	2	0.41	23.61	11.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x
36	2	2.2	125.96	62.98	5:43	5:50	4:45	6:43	7.11	6.81	7.00	6.97	7.07	6.82	6.80	6.90	8.54	8.54
37	2	0.53	30.34	15.17	6:10	6:12	4:50	7:12	7.33	7.16	7.00	7.16	7.22	7.23	7.00	7.15	8.00	8.14
38	2	1.44	82.16	41.08	6:07	6:10	4:53	7:09	7.26	7.28	7.00	7.18	7.20	7.08	7.00	7.09	7.99	8.47
39	2	0.76	43.23	21.61	6:04	6:07	4:56	7:06	7.05	7.06	7.00	7.04	7.10	6.99	7.00	7.03	8.27	8.61
40	2	3.44	196.68	98.34	6:25	6:35	5:13	6:25	7.18	7.04	7.00	7.07	7.00	6.82	6.80	6.87	8.40	8.36
41	2	3.5	200.35	100.18	6:59	7:03	5:36	7:59	7.15	6.93	7.00	7.03	7.25	7.05	6.80	7.03	8.44	7.72
42	2	3.5	200.35	100.18	7:02	7:22	6:38	8:15	6.84	6.66	6.80	6.77	7.02	6.80	7.00	6.94	8.54	8.17
43	2	3.5	200.35	100.18	7:37	7:47	7:17	8:39	7.13	6.98	7.00	7.04	6.94	6.79	6.80	6.84	8.32	7.79
44	2	3.34	190.97	95.48	8:00	8:10	7:26	9:00	6.98	6.82	6.80	6.87	7.34	6.91	x	7.13	7.87	8.04
45	2	3.5	200.35	100.18	8:27	8:37	7:30	9:26	6.94	6.80	6.80	6.85	7.02	7.07	x	7.05	8.11	8.11
46	3	2.96	169.2	84.6	10:25	10:34	8:55	11:38	6.69	6.52	6.66	6.62	6.81	6.69	6.80	6.77	7.12	7.83
47	3	3.5	200.35	100.18	10:55	11:05	10:31	11:57	6.95	6.63	6.80	6.79	6.89	6.63	6.80	6.77	7.79	8.17
48	3	2.04	116.91	58.46	11:38	11:44	10:36	12:34	6.83	6.43	6.80	6.69	6.87	7.01	6.80	6.89	7.96	8.11
49	3	3.5	200.11	100.05	12:02	12:12	11:53	1:05	6.81	6.53	6.80	6.71	6.95	6.97	6.80	6.91	7.93	8.60
50	3	3.14	179.83	89.92	12:27	12:37	12:02	1:27	6.88	6.92	6.80	6.87	7.00	6.96	7.00	6.99	8.19	8.26
51	3	3.5	200.35	100.18	12:56	1:06	12:16	1:59	6.99	6.98	6.80	6.92	6.65	6.79	6.60	6.68	8.24	8.40
52	3	1.89	108.37	54.19	1:23	1:28	12:39	2:23	6.94	6.91	7.00	6.95	6.97	7.10	6.80	6.96	8.49	8.47
53	3	1.29	74.02	37.01	1:30	1:34	1:12	2:30	6.94	7.07	6.80	6.94	6.99	7.08	6.80	6.96	8.04	7.97
54	3	1.63	93.42	46.71	1:44	1:49	1:33	2:48	6.99	7.04	7.00	7.01	7.02	7.20	6.80	7.01	8.37	7.97
55	3	2.78	159	79.5	2:20	2:17	1:36	3:05	7.01	7.06	7.00	7.02	7.02	7.24	7.00	7.09	8.34	8.04
56	3	3.5	200.35	100.18	2:36	2:46	2:19	3:53	6.90	7.00	6.80	6.90	7.00	6.93	7.00	6.98	8.00	8.41
57	3	3.5	200.35	100.18	3:11	3:21	2:32	3:14	7.10	7.17	7.00	7.09	7.06	7.26	7.00	7.11	8.26	8.38
58	3	1.68	96.28	48.14	3:38	3:39	2:58	4:57	6.99	7.16	7.00	7.05	6.98	7.13	6.80	6.97	8.29	8.03
59	3	3.5	200.34	100.17	3:54	4:05	3:51	4:55	7.01	7.09	7.00	7.03	7.02	7.16	6.80	6.99	8.27	8.28
60	3	2.21	126.78	63.39	x	4:15	4:02	5:07	7.01	7.02	6.80	6.94	7.02	7.19	7.00	7.07	8.45	8.35
61	3	2.95	168.64	84.32	x	4:38	4:21	9:07	7.06	7.33	7.00	7.13	7.03	7.29	7.00	7.11	8.46	8.28
62	3	3.5	200.35	100.18	x	5:04	7:40	6:00	6.97	6.96	6.80	6.91	7.01	7.03	6.80	6.95	8.11	8.26
63	3	3.26	186.47	93.24	x	5:29	4:49	6:30	7.10	7.25	7.00	7.12	7.11	7.06	7.00	7.06	8.49	8.27

Treatment Sector ID	Day of Treatment	Size (acres)	Amt of Aluminum Sulfate (gal.)	Amt of Sodium Aluminate (gal.)	Treatment		Sampling Event		pH								Dissolved Oxygen (mg/L)	
					Start Time	End Time	Start Time	End Time	Pre-#1	Pre-#2	Pre-#3	Mean (of Pre-#1-#3)	Post-#1	Post-#2	Post-#3	Mean (of Post-#1-#3)	Pre-	Post-
64	3	2.84	162.77	81.39	x	5:52	5:14	6:56	6.96	7.11	6.80	6.96	6.99	7.15	7.00	7.05	7.92	7.86
65	3	3.5	200.35	100.18	x	6:17	5:46	7:26	7.51	7.52	7.00	7.34	7.24	7.40	7.00	7.21	7.84	7.46
66	3	3.42	195.97	97.99	x	6:45	5:53	7:47	7.10	7.63	7.00	7.24	7.01	7.20	7.00	7.07	8.30	7.78
67	3	2.12	121.59	60.79	x	7:05	6:17	8:10	7.22	7.50	7.00	7.24	7.04	7.30	7.00	7.11	8.11	8.03
68	3	0.46	26.57	13.28	x	7:11	6:25	8:15	7.12	7.40	7.00	7.17	7.15	7.28	7.00	7.14	8.12	8.36
69	3	3.5	200.34	100.17	x	7:29	6:34	8:30	6.95	7.15	6.80	6.97	6.92	7.10	7.00	7.01	7.75	7.94
70	3	1.08	61.59	30.8	x	7:57	7:04	8:58	7.29	7.40	7.00	7.23	7.12	7.23	x	7.18	7.37	7.77
71	3	0.53	30.39	15.2	x	8:02	7:42	9:03	7.10	7.30	7.00	7.13	7.07	x	x	7.07	7.73	7.72
72	3	0.97	55.42	27.71	x	8:06	7:56	9:06	7.01	7.34	7.00	7.12	7.09	7.13	X	7.11	7.88	8.14
1	4	3.5	200.35	100.18	x	1:45	1:20	2:45	6.96	7.13	6.80	6.96	6.77	6.94	6.80	6.84	4.98	6.11
2	4	3.5	200.35	100.18	x	2:37	1:27	3:39	6.92	7.08	6.80	6.93	6.71	6.97	6.80	6.83	5.35	6.23
3	4	3.5	200.35	100.18	x	3:02	1:32	4:02	6.85	7.04	6.80	6.90	6.82	7.01	6.80	6.88	6.03	6.04
4	4	3.5	200.35	100.18	x	2:30	2:35	x	6.77	7.07	6.81	6.88	6.69	7.00	6.80	6.83	5.48	6.26
5	4	3.3	188.72	94.36	x	x	2:06	3:08	6.73	6.99	6.80	6.84	6.68	6.88	6.80	6.79	5.16	5.82
6	4	3.5	200.35	100.18	x	x	3:30	4:42	6.72	6.89	6.80	6.80	6.72	7.00	6.80	6.84	6.07	6.43
7	4	3.5	200.35	100.18	x	x	3:55	5:09	6.79	7.07	6.80	6.89	6.55	6.81	6.80	6.72	6.14	6.79
8	4	3.5	200.35	100.18	x	4:40	4:09	5:40	6.69	6.91	6.80	6.80	6.74	6.94	6.80	6.83	6.71	6.19
9	4	3.39	193.99	97	x	5:08	4:34	6:05	6.76	7.03	6.80	6.86	6.73	6.94	6.80	6.82	6.72	6.09
10	4	3.5	200.35	100.18	x	5:30	5:00	6:28	6.71	7.06	6.80	6.86	6.73	6.88	6.80	6.80	6.11	6.78
11	4	3.4	194.46	97.23	x	5:56	5:12	7:00	6.65	6.94	6.80	6.80	6.66	6.98	6.80	6.81	6.21	6.07
12	4	1.4	80.02	40.01	x	x	5:30	7:20	6.80	7.00	6.80	6.87	7.62	7.49	6.80	7.30	6.64	6.55
Note: "*" indicated an equipment malfunction																		

Table 3. 2013 - 2014 Long-Term Baseline Water Quality Monitoring Raw Data, West Basin of the Monponsett Ponds, Halifax/Hanson, MA

Site ID	Latitude (DD)	Longitude (DD)	Sampling Date	Time of Day (AM/PM)	TIME (hr:mm)	(Monitoring) Time Frame	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Alkalinity (mg/L of CaCO3)	Total Phosphorus (mg/L)	Secchi (m)	Conductivity (µS)	Water Depth (m)
1	42.0154	-70.8602	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.67	7.68	21.6	x	0.134	x	227	2.74
2	42.0154	-70.8581	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.89	8.37	21.2	x	0.145	x	226	1.37
3	42.0173	-70.8528	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.64	7.51	21.3	x	0.151	x	227	0.64
4	42.0132	-70.8489	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.72	7.95	21.6	x	0.134	x	229	1.74
5	42.0137	-70.8459	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	7	9.12	21.9	x	0.157	x	228	0.88
6	42.0102	-70.8514	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.94	8.64	21.3	x	0.178	x	226	2.74
7	42.0083	-70.8431	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.92	8.42	21.4	x	0.141	x	226	0.88
8	42.0052	-70.8453	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.89	8.34	21.2	x	0.173	x	226	1.83
9	42.0027	-70.8487	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.89	8.60	21.2	8.48	0.162	x	226	0.98
10	42.0063	-70.8417	5/23/2013	AM	x	~ 2 Wk. Pre-Treatment	6.75	8.49	20.8	8.23	0.104	x	x	3.63
1	42.0154	-70.8602	6/3/2013	x	x	1 D Pre-Treatment	6.905	6.33	24.3	x	x	x	214.3	0.88
2	42.0154	-70.8581	6/3/2013	x	x	1 D Pre-Treatment	6.74	6.79	24.2	x	x	x	215.2	2.01
3	42.0173	-70.8528	6/3/2013	x	x	1 D Pre-Treatment	6.823	6.76	24.2	x	x	x	215.2	0.94
4	42.0132	-70.8489	6/3/2013	x	x	1 D Pre-Treatment	6.84	7.45	23.9	8.15	0.06	1.10	214.6	3.35
5	42.0137	-70.8459	6/3/2013	x	x	1 D Pre-Treatment	6.81	7.49	23.6	x	x	x	215.1	1.22
6	42.0102	-70.8514	6/3/2013	x	x	1 D Pre-Treatment	6.83	7.28	23.9	x	x	x	216.6	0.98
7	42.0083	-70.8431	6/3/2013	x	x	1 D Pre-Treatment	6.845	7.51	23.6	x	x	x	214.2	1.10
8	42.0052	-70.8453	6/3/2013	x	x	1 D Pre-Treatment	6.83	7.60	23.4	x	x	1.10	215.1	3.96
9	42.0027	-70.8487	6/3/2013	x	x	1 D Pre-Treatment	6.81	7.38	22.7	8.43	0.06	x	214.9	x
10	42.0063	-70.8417	6/3/2013	x	x	1 D Pre-Treatment	6.875	7.62	23.4	8.27	0.05	x	213.8	1.46
1	42.0154	-70.8602	6/4/2013	AM	x	1st D treatment	6.345	5.82	23.3	x	x	x	x	x
2	42.0154	-70.8581	6/4/2013	AM	11:45	1st D treatment	6.495	6.49	23.4	8.75	0.06	x	215.1	x
3	42.0173	-70.8528	6/4/2013	AM	10:58	1st D treatment	6.73	7.06	23.8	x	x	x	216	x
4	42.0132	-70.8489	6/4/2013	AM	10:50	1st D treatment	6.755	7.42	23.1	x	x	x	215	3.26
5	42.0137	-70.8459	6/4/2013	AM	10:45	1st D treatment	6.675	7.30	23.1	x	x	x	216.1	x
6	42.0102	-70.8514	6/4/2013	AM	x	1st D treatment	6.73	7.04	23.25	x	x	x	214	x
7	42.0083	-70.8431	6/4/2013	AM	10:16	1st D treatment	6.835	7.36	22.47	x	x	x	215.1	x
8	42.0052	-70.8453	6/4/2013	AM	9:08	1st D treatment	6.885	7.48	22	x	x	x	216	x
9	42.0027	-70.8487	6/4/2013	AM	9:15	1st D treatment	7.135	7.59	21.8	7.17	0.04	x	217.2	x
10	42.0063	-70.8417	6/4/2013	AM	9:23	1st D treatment	6.76	7.31	22.23	x	x	x	215.8	x
1	42.0154	-70.8602	6/4/2013	PM	4:55	1st D treatment	6.405	6.80	23.7	x	x	x	216.7	x
2	42.0154	-70.8581	6/4/2013	PM	5:05	1st D treatment	6.64	7.11	23.3	8.94	0.05	x	216.1	x
3	42.0173	-70.8528	6/4/2013	PM	5:06	1st D treatment	6.9	8.36	23.2	x	x	x	214.9	x
4	42.0132	-70.8489	6/4/2013	PM	x	1st D treatment	6.78	7.96	23.4	x	x	x	214.6	x
5	42.0137	-70.8459	6/4/2013	PM	x	1st D treatment	7.02	8.49	24.35	x	x	x	216.2	x
6	42.0102	-70.8514	6/4/2013	PM	x	1st D treatment	7.095	8.10	24.1	x	x	x	213.3	x
7	42.0083	-70.8431	6/4/2013	PM	x	1st D treatment	6.9	7.90	23.6	x	x	x	215.5	x
8	42.0052	-70.8453	6/4/2013	PM	x	1st D treatment	6.93	8.17	23.06	x	x	x	216.8	x
9	42.0027	-70.8487	6/4/2013	PM	x	1st D treatment	7.095	8.34	23.4	8.39	0.05	x	216.2	x
10	42.0063	-70.8417	6/4/2013	PM	6:18	1st D treatment	6.81	8.19	23.2	X	X	x	222.3	x
1	42.0154	-70.8602	6/5/2013	AM	8:54	2nd D of Treatment	6.46	6.05	21.63	x	x	x	218.1	x
2	42.0154	-70.8581	6/5/2013	AM	8:45	2nd D of Treatment	6.415	6.54	21.53	5.43	0.06	x	217.4	x
3	42.0173	-70.8528	6/5/2013	AM	8:39	2nd D of Treatment	6.685	7.16	21.75	x	x	x	216.4	x
4	42.0132	-70.8489	6/5/2013	AM	8:27	2nd D of Treatment	6.7	7.55	22.13	x	x	x	215.5	x
5	42.0137	-70.8459	6/5/2013	AM	8:31	2nd D of Treatment	6.695	7.33	21.93	x	x	x	215.9	x
6	42.0102	-70.8514	6/5/2013	AM	8:21	2nd D of Treatment	6.72	7.32	22	x	x	x	215.9	x

Site ID	Latitude (DD)	Longitude (DD)	Sampling Date	Time of Day (AM/PM)	TIME (hr:mm)	(Monitoring) Time Frame	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Alkalinity (mg/L of CaCO3)	Total Phosphorus (mg/L)	Secchi (m)	Conductivity (µS)	Water Depth (m)
7	42.0083	-70.8431	6/5/2013	AM	8:14	2nd D of Treatment	6.77	7.79	22.4	x	x	x	217.8	x
8	42.0052	-70.8453	6/5/2013	AM	8:02	2nd D of Treatment	6.905	7.64	22.13	x	x	x	219.3	x
9	42.0027	-70.8487	6/5/2013	AM	8:06	2nd D of Treatment	6.825	7.54	22.06	8.61	0.07	x	217.9	x
10	42.0063	-70.8417	6/5/2013	AM	7:53	2nd D of Treatment	6.89	7.00	21.93	8.94	0.06	x	218.2	x
1	42.0154	-70.8602	6/5/2013	PM	7:39	2nd D of Treatment	6.77	7.98	23.63	x	x	x	216	x
2	42.0154	-70.8581	6/5/2013	PM	7:43	2nd D of Treatment	6.775	8.43	23.43	9.22	0.05	x	216	x
3	42.0173	-70.8528	6/5/2013	PM	7:47	2nd D of Treatment	6.45	8.44	23.5	x	x	x	216	x
4	42.0132	-70.8489	6/5/2013	PM	8:20	2nd D of Treatment	6.87	7.87	22.725	x	x	x	218.5	x
5	42.0137	-70.8459	6/5/2013	PM	x	2nd D of Treatment	6.905	7.99	22.56	x	x	x	219.9	x
6	42.0102	-70.8514	6/5/2013	PM	8:47	2nd D of Treatment	6.805	7.36	22.76	x	x	x	218.2	x
7	42.0083	-70.8431	6/5/2013	PM	8:52	2nd D of Treatment	6.92	8.02	22.37	x	x	x	222.2	x
8	42.0052	-70.8453	6/5/2013	PM	9:06	2nd D of Treatment	6.865	7.99	22.67	x	x	x	228.9	x
9	42.0027	-70.8487	6/5/2013	PM	9:21	2nd D of Treatment	6.785	7.64	22.6	7.53	0.05	x	223.9	x
10	42.0063	-70.8417	6/5/2013	PM	9:07	2nd D of Treatment	6.945	7.50	22.3	7.18	0.06	x	219.4	x
1	42.0154	-70.8602	6/6/2013	AM	8:49	3rd D of Treatment	6.61	7.13	22.77	x	x	x	216.6	x
2	42.0154	-70.8581	6/6/2013	AM	8:41	3rd D of Treatment	6.625	7.55	22.53	8.83	0.05	x	216.9	x
3	42.0173	-70.8528	6/6/2013	AM	8:36	3rd D of Treatment	6.66	7.29	22	x	x	x	216.7	x
4	42.0132	-70.8489	6/6/2013	AM	8:29	3rd D of Treatment	6.705	7.49	22.23	x	x	x	218.2	x
5	42.0137	-70.8459	6/6/2013	AM	8:25	3rd D of Treatment	6.7	7.59	22.23	x	x	x	217.7	x
6	42.0102	-70.8514	6/6/2013	AM	8:18	3rd D of Treatment	6.74	7.34	22.2	x	x	x	216.4	x
7	42.0083	-70.8431	6/6/2013	AM	8:11	3rd D of Treatment	6.78	7.64	22.13	x	x	x	222.4	x
8	42.0052	-70.8453	6/6/2013	AM	8:06	3rd D of Treatment	6.735	7.43	22.167	x	x	x	223.6	x
9	42.0027	-70.8487	6/6/2013	AM	7:49	3rd D of Treatment	6.735	7.29	21.77	8.61	0.04	x	224	x
10	42.0063	-70.8417	6/6/2013	AM	x	3rd D of Treatment	x	x	x	x	x	x	x	x
1	42.0154	-70.8602	6/6/2013	PM	8:55	3rd D of Treatment	7.075	8.19	23.1	x	x	x	*	x
2	42.0154	-70.8581	6/6/2013	PM	8:47	3rd D of Treatment	6.99	8.27	23.4	7.73	0.06	x	*	x
3	42.0173	-70.8528	6/6/2013	PM	8:35	3rd D of Treatment	7.16	8.34	23.23	x	x	x	*	x
4	42.0132	-70.8489	6/6/2013	PM	8:29	3rd D of Treatment	6.97	7.94	22.73	x	x	x	*	x
5	42.0137	-70.8459	6/6/2013	PM	8:41	3rd D of Treatment	7.025	7.63	22.67	x	x	x	*	x
6	42.0102	-70.8514	6/6/2013	PM	8:25	3rd D of Treatment	6.985	7.75	23.13	x	x	x	*	x
7	42.0083	-70.8431	6/6/2013	PM	8:21	3rd D of Treatment	7.09	7.84	22.9	x	x	x	*	x
8	42.0052	-70.8453	6/6/2013	PM	8:05	3rd D of Treatment	6.955	7.68	22.2	x	x	x	*	x
9	42.0027	-70.8487	6/6/2013	PM	7:58	3rd D of Treatment	6.975	7.89	22.1	7.72	0.05	x	*	x
10	42.0063	-70.8417	6/6/2013	PM	10:15	3rd D of Treatment	7.21	5.46	22.17	7.93	0.06	x	x	x
1	42.0154	-70.8602	6/7/2013	AM	8:36	4th D of Treatment	6.81	7.24	21.57	x	x	x	230.5	x
2	42.0154	-70.8581	6/7/2013	AM	8:32	4th D of Treatment	6.88	7.35	21.6	9.13	0.05	x	233.6	x
3	42.0173	-70.8528	6/7/2013	AM	8:29	4th D of Treatment	6.925	7.28	21.3	x	x	x	229.6	x
4	42.0132	-70.8489	6/7/2013	AM	8:21	4th D of Treatment	6.925	7.29	21.5	x	x	x	228.1	x
5	42.0137	-70.8459	6/7/2013	AM	8:24	4th D of Treatment	6.875	7.29	21.2	x	x	x	228	x
6	42.0102	-70.8514	6/7/2013	AM	8:18	4th D of Treatment	6.91	7.21	21.47	x	x	x	228.8	x
7	42.0083	-70.8431	6/7/2013	AM	8:12	4th D of Treatment	6.885	6.74	21.23	x	x	x	226	x
8	42.0052	-70.8453	6/7/2013	AM	8:05	4th D of Treatment	6.93	7.33	21.37	x	x	x	*	x
9	42.0027	-70.8487	6/7/2013	AM	8:03	4th D of Treatment	6.94	7.15	20.93	8.56	0.04	x	*	x
10	42.0063	-70.8417	6/7/2013	AM	7:53	4th D of Treatment	7.01	6.65	21.3	8.6	0.04	x	*	x
1	42.0154	-70.8602	6/7/2013	PM	6:09	4th D of Treatment	6.895	6.81	20.6	x	x	x	*	x
2	42.0154	-70.8581	6/7/2013	PM	6:12	4th D of Treatment	6.9	7.09	20.77	8.07	0.05	x	*	x
3	42.0173	-70.8528	6/7/2013	PM	6:22	4th D of Treatment	6.94	7.44	20.5	x	x	x	*	x
4	42.0132	-70.8489	6/7/2013	PM	6:26	4th D of Treatment	6.91	7.12	21.3	x	x	x	*	x

Site ID	Latitude (DD)	Longitude (DD)	Sampling Date	Time of Day (AM/PM)	TIME (hr:mm)	(Monitoring) Time Frame	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Alkalinity (mg/L of CaCO3)	Total Phosphorus (mg/L)	Secchi (m)	Conductivity (µS)	Water Depth (m)
5	42.0137	-70.8459	6/7/2013	PM	6:30	4th D of Treatment	6.88	7.02	20.53	x	x	x	*	x
6	42.0102	-70.8514	6/7/2013	PM	6:32	4th D of Treatment	6.745	6.51	21.13	x	x	x	*	x
7	42.0083	-70.8431	6/7/2013	PM	x	4th D of Treatment	x	x	x	x	x	x	x	x
8	42.0052	-70.8453	6/7/2013	PM	7:29	4th D of Treatment	7.06	6.77	20.16	x	x	x	x	x
9	42.0027	-70.8487	6/7/2013	PM	7:32	4th D of Treatment	6.79	6.97	20.4	8.35	0.04	x	x	x
10	42.0063	-70.8417	6/7/2013	PM	X	4th D of Treatment	x	x	x	8.69	0.13	x	x	x
CRANBERRY BOG	x	x	7/12/2013	x	x	1 Mo. Post-Treatment	x	x	x	x	0.18	x	x	x
1	42.0154	-70.8602	7/12/2013	x	11:50	1 Mo. Post-Treatment	7	6.52	27.4	10.5	0.0268	0.71	X	x
2	42.0154	-70.8581	7/12/2013	x	12:18	1 Mo. Post-Treatment	7.1	7.50	28.2	10.2	0.0255	0.61	X	x
3	42.0173	-70.8528	7/12/2013	x	12:42	1 Mo. Post-Treatment	7.2	7.65	28.3	10.1	0.0274	0.64	X	x
4	42.0132	-70.8489	7/12/2013	x	12:47	1 Mo. Post-Treatment	7.2	7.63	28.2	10.2	0.031	0.71	X	x
5	42.0137	-70.8459	7/12/2013	x	12:53	1 Mo. Post-Treatment	7.2	7.65	27.8	10.4	0.0191	0.71	X	x
6	42.0102	-70.8514	7/12/2013	x	1:11	1 Mo. Post-Treatment	7.2	7.29	28.2	9.91	0.0315	0.61	X	x
7	42.0083	-70.8431	7/12/2013	x	1:16	1 Mo. Post-Treatment	7.2	7.76	28.1	9.36	0.0238	0.66	X	x
8	42.0052	-70.8453	7/12/2013	x	1:35	1 Mo. Post-Treatment	7.1	7.43	27.9	10.2	0.0223	0.79	X	x
9	42.0027	-70.8487	7/12/2013	x	1:50	1 Mo. Post-Treatment	7.1	5.86	27.5	10.7	0.0268	x	X	x
10	42.0063	-70.8417	7/12/2013	x	1:28	1 Mo. Post-Treatment	7.2	7.04	28	9.55	0.0209	x	X	x
1	42.0154	-70.8602	7/18/2014	x	x	1 Yr. Post-Treatment	7	7.66	25.3	13	0.057	0.50	231.4	1.16
2	42.0154	-70.8581	7/18/2014	x	x	1 Yr. Post-Treatment	7	7.36	25.1	13.4	0.066	0.50	232.9	1.86
3	42.0173	-70.8528	7/18/2014	x	x	1 Yr. Post-Treatment	7.5	9.15	26.2	13.4	0.061	0.50	240.5	1.01
4	42.0132	-70.8489	7/18/2014	x	x	1 Yr. Post-Treatment	7.5	9.18	26.4	13.2	0.062	0.50	241.1	3.23
5	42.0137	-70.8459	7/18/2014	x	x	1 Yr. Post-Treatment	7	8.30	26.5	14	0.065	0.55	242.3	1.10
6	42.0102	-70.8514	7/18/2014	x	x	1 Yr. Post-Treatment	7.25	8.05	26.2	12.1	0.057	0.30	242.8	0.94
7	42.0083	-70.8431	7/18/2014	x	x	1 Yr. Post-Treatment	7.5	8.95	26.7	12.8	0.064	0.50	240.4	1.19
8	42.0052	-70.8453	7/18/2014	x	x	1 Yr. Post-Treatment	7.25	8.81	26.4	13.7	0.064	0.50	251.2	3.51
9	42.0027	-70.8487	7/18/2014	x	x	1 Yr. Post-Treatment	7.5	8.90	26.7	14.4	0.056	0.50	240.5	2.77
10	42.0063	-70.8417	7/18/2014	x	x	1 Yr. Post-Treatment	7.25	9.17	26.9	13.2	0.064	0.50	245.3	1.62
Note: '*' indicates a temporary equipment malfunction.														

Table 4. 2013 – 2014 Long-Term Sediment Cores Raw Data, West Basin of the Monponsett Ponds, Halifax/Hanson, MA.

Site ID	Latitude (DD)	Longitude (DD)	Sampling Date	Aluminum (mg/Kg) dry	Total Phosphorus (mg/Kg)	% Solids (% Wt)
2	42.0154	-70.8581	6/3/2013	5400	69	25
5	42.0137	-70.8459	6/3/2013	1400	20	78.2
9	42.0027	-70.8487	6/3/2013	2000	5.5	72.4
2	42.0154	-70.8581	7/11/2013	5200	53	22.9
5	42.0137	-70.8459	7/11/2013	870	11	77.4
9	42.0027	-70.8487	7/11/2013	3800	34	50.5
2	42.0154	-70.8581	7/18/2014	6500	26	18
5	42.0137	-70.8459	7/18/2014	980	0	65.3
9	42.0027	-70.8487	7/18/2014	3400	34	64.8

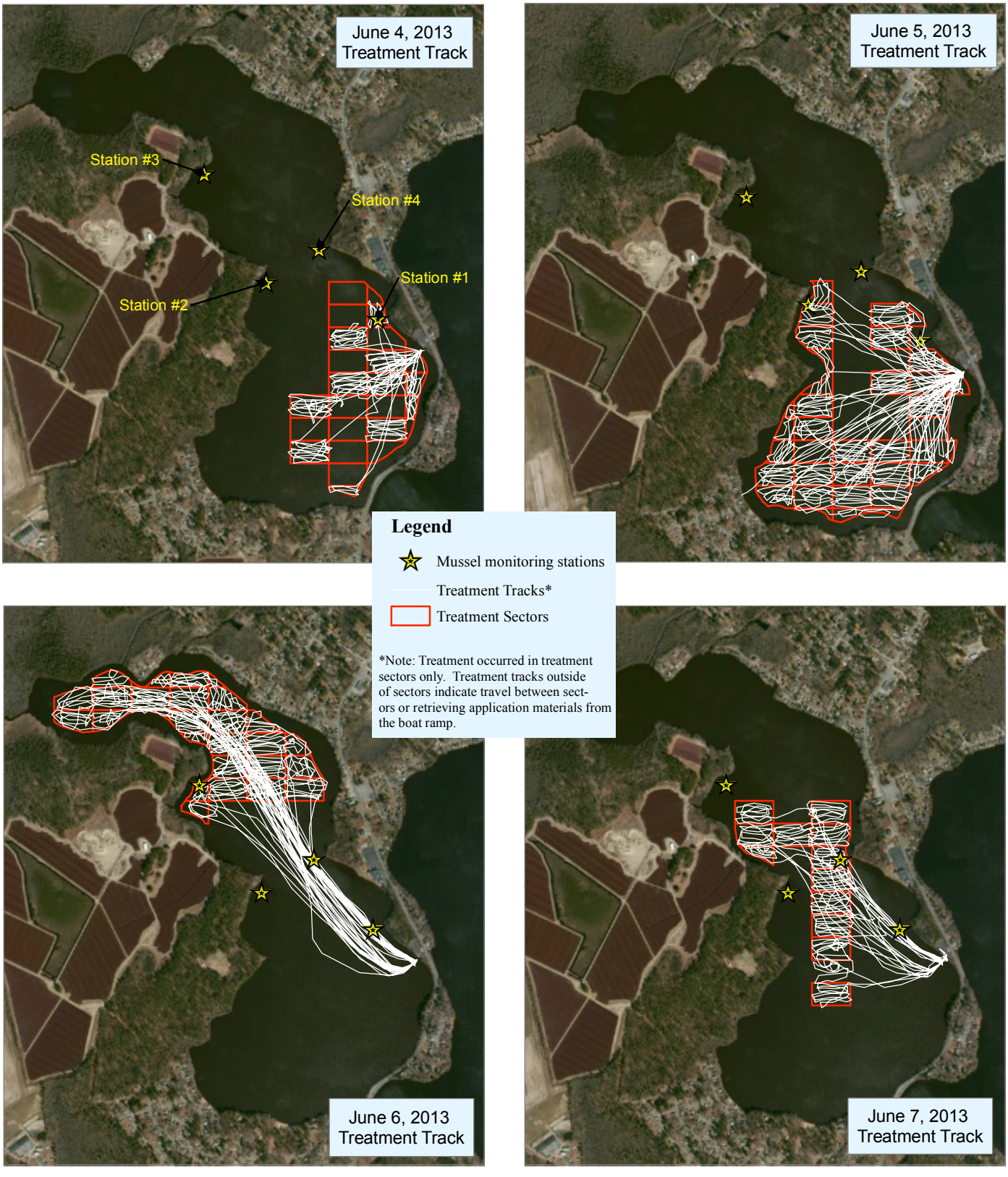
Table 5. 2013 – 2014 *In Situ* Measurement of Flocculation Raw Data, West Basin of the Monponsett Ponds, Halifax/Hanson, MA.

Site ID	Latitude (DD)	Longitude (DD)	Sampling Date	(Monitoring) Time Frame	Height of Accumulated Floc(in.)
1	42.0074	-70.8436	6/4/2013	Day of Treatment	0.079166667
1	42.0074	-70.8436	6/8/2013	Post-Treatment	0.120833333
2	42.0088	-70.849	6/5/2013	Day of Treatment	0.045833333
2	42.0088	-70.849	6/8/2013	Post-Treatment	0.158333333
3	42.0127	-70.852	6/6/2013	Day of Treatment	0.383333333
3	42.0127	-70.852	6/8/2012	Post-Treatment	0.3
4	42.01	-70.852	6/7/2013	Day of Treatment	0.133333333
4	42.01	-70.852	6/8/2013	Post-Treatment	0.1375

Appendix C

info@lycott.com
(508) 885-0101
21 West Main St (Route 9)
Spencer, MA 01562

2013 Low-Dose Alum Treatment Tracks & Mussel Monitoring Stations



Monponsett Pond
Halifax & Hanson, Massachusetts

Data Collected: 6/4 - 6/7/13
Map Prepared:11/06/2014
For Town of Halifax
Contract (#364-09)
Basemap © 2013 Esri

0 625 1,250 2,500
1:22,000 Feet

N

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