LAKE HOPATCONG HABS GRANT FINAL REPORT

MORRIS AND SUSSEX COUNTIES, NEW JERSEY

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PREPARED FOR:

LAKE HOPATCONG COMMISSION
ATTN: RON SMITH, COMMISSIONER
P.O. BOX 8519
LANDING, NJ 07850
973-601-7801

PREPARED BY:

PRINCETON HYDRO, LLC
1108 OLD YORK ROAD, SUITE 1
P.O. BOX 720
RINGOES, NJ 08551
908-235-5660

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1.0 INTRODUCTION

Lake Hopatcong (Appendix I) experienced unprecedented harmful algal blooms (HABs) of cyanobacteria over the majority of the 2019 summer season from mid-June well into October. These HABs resulted in the posting of advisories over large sections of the lake and the closing of all beaches by local/County Departments of Health. These conditions resulted in substantial impacts on the ecological, recreational, and economic resources of the lake and region. These conclusions are based on routine, baseline monitoring of Lake Hopatcong, conducted by the Lake Hopatcong Commission's (LHC) environmental consultant, Princeton Hydro (PH). These blooms were triggered by some of the highest June total phosphorus (TP) concentrations measured over the last 25 years. While prevailing weather conditions contributed toward these elevated TP concentrations, the contributing sources of TP stem from external sources, primarily stormwater and septic systems. While external, watershed-based sources, triggered the blooms in mid-June 2019, a detailed analysis of the lake's 30+ water quality database revealed that the lake's internal phosphorus load sustained these nuisance cyanobacterial blooms over the summer and into the fall.

The LHC recently updated its TMDL-based Restoration Plan in early 2021 into a Watershed Implementation Plan (WIP), with funds provided by the NJ Highlands Council. The Restoration Plan was updated to include potential streambank and shoreline projects, as well as stormwater / surface runoff projects. Additionally, wherever possible, Green Infrastructure (GI) stormwater measures were integrated into this updated WIP. There were also a very cursory assessment of the water quality benefits, specifically reductions in phosphorous, that would result from sewering the remaining portions of the watershed that are still on septic systems. Finally, the WIP followed the nine elements of a WIP, as outlined by US EPA, in order to maximize opportunities for Federal and State funding.

While the update WIP focuses on stormwater and septic management, it will take years to implement all of the recommended measures. It has taken approximately 12 years to implement watershed-control measures throughout the watershed, as identified in the original Restoration Plan, to attain 33% compliance with the lake's TMDL for TP. Thus, while these long-term, watershed measures are absolutely necessary, some more short-term, in-lake/nearshore measures needed to be implemented to minimize the local impacts of HABs to protect the lake and local economy.

There are a variety of in-lake/near-shore management measures that can prevent, mitigate, and/or control HABs on a more short-term basis and in localized areas. As the stewards of Lake Hopatcong, the LHC has been closely working with the Lake Hopatcong Foundation (LHF), Sussex and Morris Counties, and the four municipalities that surround the lake (Township of Jefferson, Borough of Hopatcong, Borough of Mt. Arlington, and Township of Roxbury) to develop both short and long-term strategies to address, minimize, or even prevent a recurrence of the HAB problems of 2019. Thus, the LHC applied for and were awarded funds from the New Jersey Department of Environmental Protection (NJDEP) to implement and evaluate a set of innovative management measures to prevent, mitigate and/or control HABs, particularly in local, near-shore areas where people have the highest degree of direct contact with the water.

This study evaluates a variety of innovative, in-lake and watershed management measures designed to prevent, mitigate, and control the development of HABs in Lake Hopatcong. These measures include floating wetland islands (FWIs), new types of phosphorus removal filter media installed in existing stormwater basins, installation of three types of aeration systems, application of a nutrient inactivating product (PhosLock), a treatment of a non-copper-based algaecide (GreenClean), the use of a filter media (Biochar) that removes phosphorus and can subsequently be used for mulch and the implementation of the Rutgers rain garden program. These innovative management techniques have been objectively evaluated through a variety of water quality monitoring activities that were conducted before and after each management measure was implemented and compared treated sites with untreated (control) sites. Thus, the overall Project Goals were two-fold. First, implement innovative, in-lake management measures that can be utilized in the control and management of HABs. Second, objectively document the cost effectiveness of these in-lake measures to determine if they are applicable to other lakes in New Jersey to combat HABs. The following report documents and objectively assesses the effectiveness of the management techniques implemented in 2020 to prevent, mitigate, and control the development of HABS in Lake Hopatcong.

2.0 METHODOLOGY

BASELINE MONITORING

As is routinely conducted, Lake Hopatcong was monitored five (5) times over the 2020 growing season. There are a total of eleven (11) standard in-lake sampling stations (Appendix I). During each monitoring event, *in-situ* data was collected at all stations, from surface to bottom at 0.5 to 1.0-meter intervals for temperature, dissolved oxygen, pH and conductivity. Water clarity was measured with a Secchi disk.

Discrete water quality samples were collected with a Van Dorn sampling device at 0.5 m below the lake surface, mid-depths and 0.5 m above the sediments at the mid-lake sampling site (Station 2). Discrete samples were collected from a sub-surface (0.5 m) position at the remaining six (6) original sampling stations (Stations 1, 3, 4, 5, 6 and 7) and additionally at the Northern Woodport Bay and Jefferson Canals sites (Stations 10 and 11, respectively) on each date. Discrete water samples were appropriately preserved, stored on ice, and transported to a State-certified laboratory for the analysis of total phosphorus (TP), soluble reactive phosphorus (SRP), ammonia-N (NH_3-N), nitrate-N (NO_3-N), chlorophyll-*a* (Chl *a)*, total suspended solids (TSS).

During each sampling event, phytoplankton and zooplankton samples were collected at the surface and mid-depths at the deep sampling station (Station 2). Phytoplankton samples were collected at the surface and mid-depths utilizing a Van Dorn sampling device and quantitatively assessed, while zooplankton samples were collected utilizing a Schindler sampling device at each of those depths and qualitatively assessed.

An updated Quality Assurance Protection Plan (QAPP) was developed for Lake Hopatcong that outlines all of the sampling locations associated with the project sites (Appendix II). The QAPP included the additional sampling stations that were associated with this HAB grant project.

OBJECTIVE 1: PHOSLOCK, BIOCHAR, AND FLOATING WETLAND ISLANDS IN ASHLEY COVE

The goal of Objective 1 was to determine if several in-lake management measures could be implemented collectively to prevent or control the development of HABs in a more isolated section of Lake Hopatcong, where flushing with the main body of the lake was minimal. Ashely Cove is a 2-acre cove separated from the main body of the lake by a narrow canal and is located in Jefferson Township. The cove is frequently used to temporarily store the mechanical weed harvesters over the growing season. In 2020 Biochar (processed wood material that has a high affinity for removing pollutants) was installed in the cove and a series of PhosLock treatments were conducted to strip the water column of available phosphorus. While not part of the original Scope of Work, a GreenClean treatment (an algicide which is a strong oxidizer) was conducted in Ashely Cove to knock down the mat and plankton algae biomass before the PhosLock treatments were conducted. In 2021 the Biochar was replaced with fresh material and a series of additional PhosLock treatments were conducted. In the late spring of 2022, an existing Floating Wetland Island (FWI) will be refurbished and a new one will be installed in the cove.

Two (2) PhosLock treatments were conducted in 2020. Pre- and post-treatment monitoring in 2020 were conducted one (1) time before the PhosLock applications and two (2) times after the applications. Five (5) PhosLock applications and three (3) monitoring events were conducted in 2021. One (1) central sampling station was established in Ashley Cove and monitored during each sampling event. During each sampling event, *in-situ* measurements with a calibrated meter were taken for dissolved oxygen (DO), pH, temperature, and conductivity. Water clarity was measured with a Secchi disk and sub-surface discrete samples for the analysis of ammonia-N, nitrate-N, total suspended solids, chlorophyll-*a* and phytoplankton (cyanobacteria cell counts) were collected during each monitoring event. Samples were also collected for various species of phosphorus (total phosphorus (TP), total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP)) from mid-cove (both sub-surface and bottom).

OBJECTIVE 2: EVALUATION OF BIOCHAR IN THE TWO STORMWATER AQUA-FILTER UNITS AT HOPATCONG BEACH CLUB

Two large Aqua-Filter units were installed to treat stormwater in the Hopatcong Beach Club drainage area, located in the Borough of Hopatcong. These units provide a means of settling solids and have the capacity to remove various forms of phosphorus. The units were designed and installed as part of a Water Quality, NPS 319(h) grant awarded to the LHC in State Fiscal Year 2010. The original filter media used to remove dissolved forms of phosphorus was fairly high in product cost and therefore was not replaced. Thus, the objective was implemented to determine if Biochar could serve as a more cost effective means of addressing the TSS and TP pollution, generated from this section of the watershed.

After the units were inspected and the old, existing filter media was removed, Biochar was installed in the two Aqua-Filter units in the parking lot of the Crescent Cove Beach. After the Biochar was installed, monitoring was conducted immediately upgradient and downgradient of the two Aqua-Filters. Five (5) monitoring events were conducted and samples were analyzed for TP, SRP, and TDP.

OBJECTIVE 3: INSTALLATION AND EVALUATION OF VARIOUS TYPES OF AERATION ALONG NEARSHORE BEACH AREAS FOR HAB CONTROL

This Objective focused on evaluating the potential application of various types of near-shore aeration to minimize or avoid the development of HABs in beach areas. The three types of near-shore aeration included the Air Curtin, Nanobubble System and a Nanobubble System with Ozone. Once the Air Curtain aeration system was installed, Princeton Hydro conducted a series of in-lake assessments of the system in 2020 to evaluate its relative effectiveness at controlling HABs. During each monitoring event, samples were collected from an area within the Air Curtain, or the "treatment zone," and outside of the area affected by the Air Curtain, or the "control zone." Samples were collected and analyzed for cyanobacteria cell counts, microcystins, phycocyanin, and water clarity. *In-situ* data was also be collected for temperature, DO, pH, and conductivity.

Note, while most HABs grant activities were completed by the end of 2021, the nanobubble systems will be evaluated over the 2022 growing season due to technical and logistic issues in 2021. Monitoring of the nanobubble systems sites will be conducted during the five standard, long-term, water quality monitoring events from May through September 2022.

OBJECTIVE 4: TREATMENT AND EVALUATION OF PHOSLOCK TO PREVENT OR MINIMIZE THE DEVELOPMENT OF CYANOHABS

Objective 4 conducted a large-scale nutrient inactivation treatment of a section of Lake Hopatcong with PhosLock, to determine how effective such a strategy would be at controlling or minimizing the development of a HAB. While a dosage rate for the PhosLock was provided for the grant, a formal assessment of the organic / inorganic fractions of phosphorus in the sediments, as well as their relative availability, needed to be conducted in order to determine the specific dosage rate and treatment strategy. Princeton Hydro collected a total of five (5) sediment samples from Landing Channel that were appropriately preserved and transported to SePRO's analytical laboratory and analyzed for various forms of phosphorus in the sediment (labile, organic, apatite, residual, etc.). The resulting data confirmed that the proposed dosage rate of 440 lbs of product per acre, over 50 acres, was appropriate for the targeted location of Landing Channel, in the Township of Roxbury.

Pre- and post-treatment monitoring were conducted one (1) time before the PhosLock application and three (3) times after the application in 2020 and five (5) times in 2021, for a total of eight (8) post-treatment monitoring events. One central sampling station was established in Landing Channel and monitored during each sampling event. During each sampling event, in-situ measurements with a calibrated meter were taken for DO, pH, temperature, and conductivity. Water clarity was measured with a Secchi disk and sub-surface discrete samples for the analysis of phytoplankton cell counts, chlorophyll a, phycocyanin, microcystins, and various species of phosphorus (total phosphorus, soluble reactive phosphorus, and total dissolved phosphorus). In addition, nearby long-term monitoring sampling sites, specifically Station 5 (ST-5) was used as pre-treatment and "control" sites to evaluate the effectiveness of the PhosLock.

OBJECTIVE 5: TREATMENT AND EVALUATION OF STRONG OXIDIZER FOR HAB CONTROL

Objective 5 conducted a treatment of GreenClean, an alternative algaecide that is a strong oxidizer and contains no copper. The treatment was conducted in August of 2020, just off Capp Beach, located in the Township of Jefferson. Pre- and post-treatment monitoring were conducted just before and after the GreenClean application at one station just off Capp Beach. During each sampling event, *in-situ* measurements with a calibrated meter were taken for DO, pH, temperature, and conductivity. Water clarity was measured with a Secchi disk and sub-surface discrete samples for the analysis of microcystins, cyanobacteria cell counts, chlorophyll a, and phycocyanin.

OBJECTIVE 6: USE OF BIOCHAR TO PREVENT HABS IN NEARSHORE INLET OR BEACH AREAS

Objective 6 was to deploy Biochar, a processed wood product that has a high affinity to removing pollution, in select areas throughout the Lake Hopatcong watershed to estimate its capacity to remove phosphorus. After the Biochar was installed, monitoring was conducted immediately upgradient and down gradient of the Biochar sleeves. Two sampling events were conducted at each sampling site over the course of the 2020 and 2021 seasons, and all collected samples will be analyzed for TP, TDP and SRP. The Biochar was installed at the following sites:

Lorettacong Drive (Stream)
Yacht Club (Stream)
Edith M Decker Elementary School (Stream)
Lakeside (Stream)
Memorial Pond (stormwater wet pond in Borough of Mount Arlington)
Duck Pond (stormwater wet pond in Borough of Roxbury)
East Shore (MTD)
Yacht Club (MTD)

3.0 OBJECTIVE 1: PHOSLOCK, BIOCHAR, AND FLOATING WETLAND ISLANDS IN ASHLEY COVE

PROJECT SUMMARY

A series of three projects were approved for Ashley Cove to be implemented and evaluated over a two-year period. The first project included a series of low-dose, PhosLock applications that were intended to determine if phosphorus stripping in an enclosed waterway can achieve the desired levels of HAB control. Thus, Ashley Cove was treated with PhosLock twice (2) over the 2020 growing season and five (5) times over the 2021 growing season to strip the water column of phosphorus and to inactivate the mobilization of phosphorus from the sediments. However, prior to the first PhosLock treatment of 2020, a treatment with the oxidizing algicide GreenClean was conducted to knock down the existing algae biomass that was in Ashley Cove. Note, Princeton Hydro's licensed applicators secured the State permit to conduct the algicide treatment in Ashley Cove prior to treatment. A GreenClean treatment was not required at the start of the 2021 growing season.

To further reduce available phosphorus in Ashely Cove, some sleeves of Biochar were also installed over the 2020 and 2021 growing seasons. The Biochar sleeves were placed directly in front of a large stormwater pipe that enters the cove just off of Espanong Road.

Finally, an existing floating wetland islands (FWIs) will be re-planted and provided with upgraded anchoring and tethering material and then relocated to an area where they will receive full sunlight. Additionally, another FWI structure (approximately 160 sq. ft in surface area) will be purchased, built, planted, and installed in a nearshore area that will receive full sunlight. An inspection of the existing FWIs over the 2021 growing season revealed that one of them is being used as a nesting site for a family of swans. Thus, it was decided to refurbish the Island that is not being used by the swans, purchase a new, larger FWI, and possibly purchase more Biochar for use at Ashley Cove. The FWI project will be conducted in June of 2022 but the materials were purchased in 2021.

SCHEDULE OF EVENTS

After a review of the baseline monitoring data in Lake Hopatcong, the first PhosLock application was scheduled for late July of 2020. Pre-treatment monitoring was conducted on 5 June 2020. Two (2) PhosLock applications were conducted in 2020 on 31 July and 28 August 2020. Two (2) post-treatment monitoring events were conducted on 4 September 2020 and 9 October 2020. As previously mentioned, a GreenClean treatment was conducted on 15 July 2020 to knock down the accumulated mat and planktonic algae before the PhosLock was added. A full breakdown of the 2020 pre- and post-treatment monitoring schedule, including the date of the treatments, is provided in Table 3.1 below.

Since baseline, pre-treatment data was collected in Ashley Cove in 2020, no pre-treatment sampling was conducted prior to the first PhosLock treatment in 2021. Five (5) PhosLock applications were conducted in 2021 on 7 June, 21 July, 20 August, 21 September, and 12 October 2021. Three (3) monitoring events were conducted over the course of the 2021 season on 14 September, 24 September, and 18 October 2021. A full breakdown of the 2021 pre- and post-treatment monitoring schedule, including the date of the treatments, is provided in Table 3.2 below.

Table 3.1: Ashley Cove: 2020 Treatment and monitoring schedule.

Ashley Cove: Treatment and Monitoring Schedule	
Date	**Activity**
6/5/2020	Pre-treatment monitoring event
7/15/2020	GreenClean application
7/31/2020	1st PhosLock application
8/28/2020	2nd PhosLock application
9/4/2020	1st post-treatment monitoring event
10/9/2020	2nd post-treatment monitoring event

Table 3.2: Ashley Cove: 2021 Treatment and monitoring schedule.

Ashley Cove: Treatment and Monitoring Schedule	
Date	**Activity**
6/7/2021	1st PhosLock application (3rd total)
7/21/2021	2nd PhosLock application (4th total)
8/20/2021	3rd PhosLock application (5th total)
9/14/2021	1st post-treatment monitoring event (3rd total)
9/21/2021	4th PhosLock application (6th total)
9/24/2021	2nd post-treatment monitoring event (4th total)
10/12/2021	5th PhosLock application (7th total)
10/18/2021	3rd post-treatment monitoring event (5th total)

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and objectively assess the results of the water quality data collected in Ashley Cove in 2020 and 2021 relative to the success of the management measures in controlling the development of HABs. This section will focus primarily on the parameters that are most closely associated with the development of HABs, such as phosphorus and chlorophyll-*a* concentrations, cyanobacteria cell counts, phycocyanin concentrations, and water clarity. All *in-situ* and discrete data collected as part of the Ashley Cove monitoring can be found in full in Appendix III.

NITROGEN (NITRATE-N AND AMMONIA-N)

Surface samples for the analysis of nitrate-N and ammonia-N were collected pre- and post-treatment in Ashley Cove (Figure 3.1). Nitrate-N and ammonia-N both decreased during the first post-treatment event following the PhosLock and GreenClean treatments. However, neither of these products have a direct effect on nitrogen in the water column. Ammonia-N concentrations remained low throughout the entire study and never exceeded the pre-treatment measure of 0.02 mg/L. These lower nitrogen concentrations may be attributed to the Biochar that was installed during both years. The only elevated nitrate-N concentrations relative to the pre-treatment monitoring event were measured in October of 2020 and 2021. These late season increases in nitrate-N can likely be attributed to the seasonal senescence of the dense macrophyte growth in Ashley Cove and the subsequent release of nutrients into the water column. Since PhosLock has no effect on nitrogen in the water column, measured concentrations increase late in the season. However, since the Biochar was installed earlier in the growing season, it is also possible that by October the Biochar's capacity to sequester nutrients was minimal.

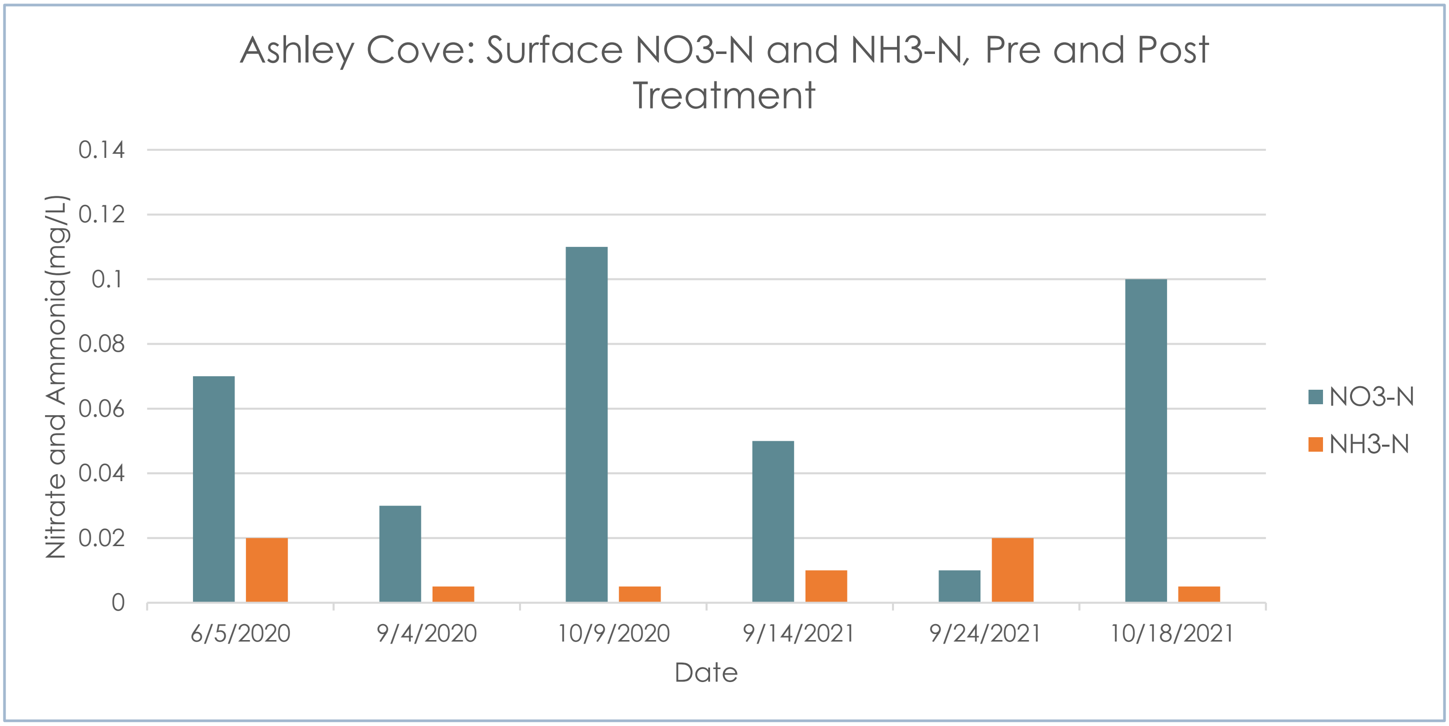


Figure 3.1: Pre- and post-treatment nitrate-N and ammonia-N concentrations in Ashley Cove.

TOTAL SUSPENDED SOLIDS

Surface samples for the analysis of total suspended solids (TSS) were collected pre- and post-treatment in Ashley Cove (Figure 3.2). TSS concentrations were low during all six monitoring events and did not exceed 5 mg/L. The pre-treatment and initial post-treatment monitoring events yielded TSS concentrations of 5 mg/L but never exceeded 3 mg/L for the remainder of the study.

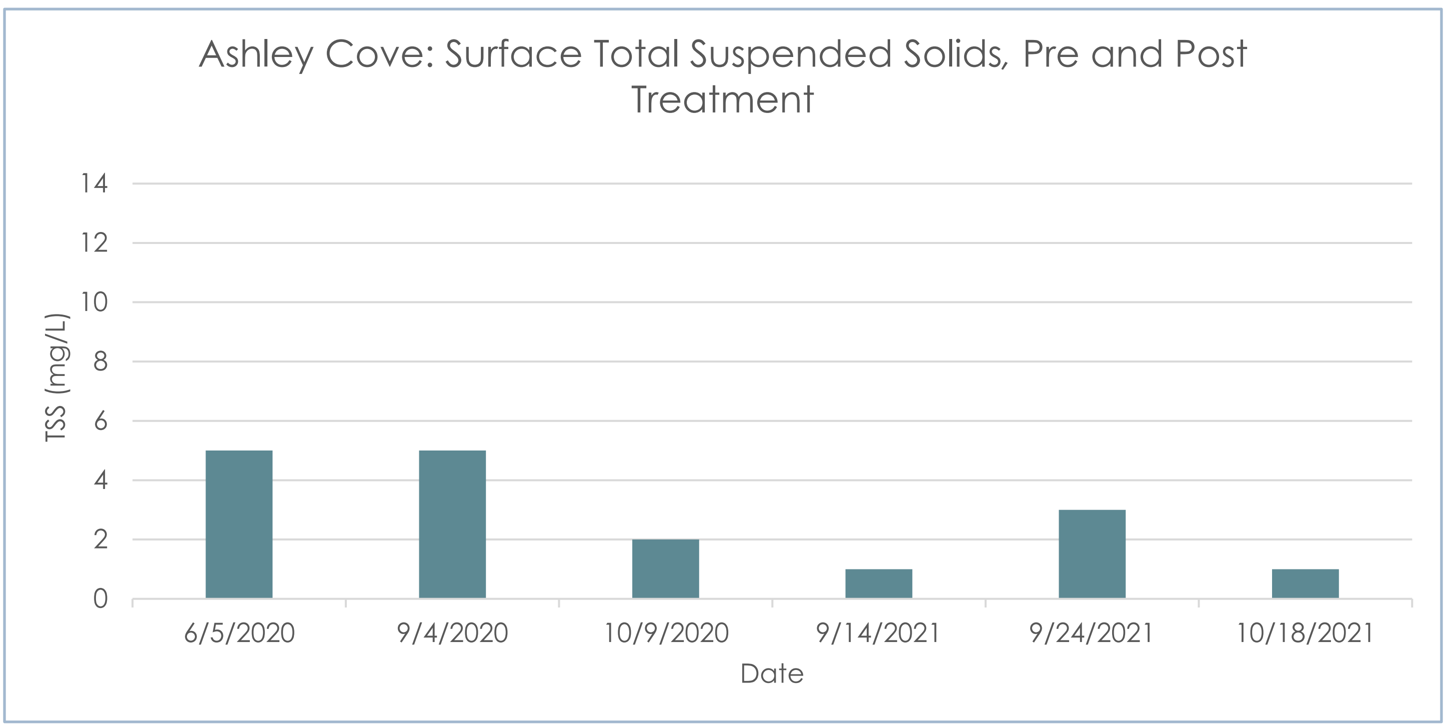


Figure 3.2: Pre- and post-treatment total suspended solid concentrations in Ashley Cove.

PHOSPHORUS (TOTAL PHOSPHORUS, SOLUBLE REACTIVE PHOSPHORUS, TOTAL DISSOLVED PHOSPHORUS)

Surface samples for the analysis of TP, SRP, and TDP were collected pre- and post-treatment in Ashley Cove (Figure 3.3). During the 2020 season, surface TP concentrations increased to 0.04 mg/L during the 4 September and 9 October monitoring events from a pre-treatment monitoring event concentration of 0.02 mg/L. However, surface TP concentrations never exceeded 0.03 mg/L during the 2021 season.

Surface TDP concentrations during the 2020 season increased to 0.02 mg/L during the 4 September and 9 October monitoring events from a pre-treatment monitoring event concentration of 0.01 mg/L. However, the first post-treatment monitoring event occurred over two months after the early season pre-treatment monitoring event in June and TP concentrations had increased lake wide by late August 2020. Surface TDP results were again promising in 2021 and never exceeded 0.01 mg/L, even as phosphorus concentrations increased lake wide. Similar to what we observed following the PhosLock application in Landing Channel, post-treatment SRP concentrations remained extremely low, even as TP and TDP concentrations increased later in the 2020 season. Surface SRP concentrations remained below the lab detection limit of 0.002 mg/L throughout the entire 2021 season.

What was particularly promising for the PhosLock treatment program is that surface water TP concentrations never exceeded 0.04 mg/L over the 2020 growing season or 0.03 mg/L over the 2021 season. This is substantially lower than the TP concentrations of 0.07 mg/L, which were measured in Ashely Cove in July 2012. Thus, the implementation of these in-lake management technique did appear to reduce phosphorus concentrations in Ashely Cove relative to historical concentrations. Also particularly important is that SRP concentrations remained essentially non-detectable throughout the study period, even as the dense macrophyte growth began to senesce in October of each year.

Deep phosphorus metrics followed similar trends as those observed in the surface water (Figure 3.4). During the 2020 season, deep TP concentrations increased from a pre-treatment monitoring concentration of 0.03 mg/L to an initial post-treatment monitoring concentration of 0.05 mg/L. However, deep TP concentrations during the second post-treatment monitoring event of 2020 decreased to 0.02 mg/L, which was lower than the surface concentration of 0.04 mg/L. During the 2021 season, deep TP concentrations reached a maximum of only 0.04 mg/L on 14 September and decreased during the two subsequent monitoring events. It should also be noted that a PhosLock treatment was conducted between the 14 September and 24 September monitoring events, and deep TP concentrations decreased over this time. Deep SRP concentrations remained low following the treatments, never exceeding 0.003 mg/L over the 2020 season and remaining below the lab detection limit of 0.002 mg/L over the 2021 season.

Overall, the PhosLock application appeared to have a positive effect on phosphorus concentrations in Ashley Cove. TP and TDP concentrations did increase slightly during the first post-treatment monitoring event in 2020, although never exceeded 0.05 mg/L for TP or 0.02 mg/L for TDP. Additionally, phosphorus concentrations lake wide had increased during the peak growing season months from July through September of 2020. Most importantly, and as expected with the PhosLock application, SRP concentrations remained extremely low throughout the entire study period, even as TP concentrations increased. This is a positive sign, as SRP is the dissolved inorganic portion of total phosphorus that is readily available for assimilation by all algal forms. Even as SRP concentrations increased slightly during the October 2020 monitoring event, concentrations never exceeded 0.003 mg/L; SRP concentrations exceeding 0.005 mg/L are often associated with increases in nuisance algal growth. Finally, 2020 TP concentrations in Ashely Cove were substantially lower relative to past (2012) concentrations. The results during the 2021 season, in which PhosLock was applied to Ashley Cove five times, were even more promising, as TP concentrations remained lower than the second half of the 2020 season and SRP concentrations remained essentially non-detectable.

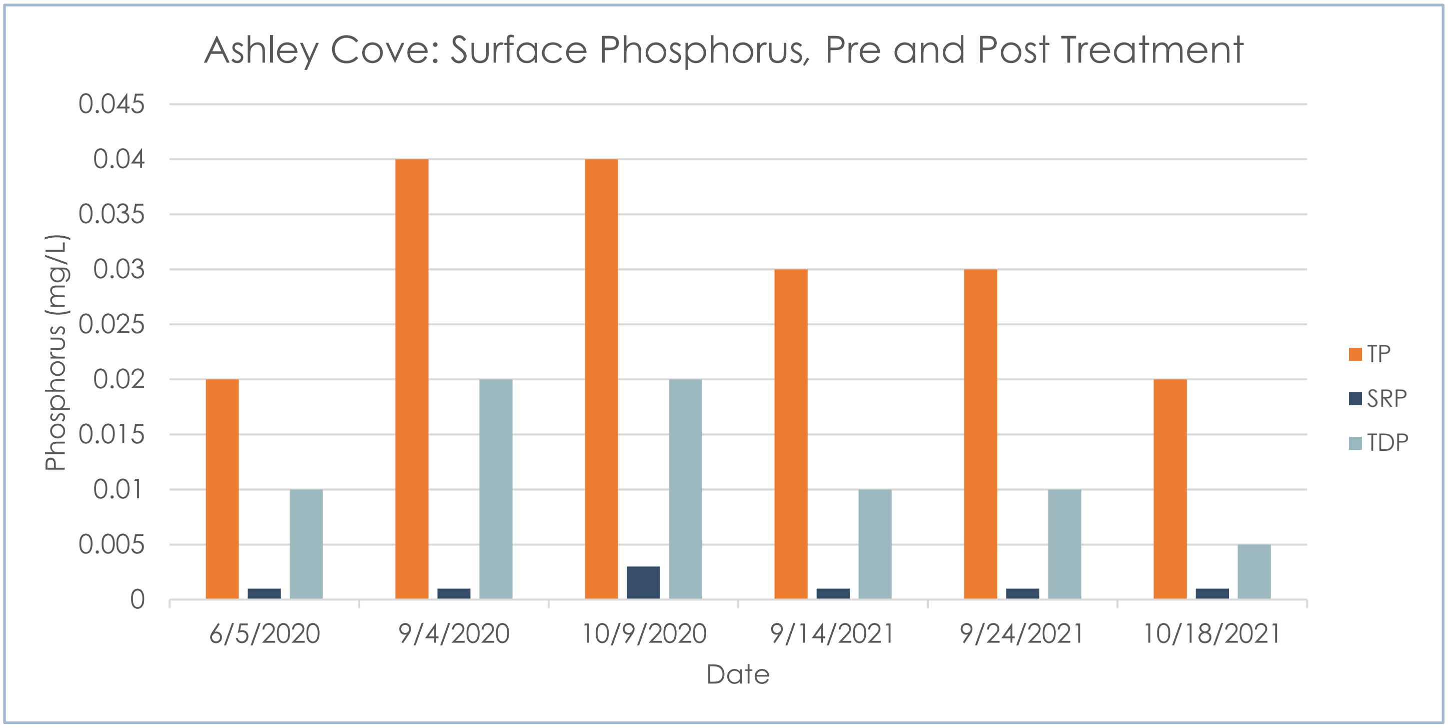


Figure 3.3: Pre- and post-treatment surface TP, TDP, and SRP concentrations in Ashley Cove.

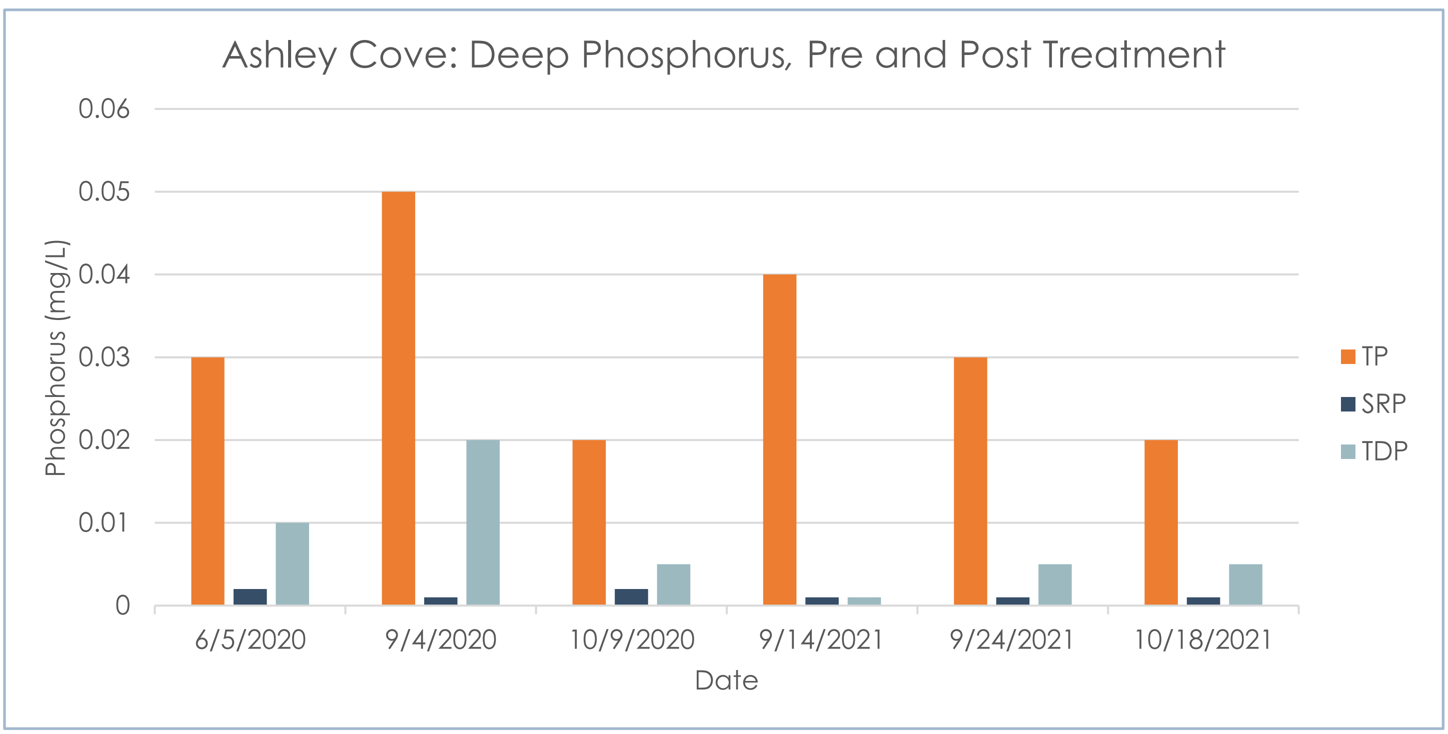


Figure 3.4: Pre-and post-treatment deep TP, TDP, and SRP concentrations in Ashley Cove.

CHLOROPHYLL *A*

Surface samples for the analysis of chlorophyll-a were collected pre- and post-treatment in Ashley Cove (Figure 3.5). Pre-treatment chlorophyll-a concentrations were low at 3.2 µg/L; however, this was early in the season before algal densities generally increase in Lake Hopatcong. Chlorophyll-*a* concentrations increased to a modest concentration of 13.0 µg/L during both post-treatment monitoring events during the 2020 season. This is not unexpected, as surface TP concentrations were 0.04 mg/L during this time. Surface chlorophyll-*a* concentrations were variable in 2021, ranging from 6.3 µg/L on 18 October up to 23.0 µg/L on 24 September. However, a review of the plankton community data from 24 September reveals that cyanobacteria densities remained low at 2,156 cells/mL during this time.

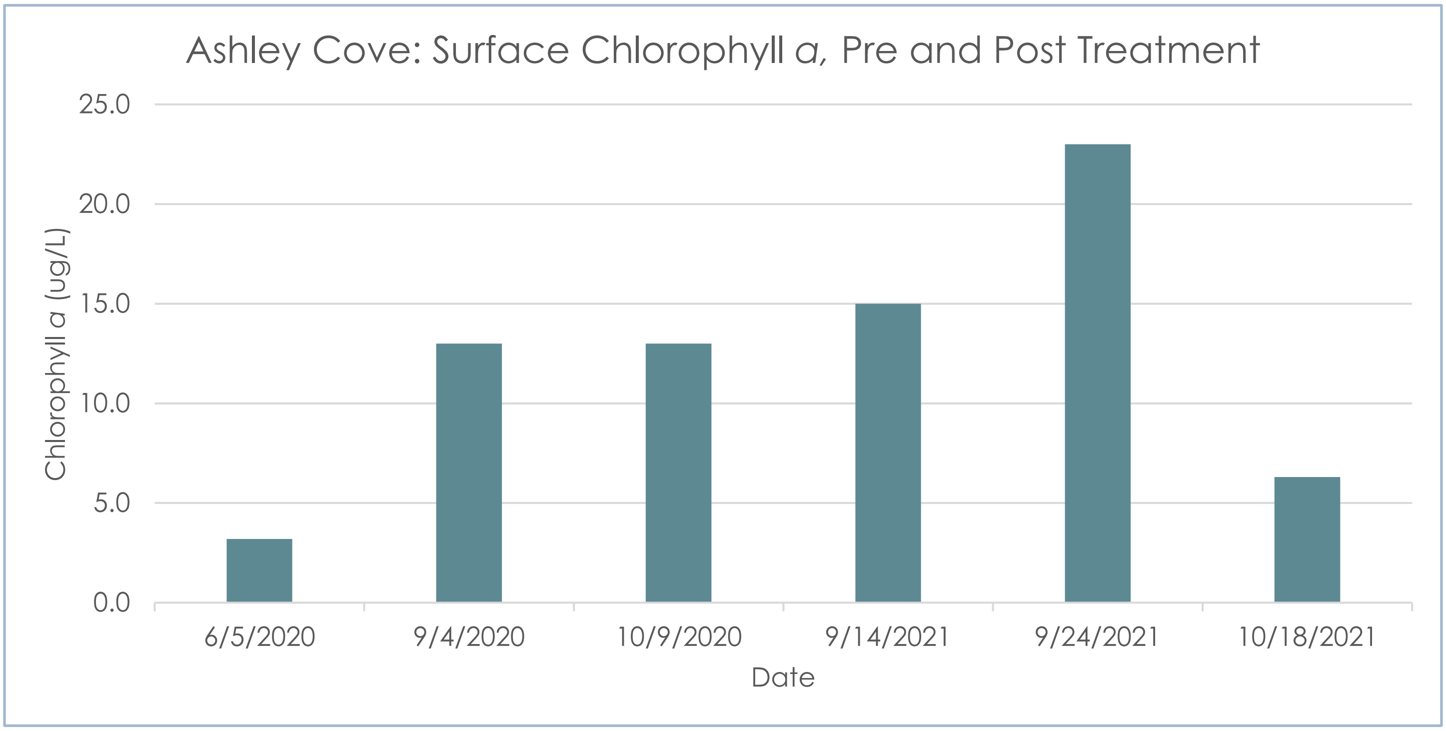


Figure 3.5: Pre-and post-treatment chlorophyll-*a* concentrations in Ashley Cove.

CYANOBACTERIA (PHYCOCYANIN AND CELL COUNT)

Surface samples for the analysis of cyanobacteria cell count and phycocyanin concentrations were collected during the pre- and post-treatment events in Ashley Cove (Figure 3.6). Cyanobacteria cell counts remained relatively low and well under any NJDEP HAB alerts during the post-treatment sampling events, with a maximum of 12,970 cells/mL during the September 2020 monitoring event. Cyanobacteria cell counts remained below 3,000 cells/mL during the remaining monitoring events. Phycocyanin concentrations also remained relatively low, following a similar trend as cyanobacteria cell counts and a maximum concentration of 10 µg/L in September 2020. Overall, it appears as though the PhosLock treatment has had a positive effect relative to cyanobacteria concentrations in Ashley Cove during the 2020 and 2021 seasons, as both metrics remained low throughout.

A few other points should be made. First, no microcystins were measured during the post-treatment monitoring events in Ashley Cove. In contrast, microcystins were measured during the pre-treatment June 2020 sampling event; however, the measured concentration, 1 ug/L, was below the State's threshold for recreational waters of 2 ug/L.

Second, while no cyanobacteria were identified in some of the post-treatment samples, there were still phycocyanin concentrations between 3.0 – 4.0 ug/L. The measurable concentrations of phycocyanin at that time was due to the presence of *Cryptomonas*, a member of the small unicellular cryptomonad group of algae also known to produce phycocyanin. Indeed, in October 2020 the *Cryptomonas* cell density was 881 cells/mL.

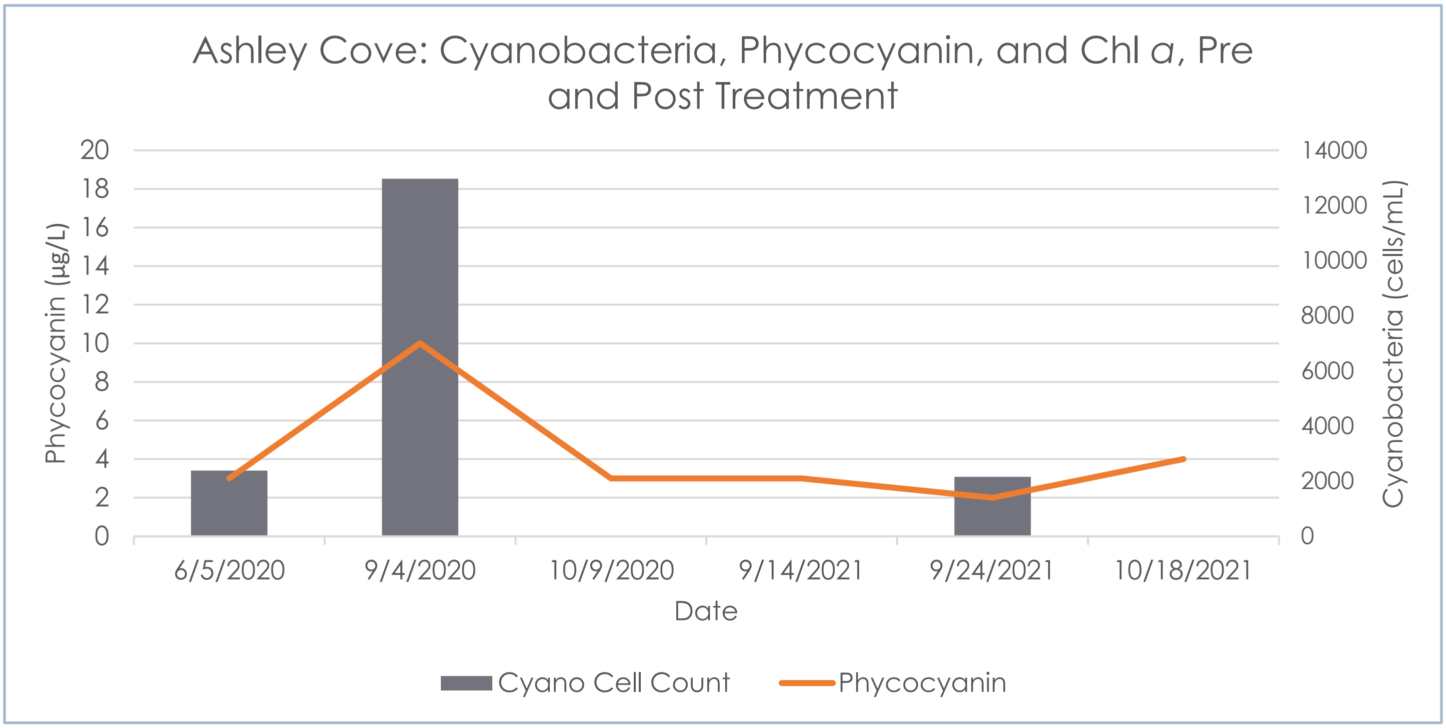


Figure 3.6: Pre- and post-treatment cyanobacteria cell counts and phycocyanin concentrations in Ashley Cove.

WATER CLARITY

Water clarity was measured with a Secchi disk pre- and post-treatment in Ashley Cove (Figure 3.7). Water clarity decreased slightly as the season progressed and chlorophyll-*a* concentrations increased. During the 2020 season, clarity slightly decreased from a pre-treatment depth of 1.5 meters in early June to post-treatment depths of 1.3 meters and 1.2 meters in September and October, respectively. During the 2021 season, water clarity was to the bottom of the cove at a depth of 1.3 meters during all monitoring events. Due to the dense macrophyte growth, the sampling station moved to an area with slightly shallower depth relative to the 2020 season. Water clarity never fell below 1.2 meters during the study period. Water clarity was exceptional during all three monitoring events of the 2021 season.

It should be noted that during the pre-treatment June sampling event, there was a dense canopy of Eurasian watermilfoil (*Myriophyllum spicatum*) and largeleaf pondweed (*Potamogeton amplifolius*). In addition, there were sporadic mats of filamentous algae. By September and October, the algal mats were gone but the sub-canopy of plants, including tapegrass (*Vallisneria americana*) were identified in Ashely Cove. Such conditions were expected, as water column phosphorus concentrations decline, there should be less algal growth (both planktonic and mat algae) and less competition for space and light. Thus, higher amounts of submerged aquatic vegetation are typically associated with a decline in algal growth, both planktonic and filamentous mat algae.

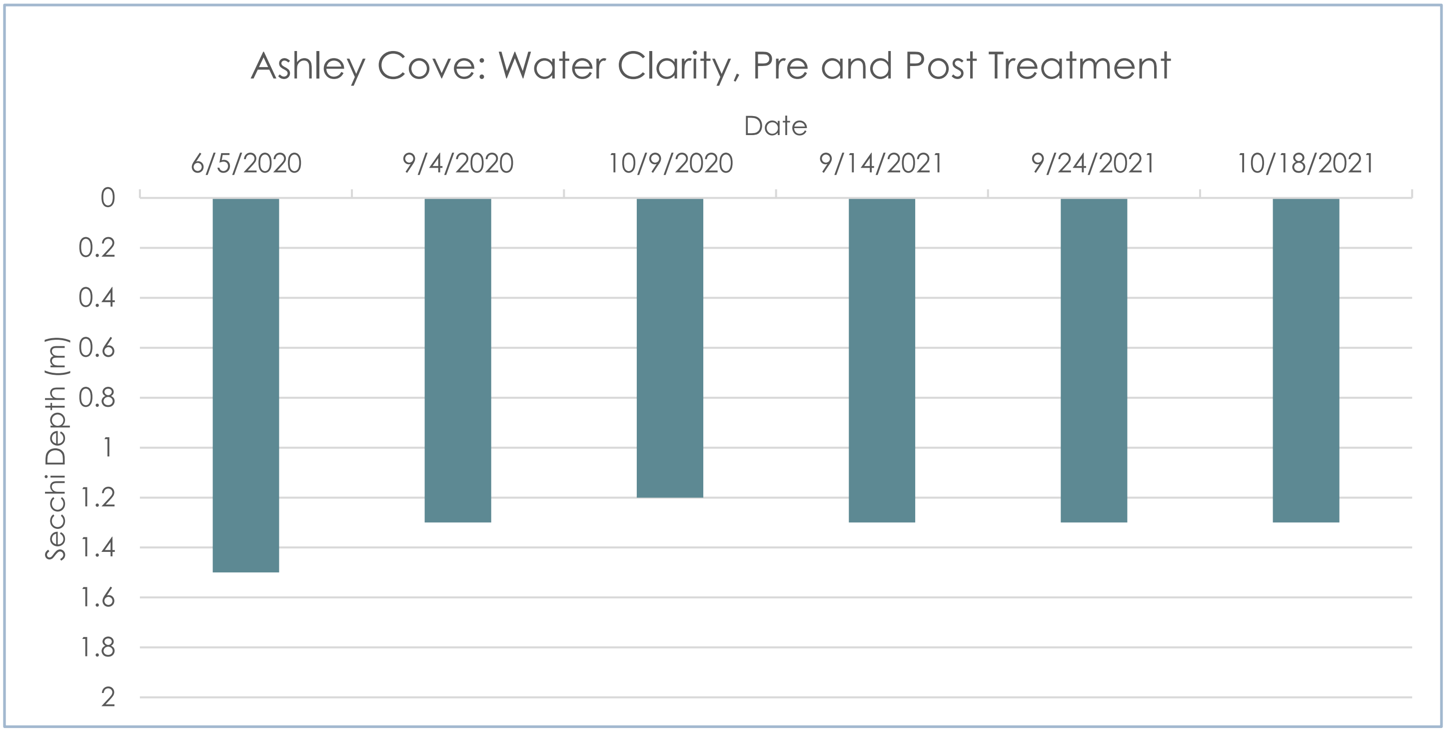


Figure 3.7: Pre- and post-treatment water clarity in Ashley Cove.

SUMMARY

The overall results of the Biochar and low-dose PhosLock applications in Ashley Cove were exceedingly positive. The mean surface TP concentration of all post-treatment monitoring events was 0.03 mg/L which correlates with the established 0.03 mg/L threshold, as per the TMDL. More importantly, and as expected with the PhosLock application, SRP concentrations remained extremely low throughout the entire study period, even as TP concentrations increased. In fact, surface and deep SRP concentrations remained non-detectable throughout the 2021 season, indicating that the PhosLock application was effective in reducing the release of dissolved phosphorus from the sediment into the second year of the study. Most importantly, no CyanoHABs or cyanobacteria cell counts that would have triggered even the minimum NJDEP WATCH level were measured throughout the entire study period.

The overall results from this project were:

Surface and deep TP concentrations remained low throughout the study, with mean post-treatment concentrations of 0.03 mg/L.

Surface and deep SRP concentrations remained extremely low throughout the study, with mean post-treatment concentrations of 0.001 mg/L.

Mean post-treatment deep TDP concentrations remained slightly below the mean post-treatment surface TDP concentrations, indicating that the PhosLock applications were effective in precluding the release of phosphorus from the sediments.

Cyanobacteria and phycocyanin concentrations remained low and no cyanobacteria cell counts above 13,000 cells/mL were measured throughout the study. No cyanobacteria were observed in a few of the samples and the positive phycocyanin concentrations were more than likely due to the presence of *Cryptomonas* that were observed in the samples.

Water clarity was exceptional throughout the study with Secchi depths often reaching the bottom of the cove.

Macrophyte growth was dense throughout the 2021 season. However, such conditions were expected, as water column phosphorus concentrations decline, there should be less algal growth (both planktonic and mat algae) and less competition for space and light. Thus, higher amounts of submerged aquatic vegetation are typically associated with a decline in algal growth, both planktonic and filamentous mat algae.

4.0 OBJECTIVE 2: EVALUATION OF BIOCHAR IN TWO STORMWATER AQUA-FILTER UNITS AT HOPATCONG BEACH CLUB

PROJECT SUMMARY

As part of a past 319(h) grant application (SFY2005), two large stormwater basins and Aqua-Filters were installed in the parking lot of the Crescent Cove Beach Club, Borough of Hopatcong, Sussex County, NJ. Based on both the stormwater and in-lake water quality data, these basins were initially very effective at reducing total phosphorus (TP) and total suspended solids (TSS); however, following the elimination of LHC funding the basins were not maintained. Now with the concern over HABs, the Commission and Borough are committed to maintaining these structures; however, they are seeking a more cost effective and environmentally friendly media to remove phosphorus.

Objective Two involved the inspection of both Aqua-Filter units by a contractor with confined space entry capability in order to determine the condition of the units and the extent of the required cleanout. The Borough of Hopatcong assisted in the removal of collected sediments from the system with its Vac-All truck. The old filter-material was also removed from the units during these inspections.

Following the cleanouts, Biochar was installed in both units to determine the cost effectiveness of the material in removing dissolved phosphorus from the incoming stormwater. This product is lower in cost than the original media that was placed into the Aqua-Filters. Additionally, once used, the Biochar can be reused as landscaping mulch. Post-installation monitoring was conducted immediately upgradient and down gradient of the structures to determine if there is a significant difference in the phosphorus species immediately up and down gradient of the material.

SCHEDULE OF EVENTS

The inspection, cleaning, and removal of old filter-media from the Aqua-Filter units was conducted on 20 May 2021. Biochar was installed in the two units on 20 May, 21 May, and 24 May 2021. Five (5) post-installation stormwater monitoring events were conducted, immediately upgradient and down gradient of the structures, on 4 June, 1 July, 23 August, 2 September, and 26 October. A full breakdown of the installation and monitoring of Biochar in the Aqua-Filter units is provided in Table 4.1 below.

Table 4.1: Schedule of Aqua-Filter activities

Aqua-Filter Biochar: Installation and Monitoring	
Date	**Activity**
5/17/2021 – 5/24/2021	Inspection, removal of existing media, and installation of Biochar
6/4/2021	1st monitoring event
7/1/2021	2nd monitoring event
8/23/2021	3rd monitoring event
9/2/2021	4th monitoring event
10/26/2021	5th monitoring event

Picture 4.1, 4.2, and 4.3: Inside view of the Aqua-Filter filtration chamber; Biochar being placed in the filtration chamber; Biochar secured in the filtration chamber.

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and objectively assess the results of the stormwater sampling data collected immediately upgradient and down gradient of the structures to determine if there is a significant difference in the phosphorus species immediately up and down gradient of the material. All discrete data collected as part of the Biochar monitoring can be found in full in Appendix IV. The upgradient sampling was conducted in surface streams just before they enter subsurface pipes while the downgradient sampling was conducted through manholes with extended sampling devices.

It is important to note that the stormwater sampling of the Aqua-Filters was difficult for a number of reasons that likely influenced the downstream phosphorus concentrations. First, the mixing of groundwater with the filtered stormwater is possible, as groundwater has the potential to seep into the system at the pipe joints since the water table is so high in close proximity to the lake. The majority of the neighborhoods in the Lake Hopatcong watershed are on septic systems which may influence phosphorus concentrations in the downgradient samples. All upgradient sampling was conducted from surface streams before they flow into subsurface pipes where mixing with groundwater may occur. Something else to consider is the fact that these Aqua-Filters are considered off-line due to the heavy flow that occurs during storm events. Thus, during heavy flow events, like most of the stormwater sampling events during this study, additional stormwater bypasses the Aqua-Filters completely and is not filtered by the Biochar. Finally, during these heavy flow events, even the water that flows through the Aqua-Filters is flowing at a fast rate which results in a very short contact time. The Biochar is also lined up along the bottom of the Aqua-Filter and during heavy flow events, a portion of the flow that passes through the units does not even come in contact with the Biochar.

TOTAL PHOSPHORUS

Stormwater samples for the analysis of TP were collected immediately upstream and downstream of both Aqua-Filter units (Figure 4.1). The removal rates throughout the season were extremely variable and the downstream samples sometimes had higher concentrations; however, this may be due to interference from additional stormwater that was not filtered by the Biochar during heavy storm events. The highest TP removal rate was 33% at the South Aqua-Filter during the first monitoring event in June. However, a 10% increase in TP concentrations in the downstream sample was measured on 23 August at the South Aqua-Filter. In total, three samples had positive removal rates, five samples had no TP removal, and two samples had TP concentrations that increased downstream of the Aqua-Filter.

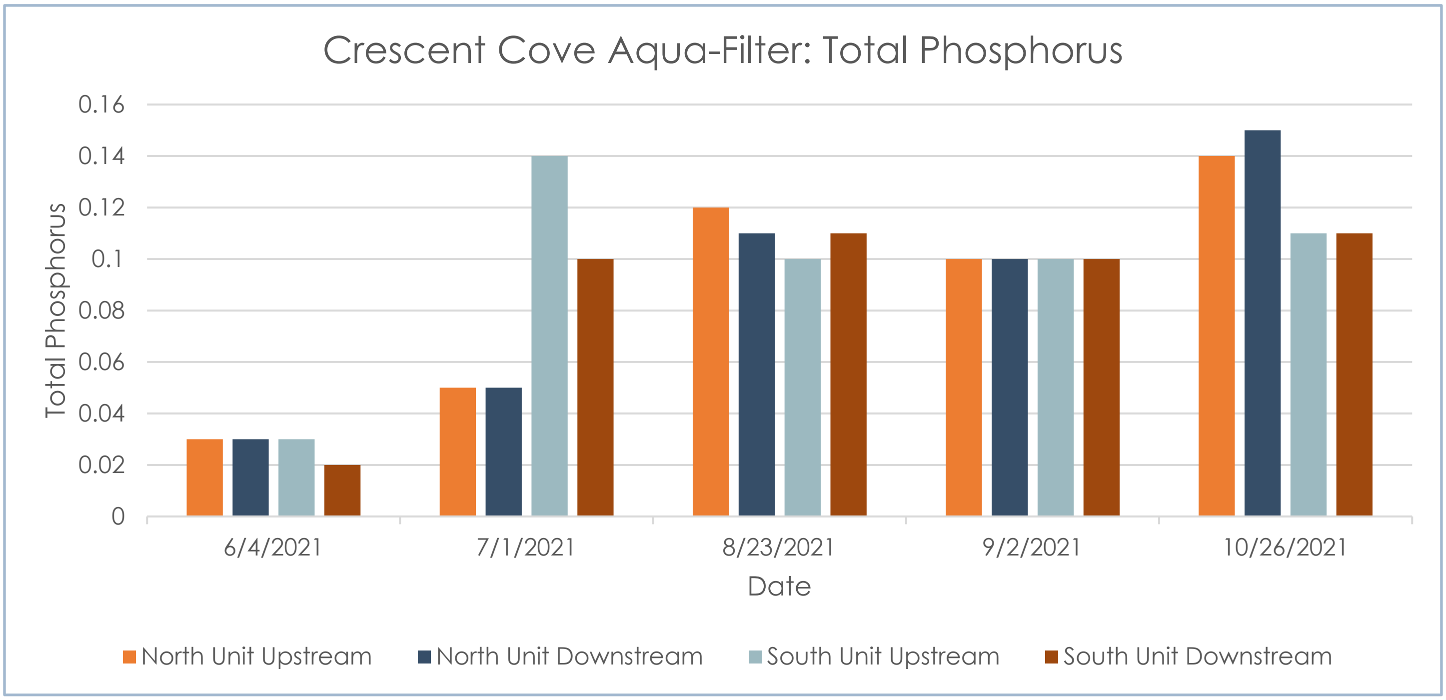


Figure 4.1: Stormwater total phosphorus concentrations upstream and downstream of the two Aqua-Filter units with Biochar.

SOLUBLE REACTIVE PHOSPHORUS

Stormwater samples for the analysis of SRP were collected immediately upstream and downstream of both Aqua-Filter units (Figure 4.2). Similar to TP, the removal rates throughout the season were extremely variable and the downstream samples sometimes had higher concentrations. The highest SRP removal rate was 46% at the South Aqua-Filter during the first monitoring event in June. However, a 31% increase in SRP concentrations in the downstream sample was measured on 2 September at the North Aqua Filter. In total, five samples had positive removal rates and five samples had SRP concentrations that increased downstream of the Aqua-Filters.

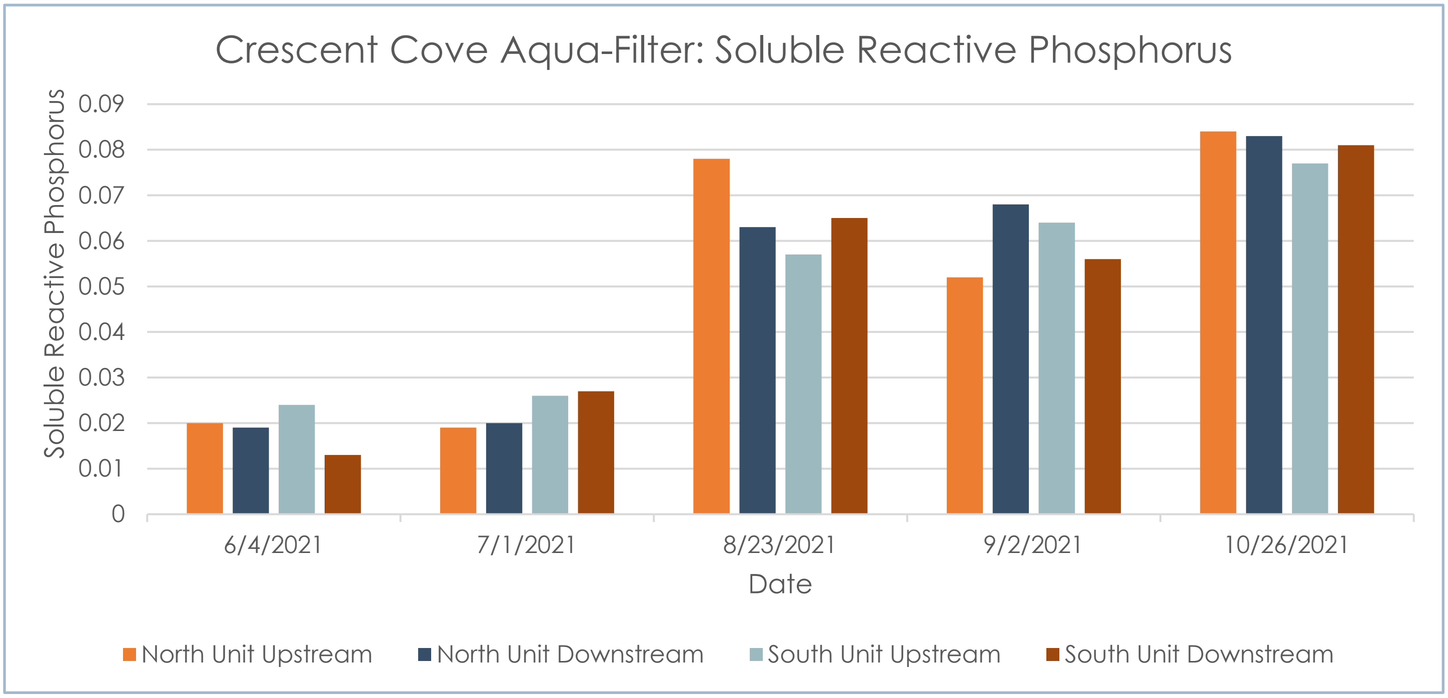


Figure 4.2: Stormwater soluble reactive phosphorus concentrations upstream and downstream of the two Aqua-Filter units with Biochar.

TOTAL DISSOLVED PHOSPHORUS

Stormwater samples for the analysis of TDP were collected immediately upstream and downstream of both Aqua-Filter units (Figure 4.3). Similar to the other phosphorus constituents, the removal rates throughout the season were extremely variable and the downstream samples sometimes had higher concentrations. The highest TDP removal rate was 25% at the North Aqua-Filter during the 23 August sampling event. However, a 25% increase in TDP concentrations in the downstream sample was measured on 1 July at the South Aqua-Filter. In total, three samples had positive removal rates, four samples had no TDP removal, and three samples had TDP concentrations that increased downstream of the Aqua-Filter.

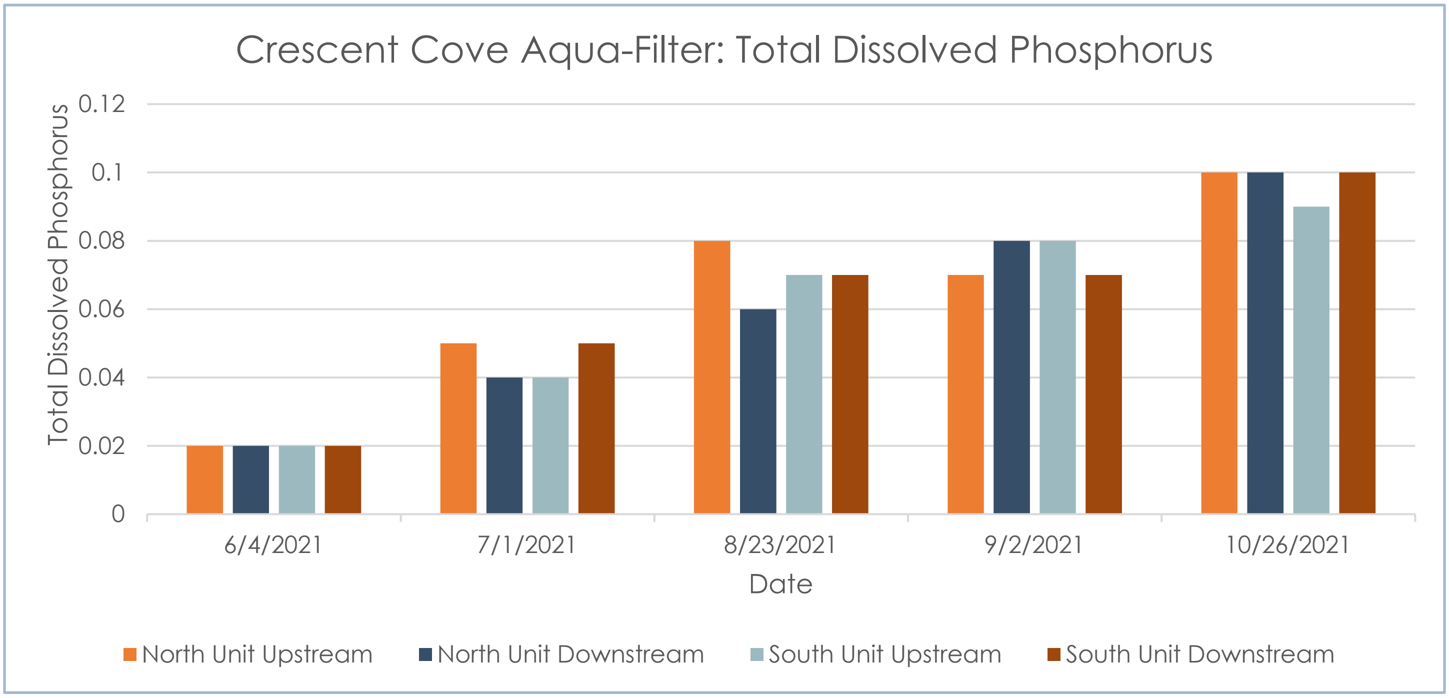


Figure 4.3: Stormwater soluble reactive phosphorus concentrations upstream and downstream of the two Aqua-Filter units with Biochar.

SUMMARY

The phosphorus removal rates provided by the Biochar socks in the Aqua-Filters varied greatly throughout the season. It should be noted that the removal rates during the first monitoring event, which occurred a couple of weeks after the Biochar was installed, were generally positive; this is the only monitoring event where none of the downstream samples concentrations were higher than upstream concentrations. Similar to what has been observed with our other Biochar stormwater sampling, it appears as though contact time between the Biochar and the stormwater is key, with extended contact times resulting in higher removal rates, as shown by the superior removal rates provided by the Biochar socks in two ponds as part of Objective 6.

The two streams that pass through these Aqua-Filters flow throughout the year and discharge rates increase substantially during storm events. In 2021 in particular, there were some extreme rain events throughout the season, including Hurricane Ida, and these Aqua-Filters were sampled following these events. As such, contact time between the stormwater and Biochar was likely minimal during these storm events. As mentioned above, the influence of un-filtered water mixing with the filtered water between the upstream and downstream sampling points likely occurred. Sources of phosphorus for these potential influences include septic leachate as a result of the high water table and stormwater that bypassed the Aqua-Filters completely during storm events. In addition, most stormwater MTDs such as Aqua-Filters are designed to have their highest rates of pollutant removal during the more frequent small to medium sized storm events, typically the 2 to 10 year storm events.

The stormwater results indicate the following about phosphorus removal efficiencies in Aqua-Filters:

> Total phosphorus results indicate that Biochar placed in Aqua-Filters that receive a substantial volume of stormwater can provide TP removal rates up to 33%.

Soluble reactive phosphorus results indicate that Biochar placed in Aqua-Filters that receive a substantial volume of stormwater can provide SRP removal rates between up to 46%.

Total dissolved phosphorus results indicate that Biochar placed in Aqua-Filters that receive a substantial volume of stormwater can provide TDP removal rates between up to 25%.

The key takeaway from this study appears to be that extended contact time results in higher nutrient removal. It also appears that phosphorus removal rates decreased after the first monitoring event, which could be a result of the consistent flow. Thus, if Biochar is to be placed in Aqua-Filters or any place where a large volume of water is filtered through, the material will need to be replaced at a higher frequency relative to lower flow locations, likely every one to two months. Thus, the stormwater removal rates and replacement frequency is closer to what was observed in streams than in standing waters.

Even with modest phosphorus removal rates in the two Aqua-Filters in Crescent Cove, the overall phosphorus load removed on an annual basis is still substantial due to the large volume of stormwater that these two systems receive. To calculate the phosphorus loads removed on an annual basis under varying removal efficiencies, the average inflow phosphorus load was calculated using the volume of stormwater per the drainage area of each Aqua-Filter based on 2021 rainfall records from March through November at the Mount Arlington 0.8 S weather station. Removal efficiencies between 10% - 50% were then applied to the inflow phosphorus loads, depending on the specific phosphorus parameter and the results from the stormwater sampling. As such, the estimated total annual phosphorus loads removed under varying removal efficiencies are as follows:

The annual TP load removed from the two Aqua-Filters assuming a modest stormwater removal rate of 10% is approximately 5.2 lbs. The annual TP load removed assuming a stormwater removal rate of 30% is approximately 15.6 lbs. Since the TMDL for Lake Hopatcong is specifically for TP, these values are the most relevant in terms of tracking pollutant reductions. In addition, it should be noted that at 30% the amount of phosphorus estimated to be removed with Biochar (15.6 lbs) is very similar to the original filter media (15.3 lbs) which was more expensive and could not be reused as mulch like Biochar.

The annual SRP load removed from the two Aqua-Filters assuming a modest stormwater removal rate of 10% is approximately 2.8 lbs. The annual SRP load removed assuming a stormwater removal rate of 30% is approximately 8.4 lbs. The annual SRP load removed assuming a stormwater removal rate of 50% is approximately 14.0 lbs.

The annual TDP load removed from the two Aqua-Filters assuming a modest stormwater removal rate of 10% is approximately 3.3 lbs. The annual TDP load removed assuming a stormwater removal rate of 30% is approximately 10.0 lbs.

5.0 OBJECTIVE 3: INSTALLATION AND EVALUATION OF VARIOUS TYPES OF AERATION ALONG NEARSHORE BEACH AREAS FOR HAB CONTROL

PROJECT SUMMARY

Three varying forms of near-shore aeration for HAB prevention, mitigation, and/or control were installed along three specific beach areas in Lake Hopatcong. The first is the installation of an Air Curtain system along Shore Hills Beach (195 Mt. Arlington Blvd, Landing; Township of Roxbury). Air Curtain systems can be very effective at preventing the accumulation of cyanobacteria cells / biomass along near-shore areas. The second is the installation of a Nanobubble oxygen system along the Mount Arlington Municipal Beach (511 Windemere Ave, Borough of Mt. Arlington). The third is the installation of a Nanobubble ozone system along the Lake Forest Yacht Club (35 Yacht Club Drive, Lake Hopatcong: Township of Jefferson). Nanobubble technology is a fairly new form of aeration that has started to yield very positive results relative to HAB control and prevention. Thus, this new aeration technology was evaluated at Lake Hopatcong.

SCHEDULE OF EVENTS

The Air Curtain was installed at the Shore Hills Country Club (Roxbury) on 4-6 November 2020 (Picture 5.1). An evaluation of the Air Curtain and how it can prevent, mitigate and/or control HABs was conducted over three (3) monitoring events on 19 May, 29 June, and 27 July 2021.


Picture 5.1: Shore Hills Air Curtain

In contrast, the Nanobubble system at the Memorial Municipal Beach (Mt. Arlington) and the Nanobubble / Ozone system at the Lake Forest Yacht Club (Jefferson) were installed in 2021. However, due to logistical and infrastructure issues the nanobubble systems will be evaluated over the 2022 growing season. These systems will be turned on in June 2022.

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and objectively assess the results of the water quality data collected in Lake Hopatcong relative to the success of the Air Curtain and how it can prevent, mitigate and/or control HABs. This section will focus primarily on the parameters that are most closely associated with the development of HABs, such as cyanobacteria cell counts, phycocyanin concentrations, and water clarity. During each monitoring event, samples were collected from an area within the Air Curtain, or the treatment zone, and outside of the area affected by the Air Curtain, or the control zone. All *in-situ* data collected as part of the aeration monitoring can be found in full in Appendix V.

Again, the nanobubble systems will be evaluated over the 2022 growing season. Monitoring of the nanobubble systems sites will be conducted during the five standard, long-term, water quality monitoring events from May through September. Each nanobubble system site will include stations within the treatment zone and a control, outside of the treatment zone.

WATER CLARITY

Water clarity was measured with a Secchi disk at a station within the Air Curtain, or the treatment zone, and outside of the area affected by the Air Curtain, or the control zone three times during the 2021 season (Figure 5.1). It should be noted that due to the location of the Air Curtain in Landing Channel, the control site was still in the area of the lake where PhosLock was applied in 2020, and thus water quality conditions were favorable throughout the season. Secchi depth was to the bottom of the lake at both the treatment and control sites in May and June. Water clarity decreased to a depth of 1.1 meters at both stations on 27 July. However, water clarity had begun to decrease at most shallow stations throughout the lake during this time. It is also important to note that visual observations during the July monitoring event indicate that the treatment zone had less of a surface accumulation of particulates during this time.

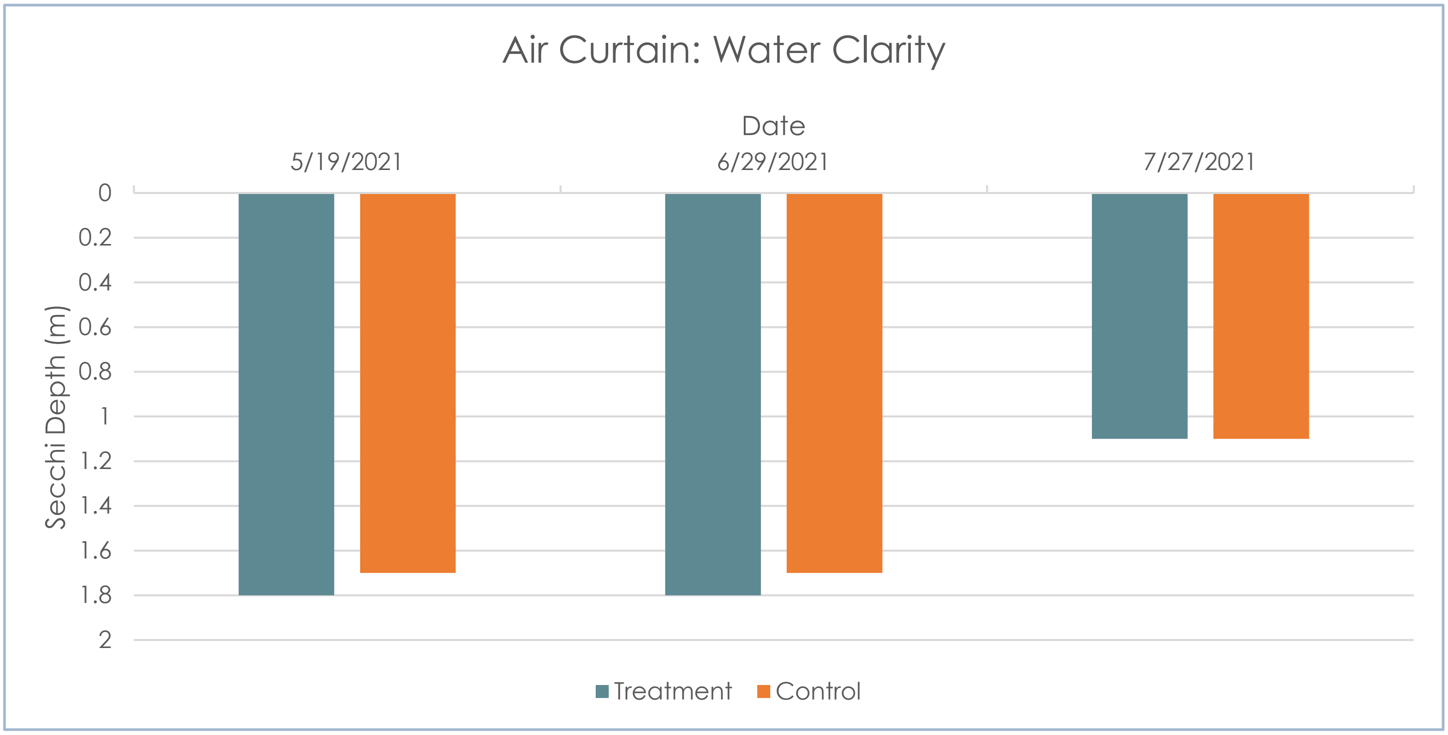


Figure 5.1: Secchi depth in the Air Curtain treatment and control zones.

PHYCOCYANIN

Phycocyanin concentrations were measured at a station within the Air Curtain, or the treatment zone, and outside of the area affected by the Air Curtain, or the control zone three times during the 2021 season (Figure 5.2). It should be noted that due to the location of the Air Curtain in Landing Channel, the control site was still in the area of the lake where PhosLock was applied in 2020, and thus water quality conditions were favorable throughout the season. Similar to water clarity, phycocyanin concentrations were essentially uniform in both the treatment and control zones throughout the season and only became slightly elevated in late July. However, it should be noted that based on some detailed monitoring of both phycocyanin and cyanobacteria cell counts throughout 2020, a phycocyanin reading of 12 ug/L typically represents a cyanobacteria cell count of 20,000 cells / mLs, which is the threshold when NJDEP's first HAB Alert Level of Watch is reached.

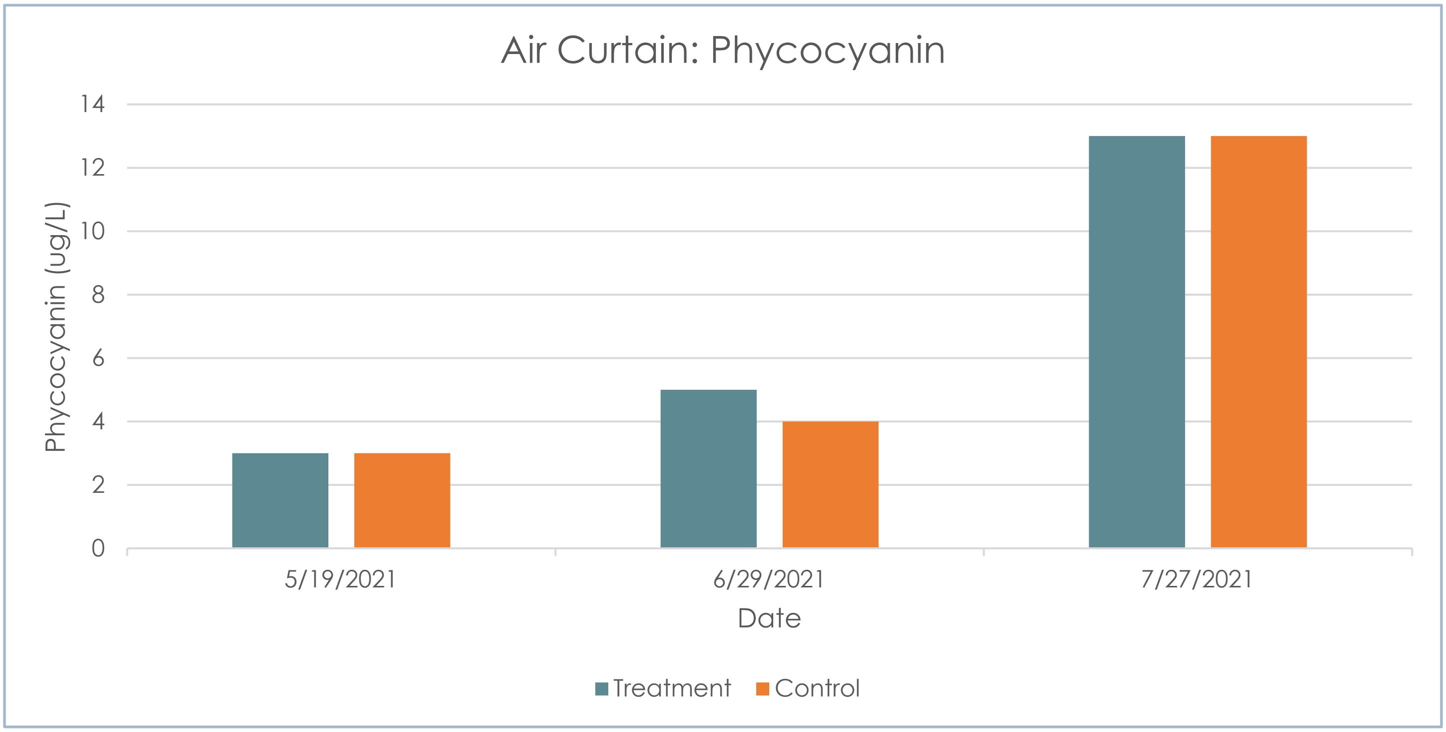


Figure 5.2: Phycocyanin concentrations in the Air Curtain treatment and control zones.

CYANOBACTERIA CELL COUNTS

Surface samples for the analysis of cyanobacteria cell counts were collected at a station within the Air Curtain, or the treatment zone, and outside of the area affected by the Air Curtain, or the control zone three times during the 2021 season. Again, it should be noted that due to the location of the Air Curtain in Landing Channel, the control site was still in the area of the lake where PhosLock was applied in 2020, and thus water quality conditions were favorable throughout the season. Similar to the other water quality metrics, cyanobacteria cell densities were similar in the treatment and control zones throughout the summer, with the exception of 29 June, in which the treatment zone had a cyanobacteria cell count of 8,375 cells/mL and the control zone had a cell count of 1,491 cells/mL. However, please note that both of these cell counts are low and are not indicative of impaired water quality. Cyanobacteria cell counts in the treatment zone never exceeded 17,000 cells/mL and thus never triggered any of NJDEP's HAB Alert Levels. Additionally, all cyanotoxin samples analyzed for microcystins, one of the more commonly occurring group of cyanotoxins, were negative throughout the study.

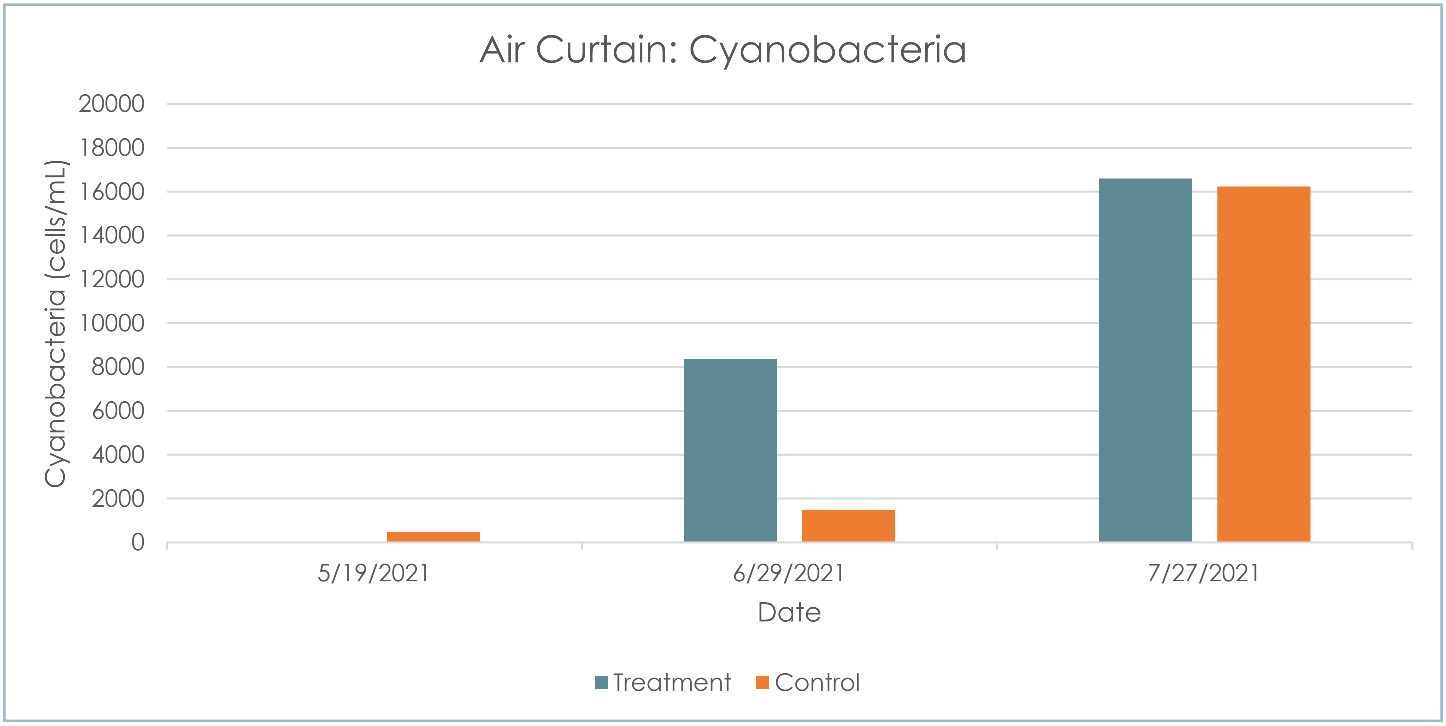


Figure 5.3: Cyanobacteria cell counts in the Air Curtain treatment and control zones.

SUMMARY

The results of the Air Curtain aeration system at Shore Hills Beach Club were positive, as water quality conditions within the treatment zone were favorable all season. Shore Hills Beach Club is located along the shoreline in the shallow, secluded Landing Channel. These types of locations are susceptible to the wind-blown accumulation of cyanobacteria and other undesirable organic matter, including plant fragments. Landing Channel in particular is prone to dense SAV growth, especially in 2021 following the PhosLock application of 2020. As such, the Air Curtain was effective in preventing the accumulation of nuisance particulates and other organic matter in the Shore Hills Beach Club marina or swim area throughout the season. Cyanobacteria cell counts remained below the minimum NJDEP HAB Alert Level throughout the season, even as cyanobacteria cell densities increased in other shallow areas across the lake during the peak summer months.

Also, as noted above, both nanobubble systems will be evaluated over the 2022 growing season. Monitoring of the nanobubble systems sites will be conducted during the five standard, long-term, water quality monitoring events from May through September. Each nanobubble system site will include stations within the treatment zone and a control, outside of the treatment zone. Upon completion of the 2022 monitoring of these systems, a summary of all three aeration systems and their benefits and any potential limitations will be provided.

6.0 OBJECTIVE 4: TREATMENT AND EVALUATION OF PHOSLOCK TO PREVENT OR MINIMIZE THE DEVELOPMENT OF CYANOHABS

PROJECT SUMMARY

To better address the phosphorus that is fueling HABs from the shallow, organically enriched sediments, the LHC was interested in using an alternative to both copper-based algaecides and alum. Specifically, a treatment of PhosLock was conducted in Landing Channel in the early summer of 2020. PhosLock is a clay-based, non-aluminum-based nutrient inactivator that has been used in a variety of ways to inactivate phosphorus, making it unavailable for algal growth. While the product is frequently used to strip the water column of dissolved phosphorus, as well as to inactivate phosphorus generated from deep, anoxic sediments, it has recently been effectively used to inactivate the mobilization of phosphorus from shallow sediments where there is a mobilization of phosphorus from both chemical and biological processes.

Objective 4 involved a PhosLock treatment in Landing Channel to determine if this can be used to minimize or avoid HABs without the use of copper-based algaecides. The treatment was designed to inactivate some of the phosphorus originating from organically enriched sediments. Pre- and post-treatment monitoring, before and after the treatment, were conducted as part of the existing baseline monitoring for Lake Hopatcong. The monitoring program was also used to assess the effectiveness of the treatment relative to water quality parameters that quantify the impacts associated with HABs.

SCHEDULE OF EVENTS

Sediment sampling in Landing Channel was conducted early in the 2020 season so the dosage rate could be calculated. These sediment samples were collected on 23 April 2020. After a review of the baseline monitoring data in Lake Hopatcong, the PhosLock application was scheduled for mid-June 2020. As such, pre-treatment monitoring was conducted on 12 June 2020. The PhosLock application was conducted from 15 June 2020 – 17 June 2020. Finally, three (3) post-treatment monitoring events were conducted in 2020 on 24 June, 22 July, and 23 September. Additionally, post-treatment monitoring was continued throughout the 2021 season for a total of five (5) additional events on 19 May, 9 June, 13 July, 17 August, and 13 September. In total, eight (8) post-treatment monitoring events were conducted in 2020 and 2021. A full breakdown of the pre- and post-treatment monitoring schedule, including the date of the treatments, is provided in Table 6.1 below.

Table 6.1: Landing Channel: Treatment and monitoring schedule.

Ashley Cove: Treatment Schedule	
Date	**Activity**
4/22/2020	Sediment sampling in Landing Channel
6/12/2020	Pre-treatment monitoring
6/15/2020 – 6/17/2020	PhosLock application in Landing Channel
6/24/2020	1st post-treatment monitoring event
7/22/2020	2nd post-treatment monitoring event
9/23/2020	3rd post-treatment monitoring event
5/19/2021	4th post-treatment monitoring event
6/9/2021	5th post-treatment monitoring event
7/13/2021	6th post-treatment monitoring event
8/17/2021	7th post-treatment monitoring event
9/13/2021	8th post-treatment monitoring event

The PhosLock application was conducted by Princeton Hydro. Approximately 22,000 lbs. of PhosLock were applied over an area of approximately 50.0 acres over the course of three (3) days. Thus, the dosage rate, as determined through the sediment sampling, was 440.0 lbs of PhosLock per acre.

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and assess the results of the water quality data collected in Lake Hopatcong relative to the success of the PhosLock treatment in controlling the development of HABs. This section will focus primarily on the parameters that are most closely associated with the development of HABs, such as phosphorus and chlorophyll-*a* concentrations, cyanobacteria cell counts, phycocyanin concentrations, and water clarity. Additional water quality data collected during the baseline monitoring of Lake Hopatcong will also be included in the analysis; Station 5 (ST-5) from the baseline monitoring program was used as a control site. All *in-situ* and discrete data collected as part of the PhosLock monitoring can be found in full in Appendix VI.

TOTAL PHOSPHORUS

Surface and deep-water samples for the analysis of TP were collected during pre- and post-treatment events in Landing Channel; surface samples were collected at Station 5 (ST-5) during the baseline monitoring as a control site (Figure 6.1). The initial TP results during the first post-treatment monitoring event were positive, as surface and deep TP concentrations in Landing Channel decreased from pre-monitoring concentrations of 0.03 mg/L and 0.04 mg/L to post treatment concentrations of 0.02 mg/L and 0.02 mg/L, respectively. However, TP concentrations in Landing channel increased during the following monitoring event in July 2020 while control zone TP concentrations remained at 0.03 mg/L. It should be noted that water temperatures throughout the lake were elevated during this time and remained above 28.00 °C throughout the water column in Landing Channel, which may have led to an increase in the oxic release of phosphorus from the bottom sediment. Additionally, TP concentrations exceeded 0.04 mg/L at three (3) additional baseline monitoring stations during this sampling event. The slight increase in TP throughout the lake was the result of a storm event that transported NPS pollution to the lake immediately prior to the July sampling event. Finally, surface and deep TP in Landing Channel as well as the surface TP in the control zone were uniform at 0.03 mg/L during the final monitoring event in September 2020. The 2020 seasonal mean of surface TP concentrations in Landing Channel was 0.033 mg/L based on these four sampling events, which is slightly above the established 0.03 mg/L goal, as per the TMDL.

Surface TP concentrations during the 2021 growing season were similar to those measured in 2020 but never exceeded 0.03 mg/L; control zone concentrations were generally similar. Likewise, deep TP concentrations were similar to those measured in 2020, with only one sample slightly elevated at 0.06 mg/L on 13 July; no other deep TP concentrations exceeded 0.03 mg/L. The 2021 seasonal mean of surface TP concentrations in Landing Channel was 0.028 mg/L based on these four sampling events, which is slightly below the established 0.03 mg/L goal, as per the TMDL.

The mean of post-treatment surface TP concentration across the entire study period was 0.03 mg/L which is right on the mark of the established 0.03 mg/L goal, as per the TMDL.

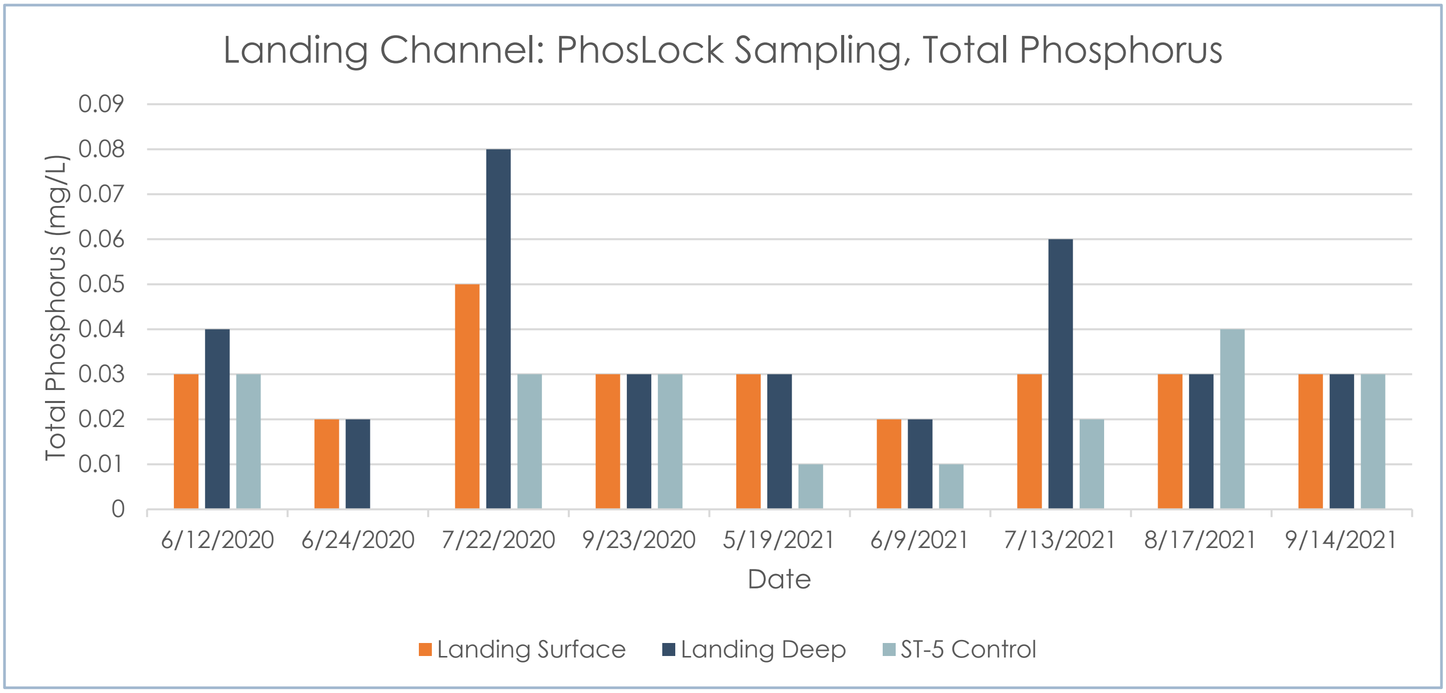


Figure 6.1: Pre- and post-treatment total phosphorus concentrations in Landing Channel. Please note that no sample was taken from the control site on 24 June 2020.

SOLUBLE REACTIVE PHOSPHORUS

Surface and deep-water samples for the analysis of SRP were collected during pre- and post-treatment events in Landing Channel; surface samples were collected at Station 5 (ST-5) during the baseline monitoring as a control site (Figure 6.2). SRP concentrations remained below the detection limit (< 0.002 mg/L) at both surface stations during the pre-treatment monitoring event while the Landing Channel deep sample had a concentration of 0.002 mg/L. Following the treatment, both surface and deep SRP concentrations in Landing Channel remained below the detection limit during the following two post-treatment events in June and July of 2020. It is a positive sign that deep-water SRP remained below the detection limit during the July monitoring event while TP concentrations were slightly elevated at 0.08 mg/L. Surface SRP concentrations did increase to 0.004 mg/L during the final monitoring event in September, although deep-water and control zone SRP concentrations remained below the detection limit. However, it is not likely that the SRP in the surface water of Landing Channel originated from the sediments since deep-water SRP concentrations at that station were below the detection limit. All SRP samples, including surface and deep Landing Channel and control site samples, were below the lab detection limit of 0.002 mg/L throughout the 2021 season with the exception of the surface sample in Landing Channel on 19 May at a concentration of 0.002 mg/L.

Overall, it appears as though the PhosLock application had a positive effect on SRP concentrations in Landing Channel, as surface water concentrations remained non-detectable through July of 2020 while deep-water concentrations remained non-detectable through the end of the study period. Additionally, as TP concentrations increased in both the surface and deep-water of Landing Channel during the July 2020 monitoring event, SRP concentrations remained non-detectable. This is a positive sign, as SRP is the dissolved inorganic portion of total phosphorus that is readily available for assimilation by all algae. Even as SRP concentrations increased in Landing Channel later in the 2020 season, concentrations remained below 0.005 mg/L; SRP concentrations exceeding 0.005 mg/L are often associated with increases in nuisance algal growth.

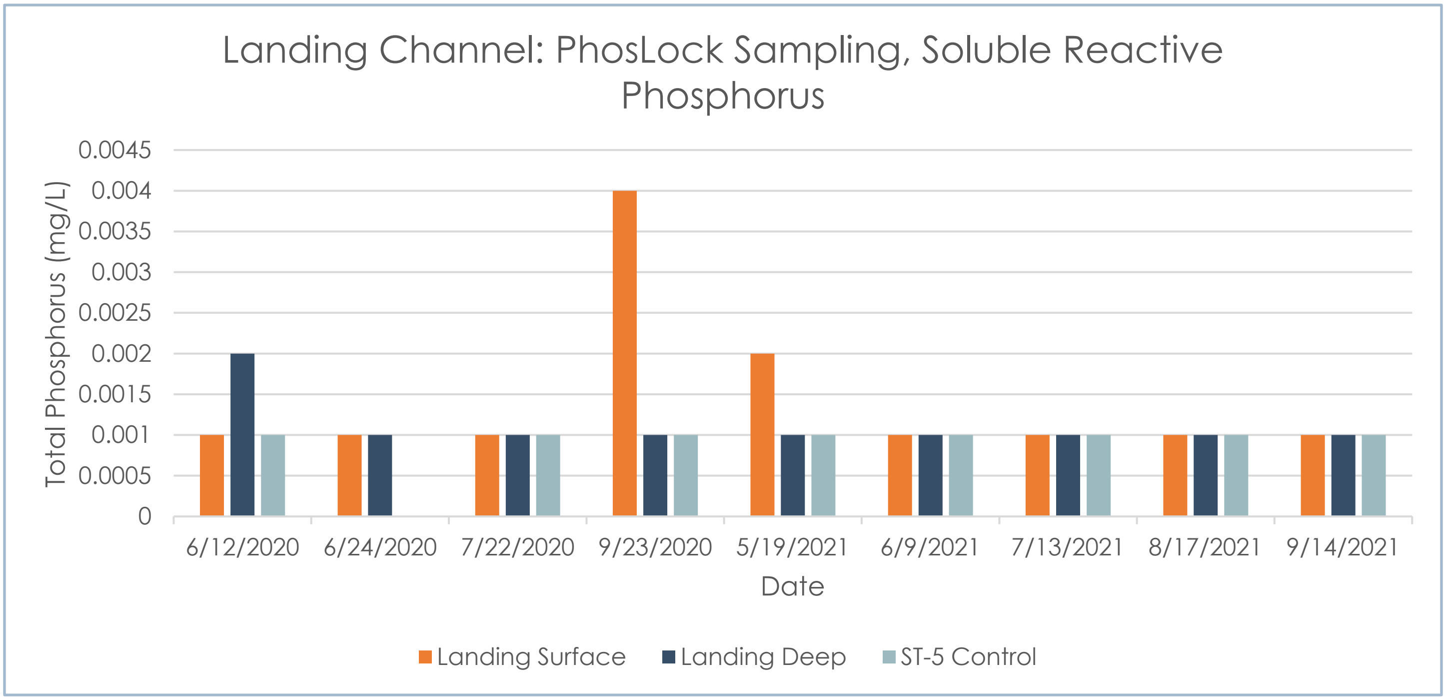


Figure 6.2: Pre- and post-treatment soluble reactive phosphorus concentrations in Landing Channel. Please note that no sample was taken from the control site on 24 June 2020.

TOTAL DISSOLVED PHOSPHORUS

Surface and deep-water samples for the analysis of TDP were collected during pre- and post-treatment events in Landing Channel; no samples were collected at Station 5 (ST-5) during the baseline monitoring as a control site since this parameter is not routinely monitored (Figure 6.3). TDP concentrations were uniform at 0.02 mg/L in the surface and deep-water of Landing Channel during the pre-treatment monitoring event in June. TDP concentrations decreased in the surface and deep water stations following the treatment, with respective concentrations of 0.005 mg/L and 0.01 mg/L on 24 June 2020. As TP concentrations increased in Landing Channel during the July 2020 monitoring event, TDP concentrations also increased. Surface and deep-water TDP concentrations during this sampling event were 0.04 and 0.05, respectively; TP concentrations were 0.05 and 0.08, respectively, during this time. TDP concentrations were low again during the final monitoring event in September 2020, at 0.02 mg/L. Surface and deep TDP concentrations remained extremely low and never exceeded 0.01 mg/L throughout the entire 2021 season. Deep TDP concentrations were below the lab detection limit of 0.01 mg/L during two of the 2021 monitoring events.

The initial TDP results during the first post-treatment monitoring event were positive, as surface and deep TDP concentrations in Landing Channel decreased from a pre-monitoring concentration of 0.02 mg/L to post treatment concentrations of 0.005 mg/L and 0.01 mg/L, respectively. However, similar to TP concentrations, TDP concentrations in Landing channel increased during the following monitoring event in July. As previously mentioned, water temperatures were elevated and above 28.00 °C during this time, and TP concentrations throughout the lake were elevated as a result of a recent storm. The results of the TDP sampling in 2021 were positive, as concentrations never exceeded 0.01 mg/L. Thus, most of the phosphorus measured throughout 2021 season was particulate phosphorus rather than dissolved phosphorus which is generally more available for algal assimilation.

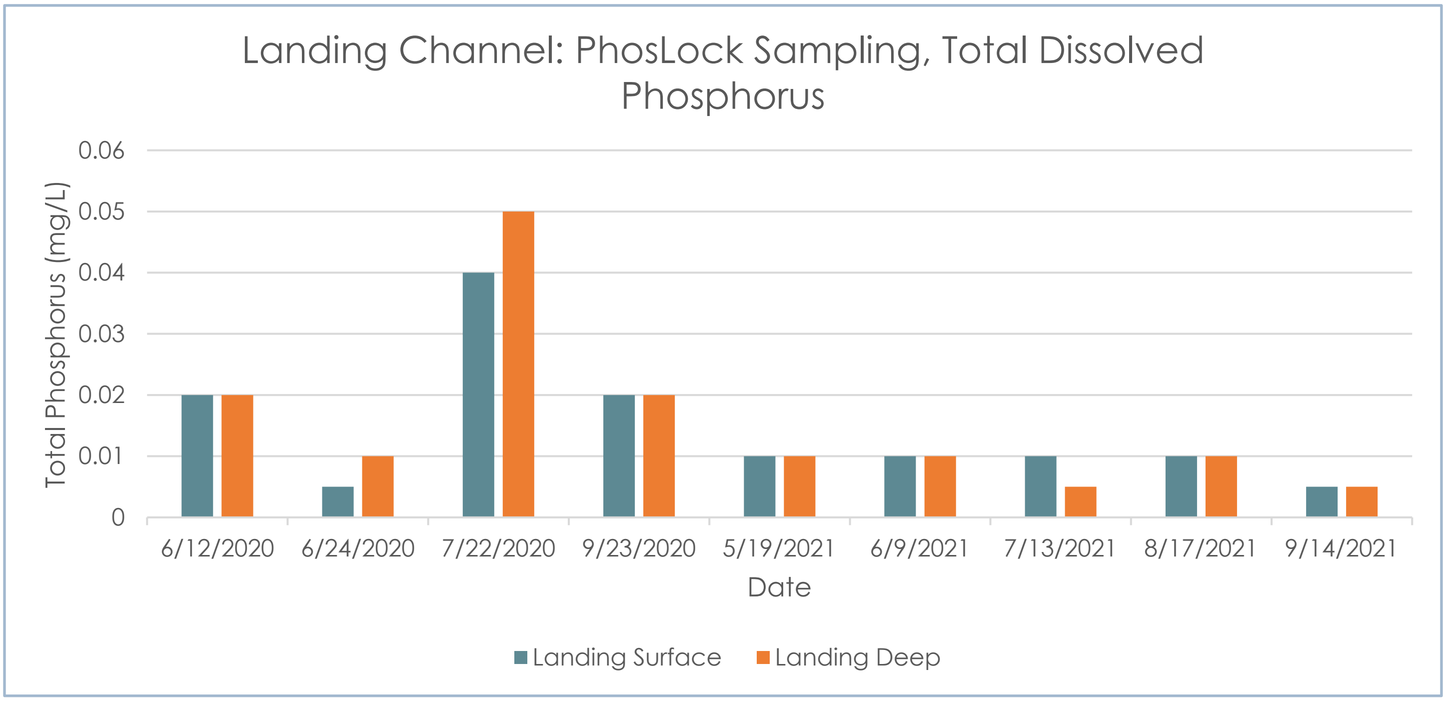


Figure 6.3: Pre- and post-treatment soluble reactive phosphorus concentrations in Landing Channel. Please note that no sample was taken from the control site on 24 June 2020.

CHLOROPHYLL *A*

Surface samples for the analysis of chlorophyll-*a* were collected during pre- and post-treatment events in Landing Channel; surface samples were collected at Station 5 (ST-5) during the baseline monitoring as a control site (Figure 6.4). Chlorophyll-*a* concentrations were relatively low during the pre-treatment monitoring event, with a concentration of 5.2 µg/L in Landing Channel. Following the PhosLock application, chlorophyll-*a* in Landing Channel decreased slightly to 4 µg/L. As temperatures rose and phosphorus concentrations increased lake wide during the July 2020 monitoring event, chlorophyll-*a* concentrations increased in Landing Channel and the control zone, with respective concentrations of 26 µg/L and 22 µg/L. Chlorophyll-*a* concentrations exceeded 25 µg/L in three other baseline monitoring stations during this monitoring event.

A similar trend was observed in chlorophyll-*a* concentrations in Landing Channel during the 2021 season, including low early season concentrations and a peak in July. Chlorophyll-*a* concentrations in Landing Channel and the control site remained below 7 µg/L in May and June before reaching a seasonal high of 30 µg/L and 16 µg/L, respectively. Similar to the 2020 monitoring, five other baseline monitoring sites had chlorophyll-*a* concentrations that met or exceeded 25 µg/L and three sites exceeded 45 µg/L. A review of the cyanobacteria data from the July 2021 monitoring event also indicates that cyanobacteria densities remained below 500 cells/mL during this time but a diversity of green algae and cryptomonads were present. Thus, the elevated chlorophyll-*a* concentrations were attributed to desirable algae and not those known to produce HABs (cyanobacteria).

The initial chlorophyll-*a* results during the first post-treatment monitoring event were positive, as chlorophyll-*a* concentrations remained relatively consistent; chlorophyll-*a* concentrations were already low during the pre-treatment monitoring event. However, chlorophyll-*a* concentrations increased in July as they did at most stations throughout the lake, including the control station. Increased water temperatures and a recent storm more than likely had an effect on chlorophyll-*a* concentrations during this time.

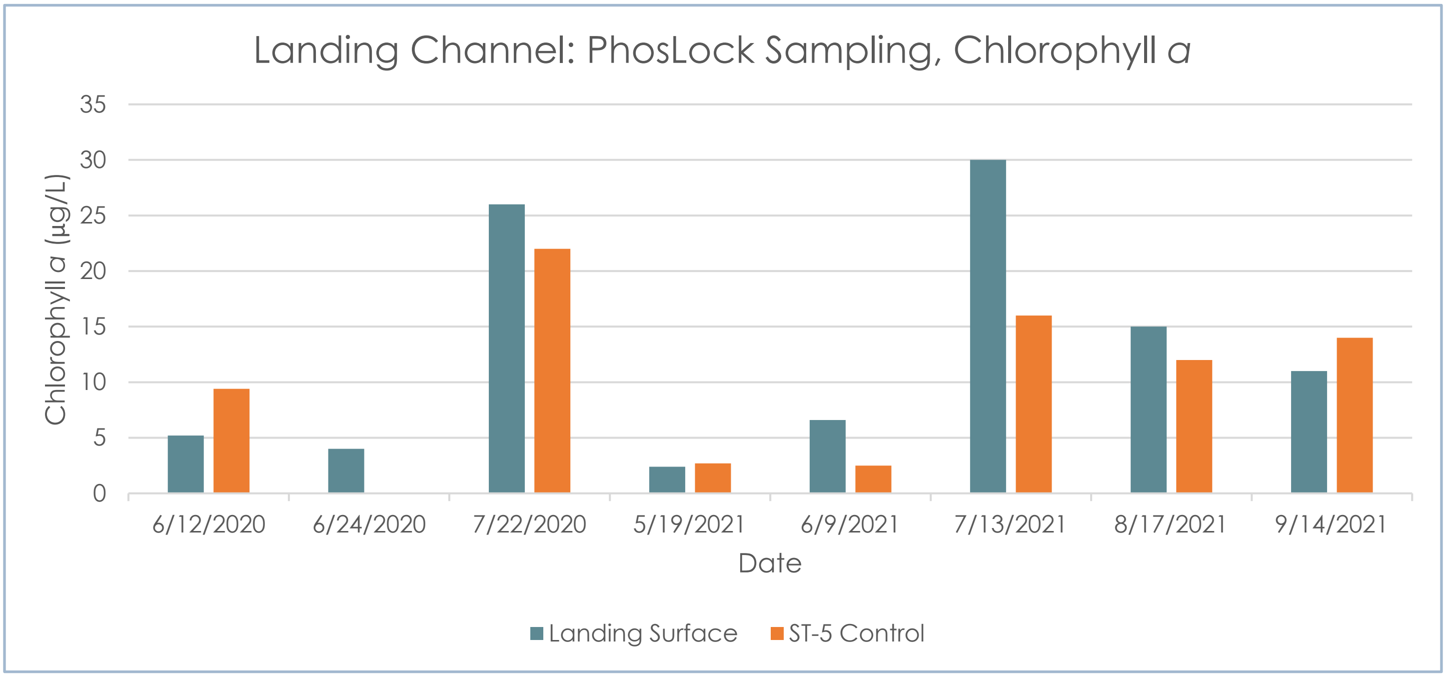


Figure 6.4: Pre- and post-treatment chlorophyll-*a* concentrations in Landing Channel. Please note that no sample was taken from the control site on 24 June 2020.

PHYCOCYANIN

Phycocyanin is a supplemental pigment that cyanobacteria almost exclusively produce. Thus, while chlorophyll-a can be a surrogate measure of total algae biomass, phycocyanin can be surrogate measure of cyanobacteria biomass. Phycocyanin were measured during the pre- and post-treatment event in Landing Channel; surface measurements were collected at Station 2 (ST-2) during the baseline monitoring as a control site (Figure 6.5). Phycocyanin concentrations were low during the pre-treatment monitoring event in Landing Channel and remained at a concentration of 3 µg/L during the initial post-treatment monitoring event on 24 June 2020. Similar to the other primary productivity metrics, phycocyanin concentrations increased to a concentration of 22 µg/L in Landing Channel during the July 2020 monitoring event, while phycocyanin concentrations at the control station were 11 µg/L. Finally, phycocyanin concentrations in Landing Channel were lower, at 10 µg/L, during the final monitoring event in September. It should be noted that based on some detailed monitoring of both phycocyanin and cyanobacteria cell counts throughout 2020, a phycocyanin reading of 12 ug/L typically represents a cyanobacteria cell count of 20,000 cells / mLs, which is the threshold when NJDEP's first HAB Alert Level of WATCH is reached.

Phycocyanin concentrations in Landing Channel did not exceed 4 µg/L in May and June 2021; phycocyanin concentrations were slightly higher at the control site during this time. Concentrations in Landing Channel increased in July and August 2021, with respective concentrations of 14 and 16 µg/L; control site concentrations remained at 10 µg/L during these events. However, a review of the cyanobacteria data from the July 2021 monitoring event also indicates that cyanobacteria densities remained below 500 cells/mL during this time, but *Cryptomonas* were present, which are a small group of algae also known to produce phycocyanin.

The initial phycocyanin results during the first post-treatment monitoring event were positive, as phycocyanin concentrations remained relatively consistent; phycocyanin concentrations were already low during the pre-treatment monitoring event. However, phycocyanin concentrations increased in July of both years as they did at most stations throughout the lake, including the control station. Similar to the results observed with chlorophyll-*a*, increased water temperatures and a recent storm resulted in the elevated phycocyanin concentrations in July of 2020. However, by September of both years the phycocyanin concentration was below 12 ug/L.

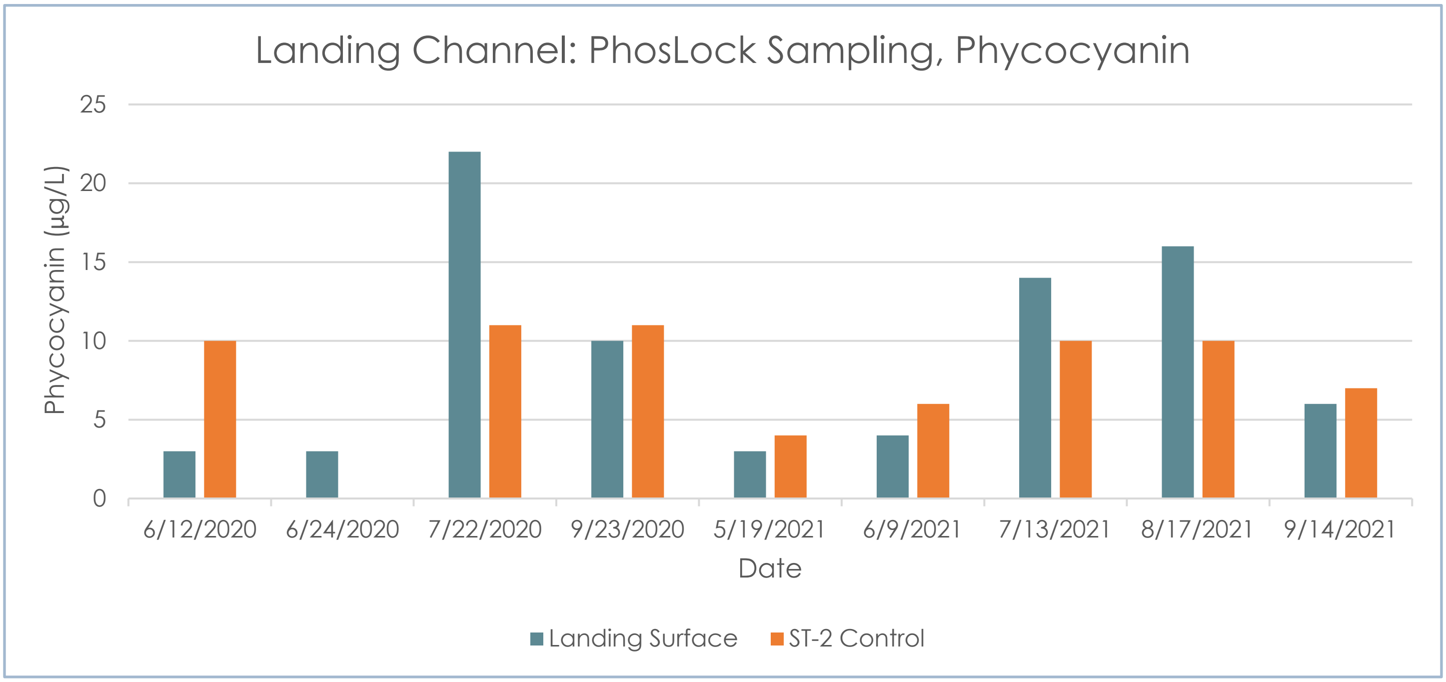


Figure 6.5: Pre- and post-treatment phycocyanin concentrations in Landing Channel. Please note that no sample was taken from the control site on 24 June 2020.

CYANOBACTERIA CELL COUNTS

Since cyanobacteria have the potential to produce dozens of various cyanotoxins, it would be extremely difficult to monitor for all of these compounds. Thus, various regulatory agencies including NJDEP as well as the World Health Organization, use cyanobacteria cell counts as a means of assessing the potential risk of cyanotoxins being present. For example, based on NJDEP's developed Recommended HAB Alert Levels, the first level of a Watch is reached when the cyanobacteria cell count is 20,000 cells/mL or greater. The raw data of the plankton cell counts, including cyanobacteria, are included in Appendix VI.

Prior to the conducting the PhosLock treatment, on 12 June 2020, total algal cell count and cyanobacteria cell count values were 7,889 and 5,969 cells/mL, respectively and cyanobacteria accounted for 76% of the total count. In contrast after the treatment, 24 June 2020, total algal cell count and cyanobacteria cell count values were 5,266 and 1,624 cells/mL, respectively and cyanobacteria accounted for 31% of the total count. On 22 July 2020, total algal cell count and cyanobacteria cell count values increased to 75,085 cells/mL and 63,230 cells/mL, respectively and cyanobacteria accounted for 84% of the total count. By September, total algal cell count and cyanobacteria cell count values were 32,216 and 26,214 cells/mL, respectively and cyanobacteria accounted for 81% of the total count. While the cyanobacteria cell counts were high in July and September, both samples had cyanobacteria cell counts at the Watch level which is the lowest Alert Level.

Cyanobacteria and total algal cell counts remained low from May through July 2021, with cyanobacteria representing 52%, 45%, and 8% of the total count during May, June, and July, respectively (Figure 6.6). Cyanobacteria cell counts remained below 4,000 cells/mL during this time. Total algal and cyanobacteria cell counts increased in August and September, with cyanobacteria representing 75% and 89% of the total algal cell counts during this time. Cyanobacteria cell counts in August and September were 22,842 cells/mL and 25,268 cells/mL, respectively. As such, cyanobacteria cell counts never exceeded the NJDEP Watch level which is the lowest Alert Level.

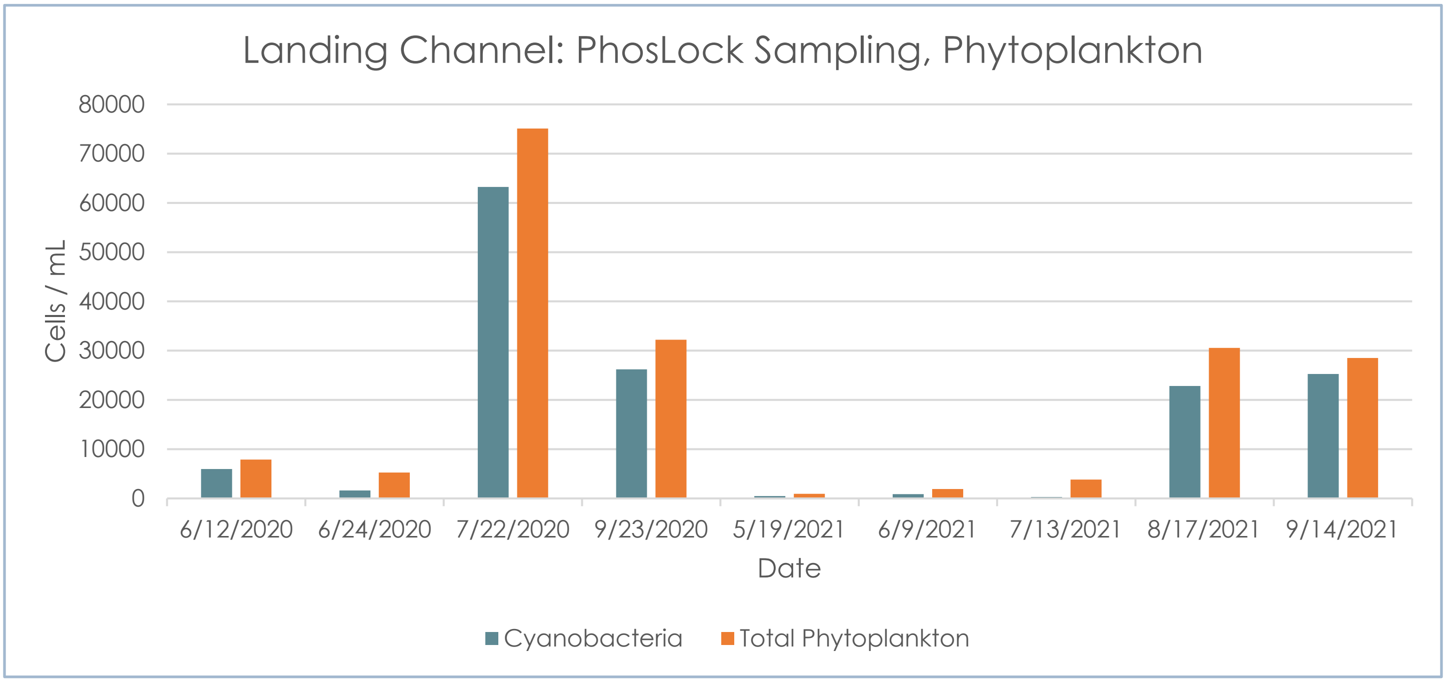


Figure 6.6: Total phytoplankton and cyanobacteria cell counts in Landing Channel.

WATER CLARITY

Water clarity was measured with a Secchi disk during the pre- and post-treatment event in Landing Channel and the control zone (Figure 6.7). Water clarity in Landing Channel increased following the PhosLock application, from a pre-treatment Secchi depth of 1.5 meters to a post-treatment depth of 1.9 meters; water clarity at the control station was 1.5 meters during this post-treatment monitoring event. Water clarity decreased at both stations during the July 2020 sampling event, with respective depths of 1.0 meters and 1.1 meters in Landing Channel and the control zone. These decreases in water clarity followed lake-wide increases in productivity. Water clarity was similar between both stations during the final monitoring event of 2020 in September, with respective depths of 1.1 meters and 1.0 meters in Landing Channel and the control zone.

Water clarity followed a similar trend over the course of the 2021 season, with lower Secchi depths in Landing Channel and the control station in July and August. While Figure 6.7 indicates that water clarity was greater at the control station relative to Landing Channel in May and June 2021, Secchi depths in Landing Channel were clear to the lake bottom at 1.7 meters. Secchi depths were consistent across both stations for the remainder of the season.

The initial post-treatment monitoring results indicate that the PhosLock application led to an increase in water clarity, as Secchi depth in the treatment zone increased from 1.5 meters to 1.9 meters, while the control zone increased from 1.4 meters to 1.5 meters. During both years water clarity at both stations decreased during the July monitoring event as water temperatures, nutrient concentrations, and primary productivity increased throughout the lake. However, the targeted Secchi depth for Lake Hopatcong is 1.0 meters or greater. Secchi depths less than 1.0 meter are generally perceived by the layperson to represent "dirty" or "scummy" water. Thus, the Secchi depth remained accepted in Landing Channel across all post-treatment monitoring events.

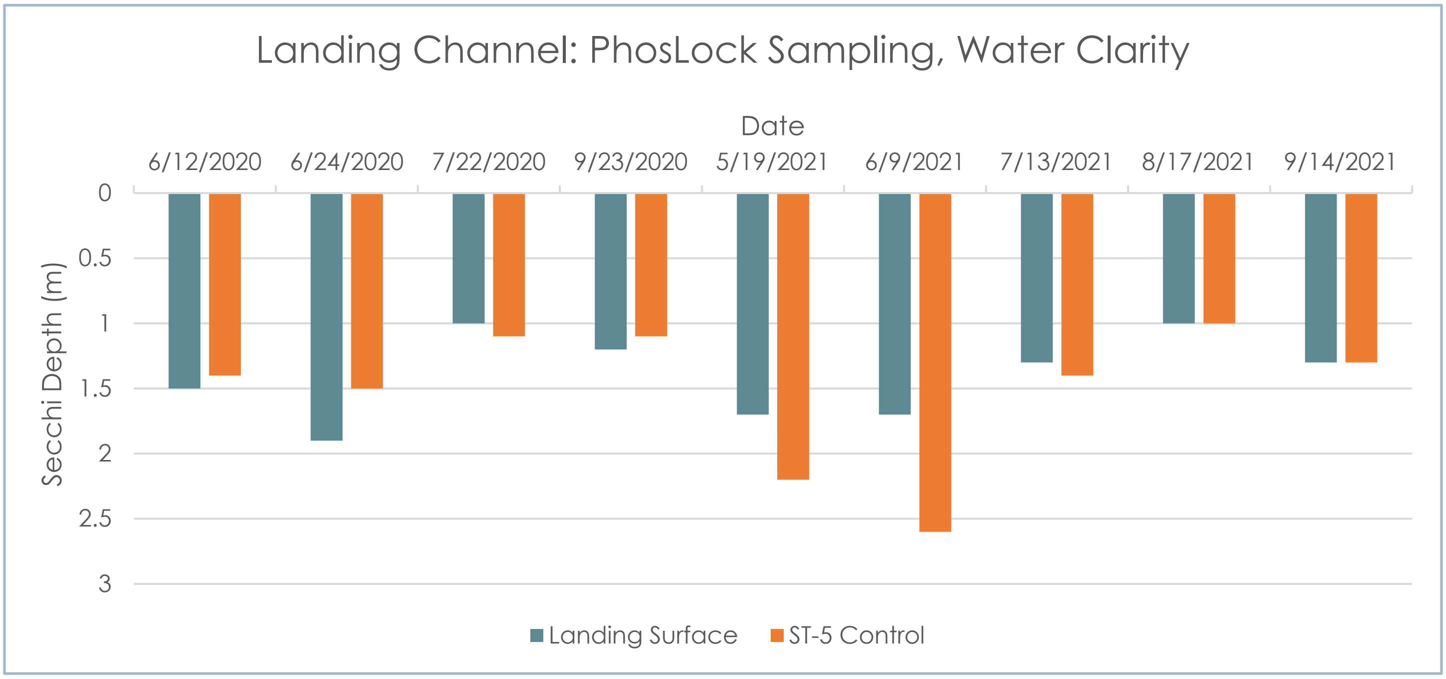


Figure 6.7: Pre- and post-treatment Secchi depths in Landing Channel and the control site.

SUMMARY

The initial results one week after the PhosLock treatment were positive in Landing Channel, as all metrics responded in a positive manner – phosphorus concentrations decreased, phycocyanin and chlorophyll-*a* concentrations decreased, and water clarity increased by almost half a meter. As the seasons progressed and water temperatures and nutrient and primary productivity metrics increased lake wide, most phosphorus species as well as primary productivity metrics also increased in Landing Channel. However, it is a very positive sign that SRP concentrations in both the surface and deep-water of Landing Channel remained non-detectable while total phosphorus concentrations increased in July. This indicates that SRP was likely not being released by a significant amount in the treated sediment of Landing Channel. SRP and TDP also remained extremely low and were often non-detectable across the entire 2021 season, indicating that the PhosLock application was effective in reducing the release of dissolved phosphorus from the sediment into the second year of the study. Most importantly, no CyanoHABs or cell counts above the NJDEP Watch level were measured across all post-treatment events. The overall results from this study indicate the following:

> The initial TP results during the first post-treatment monitoring event were positive, as surface and deep TP concentrations in Landing Channel decreased from pre-monitoring concentrations of 0.03 mg/L and 0.04 mg/L to post treatment concentrations of 0.02 mg/L at both depths. However, TP concentrations in Landing channel increased during the following monitoring event in July 2020 while control zone TP concentrations remained at 0.03 mg/L; TP concentrations increased lake wide during this time due to a mid-summer storm event. TP then declined by September 2020. The 2021 TP results continued to be exceedingly positive as surface concentrations never exceeded 0.03 mg/L and deep concentrations only exceeded 0.03 mg/L during one event in July 2021. **The mean of post-treatment surface TP concentration across the entire study period was 0.03 mg/L, which is right on the mark of the established 0.03 mg/L goal, as per the TMDL.**
>
> Overall, it appears as though the PhosLock application had a positive effect on SRP concentrations in Landing Channel, as surface water concentrations remained non-detectable through July 2020 while

deep-water concentrations remained non-detectable through the end of the season. Additionally, as TP concentrations increased in both the surface and deep-water of Landing Channel during the July 2020 monitoring event, SRP concentrations remained non-detectable. All SRP samples, including surface and deep Landing Channel samples, were below the lab detection limit of 0.002 mg/L throughout the 2021 season with the exception of the surface sample in Landing Channel on 19 May 2021, with at a concentration of 0.002 mg/L.

The initial TDP results during the first post-treatment monitoring event were positive, as surface and deep TDP concentrations in Landing Channel decreased from a pre-monitoring concentration of 0.02 mg/L to post treatment concentrations of 0.005 mg/L and 0.01 mg/L, respectively. However, similar to TP concentrations, TDP concentrations in Landing channel increased during the following monitoring event in July 2020. TDP concentrations never exceeded 0.01 mg/L during the 2021 season, indicating that the majority of phosphorus was present in the particulate form rather than the more readily-available dissolved form.

The initial chlorophyll-*a* and phycocyanin results during the first post-treatment monitoring event were positive, as concentrations remained relatively consistent; chlorophyll-*a* and phycocyanin concentrations were already low during the pre-treatment monitoring event. However, these concentrations increased in July of both years as they did at most stations throughout the lake, including the control station.

Cyanobacteria cell counts declined immediately after the PhosLock treatment. While the cell count increased in Landing Channel later in the season of both years, no CyanoHABs or cell counts above the NJDEP Watch level were measured across all post-treatment events.

The initial post-treatment monitoring results indicate that the PhosLock application led to an increase in water clarity, as Secchi depth in the treatment zone increased from 1.5 meters to 1.9 meters, while the control zone increased from 1.4 meters to 1.5 meters. Water clarity at both stations decreased during the July monitoring event during both years as water temperatures, nutrient concentrations, and primary productivity increased throughout the lake. However, water clarity continued to be at or near the bottom in the treatment area. Not surprising, the increase in clarity led to an increase in the amount of observed rooted, submerged aquatic vegetation in Landing Channel.

7.0 OBJECTIVE 5: TREATMNENT AND EVALUATION OF STRONG OXIDIZER FOR HAB CONTROL

PROJECT SUMMARY

One of the most frequently used group of algicides to control cyanobacteria and HABs are copper-based products. While the copper does kill algae there are a number of undesirable ecological issues such as the accumulation of copper in sediments, lysing of algal cells and releasing dissolved cyanotoxins and taste & odor compounds into the water, impacts on nontarget organisms such as zooplankton and young-of-the-year fish, and the increased tolerance to such products by algae. Thus, the LHC was interested in conducting one treatment of GreenClean (a strong oxidizer that uses a form of hydrogen peroxide) at a beach site at Lake Hopatcong and critically evaluate its effectiveness as a more ecologically friendly replacement to copper-based algaecides.

Objective 5 involved a GreenClean treatment at the nearshore, beach site of Capp Beach to determine if this product can be used as an effective alternative to copper-based algaecides. Pre- and post-treatment monitoring, before and after the treatment, were conducted as part of the existing baseline monitoring for Lake Hopatcong.

SCHEDULE OF EVENTS

After a review of the baseline monitoring data in Lake Hopatcong, the first GreenClean treatment was scheduled for mid-August. Princeton Hydro's certified applicators filed for and obtained the permit for the treatment. Pre-treatment monitoring was conducted on 12 August 2020. The GreenClean treatment was conducted on 13 August 2020. Finally, the post-treatment monitoring event was conducted on 17 August 2020. A full breakdown of the pre- and post-treatment monitoring schedule, including the date of the treatment, is provided in Table 7.1 below.

Table 7.1: CAPP Beach: Treatment and monitoring schedule.

Capp Beach GreenClean: Treatment Schedule	
Date	**Activity**
8/12/2020	Pre-treatment monitoring event
8/13/2020	GreenClean application
8/17/2020	Post-treatment monitoring event

The treatment was conducted by Princeton Hydro. The treatment was conducted at the prescribed labelled rate of 12.8 gallons/acre-ft, focusing on the upper 3 feet of the water column.

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and objectively assess the results of the water quality data collected in Lake Hopatcong relative to the success of the GreenClean treatment in controlling the development of HABs. This section will focus primarily on the parameters that are most closely associated with the development of HABs, such as chlorophyll-*a* concentrations, cyanobacteria cell counts, phycocyanin concentrations, and water clarity. All *in-situ* and discrete data collected as part of the GreenClean monitoring can be found in full in Appendix VII.

PHYCOCYANIN

Surface phycocyanin concentrations were monitored via multi-probe pre- and post-treatment in the Capp Beach treatment zone. Phycocyanin concentrations increased from a pre-treatment concentration of 23 µg/L to a post-treatment concentration of 31 µg/L (Figure 7.1). However, the post-treatment sampling event occurred four (4) days post-treatment and may have been influenced by the site location. Capp Beach is located along a relatively open part of Lake Hopatcong, and, as a result, is subject to significant mixing and water movement. Because of the significant mixing that likely occurs around Capp Beach, results are likely to be heavily influenced by non-treated lake water that mixes with the water in the treatment zone, especially four (4) days after the treatment. It does not appear as though the GreenClean treatment had a significant effect on phycocyanin concentrations in the treatment zone.

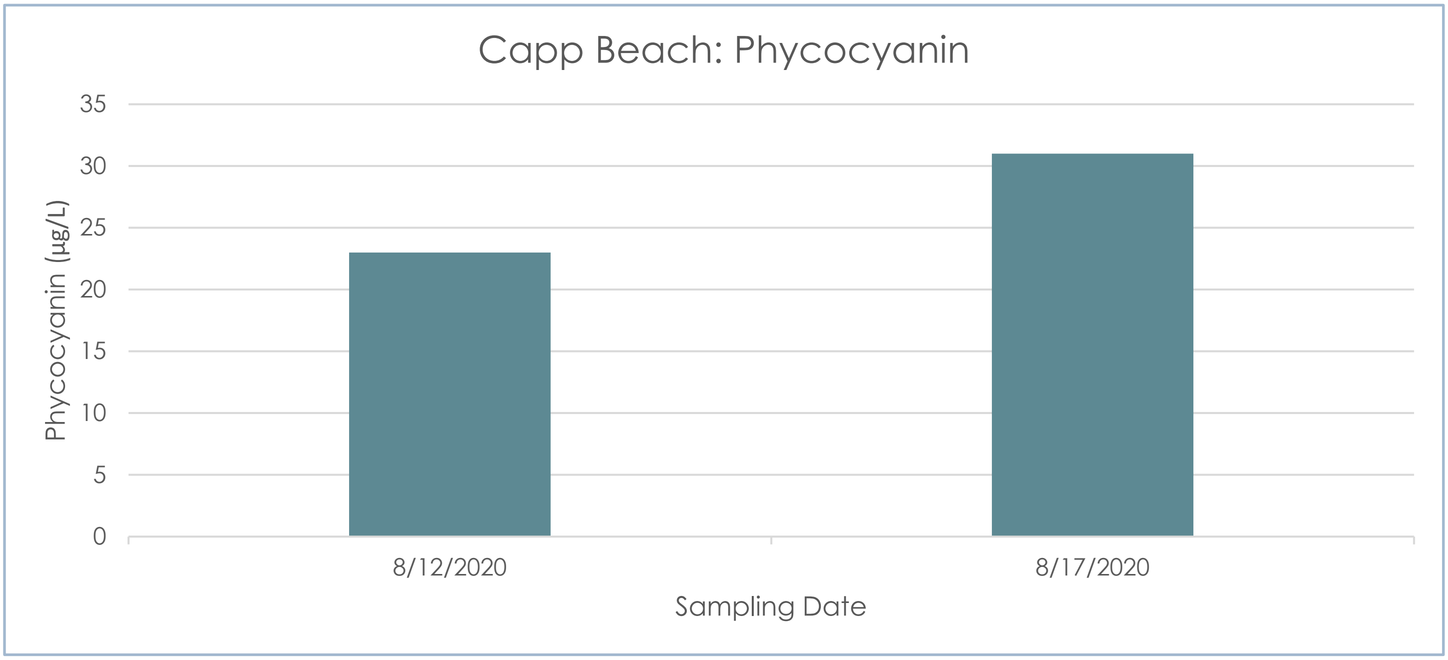


Figure 7.1: Pre- and post-treatment phycocyanin concentrations at Capp Beach.

CHLOROPHYLL *A*

Surface chlorophyll-*a* concentrations were monitored via multi-probe pre- and post-treatment in the Capp Beach treatment zone. Chlorophyll-*a* concentrations increased from a pre-treatment concentration of 20 µg/L to a post-treatment concentration of 26 µg/L (Figure 7.2). As mentioned above, the post-treatment results were likely influenced by the site location and the significant mixing that would have occurred post-treatment.

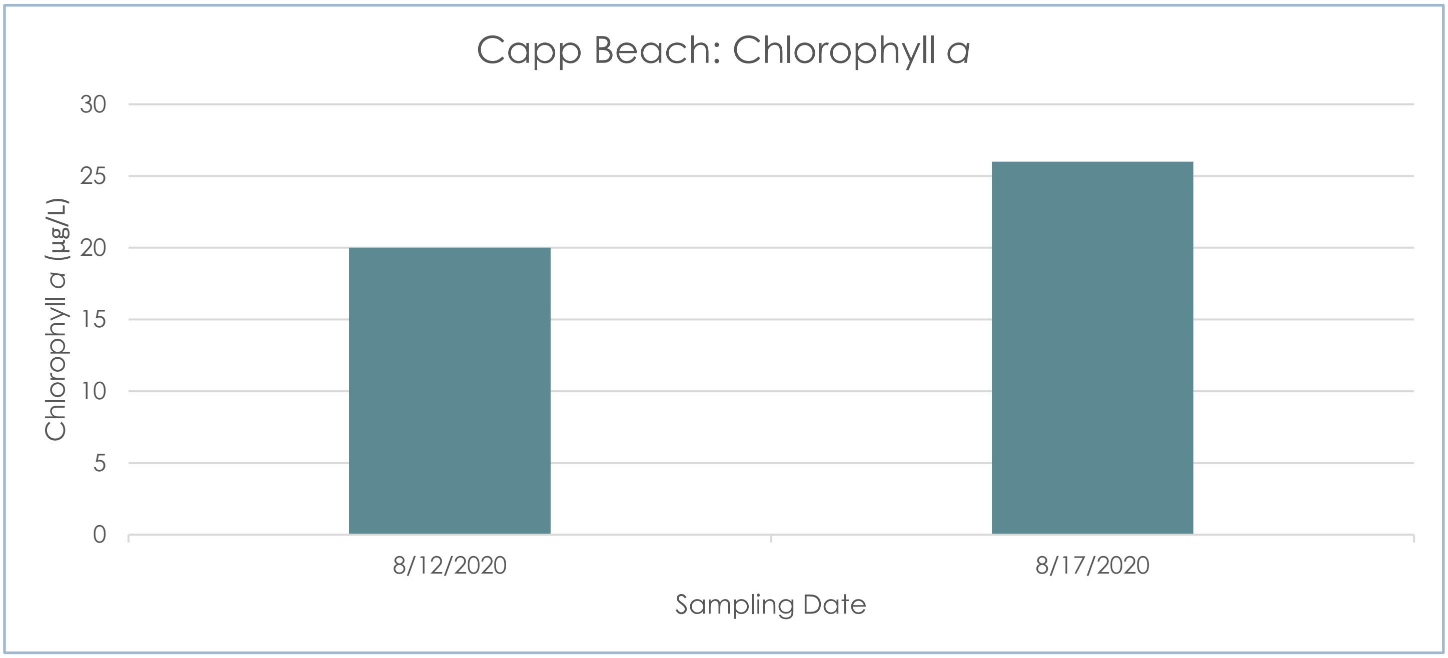


Figure 7.2: Pre- and post-treatment chlorophyll-*a* concentrations at Capp Beach.

WATER CLARITY

Water clarity was measured with a Secchi disk during the pre- and post-treatment events in the Capp Beach treatment zone. Water clarity increased slightly from a pre-treatment Secchi depth of 0.8 meters to a post-treatment depth of 1.1 meters (Figure 7.3).

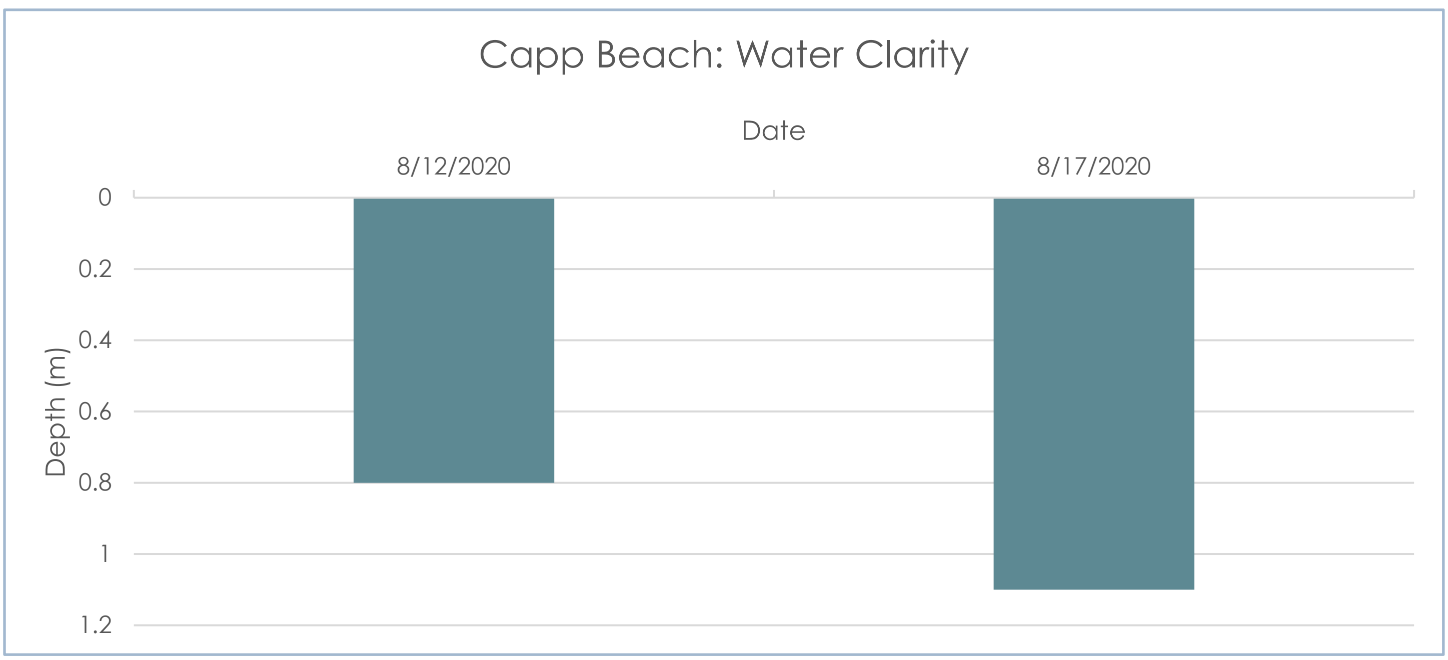


Figure 7.3: Pre- and post-treatment Secchi depths at Capp Beach.

SUMMARY

The results of the GreenClean treatment were variable by parameter but remained inconclusive overall due to mixed results. The small sample size of only one (1) pre-treatment and one (1) post-treatment monitoring event limits the capability to perform meaningful statistical analyses. Additionally, due to the small size of the treatment zone and the significant mixing that occurs due to its position on the main body of the lake, the GreenClean treatment did not appear to be successful in lowering phycocyanin or chlorophyll-*a* concentrations.

While the results of the GreenClean treatment at Capp Beach was somewhat inconclusive, the treatment appeared to be far more effective at Ashley Cove. Based on these observations it appears that GreenClean may be more appropriate and more cost effective for areas that are not prone to high amounts of flushing or water movement. Thus, if GreenClean is considered for any near-shore algal treatment, the local flushing and mixing with the rest of the waterbody should be taken into account. Such treatments would tend to be more effective in the level of control and duration in more isolated, near-shore areas.

8.0 OBJECTIVE 6: USE OF BIOCHAR TO PREVENT HABS IN NEARSHORE INLET OR BEACH AREAS

PROJECT SUMMARY

Biochar was assessed for dissolved phosphorus removal from the Aqua-Filters (Objective 2). As previously stated, Biochar is a woody material that has a high affinity for a variety of pollutants including phosphorus. Thus, another possible way this material can be used is to place it into floatation balls, sleeves, or cages and tether them along streams, in stormwater ponds, or where an inlet enters the lake. Such Biochar implementation strategies have been shown to remove dissolved phosphorus directly out of the nearshore waters, contributing toward limiting algal growth. Additionally, the relatively low cost of the Biochar and its re-use as a form of mulch make it a particularly attractive means of contributing toward the removal of in-lake phosphorus.

Objective 6 involved the installation of a series of "Biochar socks" or sleeves in drainage streams, stormwater ponds, and nearshore locations of Lake Hopatcong where stormwater pipes discharge to determine if they are a cost-effective means of reducing available phosphorus and contribute towards preventing HABs. Post-installation monitoring was conducted immediately upgradient and down gradient of the structures to determine if there is a significant difference in the phosphorus species immediately up and down gradient of the material. Prior to the implementing this project, a feasibility study was conducted to identify potential locations for the installation of the Biochar sleeves. This study report can be found in Appendix VIII.

SCHEDULE OF EVENTS

2020

Based on the findings of the feasibility study (Appendix VIII), Biochar sleeves were installed at different sites throughout the watershed in July of 2020. Biochar socks were installed at the following locations and dates:

Lorettacong Drive (stream) – 2 July 2020
Yacht Club (stream) – 2 July 2020
Edith M. Decker Elementary School (stream) – 2 July 2020
Lakeside Blvd (stream) – 2 July 2020
Memorial Pond – 31 July 2020
Duck Pond – 31 July 2020

The post-installation monitoring events occurred on 10 July and 29 October 2020.

2021

Biochar socks were replaced at some of the original sites from 2021 and placed in additional sites throughout the watershed on 23 April 2021. In order to assess the effectiveness of Biochar in various locations and structures, the stream sites were not sampled during stormwater events in 2021 but the two Manufactured Treatment Devices (MTDs) were sampled. The sites sampled in 2021 include:

Yacht Club (MTD)
East Shore Road (MTD)
Memorial Pond
Duck Pond

The post-installation monitoring events occurred on 4 June and 1 July.

MONITORING RESULTS AND DATA ANALYSIS

The following section will discuss and objectively assess the results of the stormwater sampling data collected immediately upgradient and down gradient of the structures to determine if there is a significant difference in the phosphorus species immediately up and down gradient of the material. All discrete data collected as part of the Biochar monitoring can be found in full in Appendix IX. Please note that the data from the sites that were monitored in 2020 and 2021 are displayed on separate figures since some site locations differed.

It is important to note that the stormwater sampling of the MTDs in 2021 was difficult for a number of logistical reasons that likely influenced the phosphorus concentrations. First, the close proximity of the outflow structures to Lake Hopatcong resulted in backwater influence, especially during storm events when the lake water levels were higher. This was particularly difficult at the East Shore MTD site, in which the only viable location to sample was the outflow pipe that was in direct contact with the lake and had the obvious influence of backwater. Another potential influence on downstream phosphorus concentrations is the mixing of groundwater, as groundwater has the potential to seep into the system at the pipe joints since the water table is so high in close proximity to the lake. The majority of the neighborhoods in the Lake Hopatcong watershed are on septic systems which may influence phosphorus concentrations in the downgradient samples. All upgradient sampling was conducted from surface streams before they discharged into subsurface pipes where mixing with groundwater may have occurred.

TOTAL PHOSPHORUS

Stormwater samples for the analysis of TP were collected immediately upgradient and down gradient of all Biochar structures (Figure 8.1). TP reductions downgradient of all Biochar structures was substantial at all sites besides Edith Decker during the first stormwater sampling event on 10 July 2020, 8 days after the Biochar was installed. Note that the Biochar in Memorial Pond and Duck Pond was not installed until 31 July 2020. TP concentrations during this first monitoring event were reduced by 44% at Lorettacong Drive, 55% at the Yacht club, and 21% at the Lakeside Blvd. site. However, TP concentrations increased by over 200% at the Edith M Decker site. Please note that there was an additional pipe discharging into the sampling area at Edith Decker that was not being filtered by the Biochar and likely had an influence on the extremely elevated downstream TP samples; the Biochar in this site was later adjusted.

The second stormwater sampling event occurred on 29 October 2020, approximately three (3) months after the initial Biochar was installed in the streams and two (2) months after the Biochar was installed in the two ponds. TP reductions downgradient of the four (4) stream sites was minimal during this event, with concentrations decreasing at only the Edith M Decker site by 8 %; TP concentrations were uniform upstream and downstream of the three (3) other stream sites. However, the TP reductions downgradient of the Biochar that was placed near the outlet of two ponds was substantial. TP concentrations at Memorial Pond and Duck Pond were reduced by 67% and 81%, respectively.

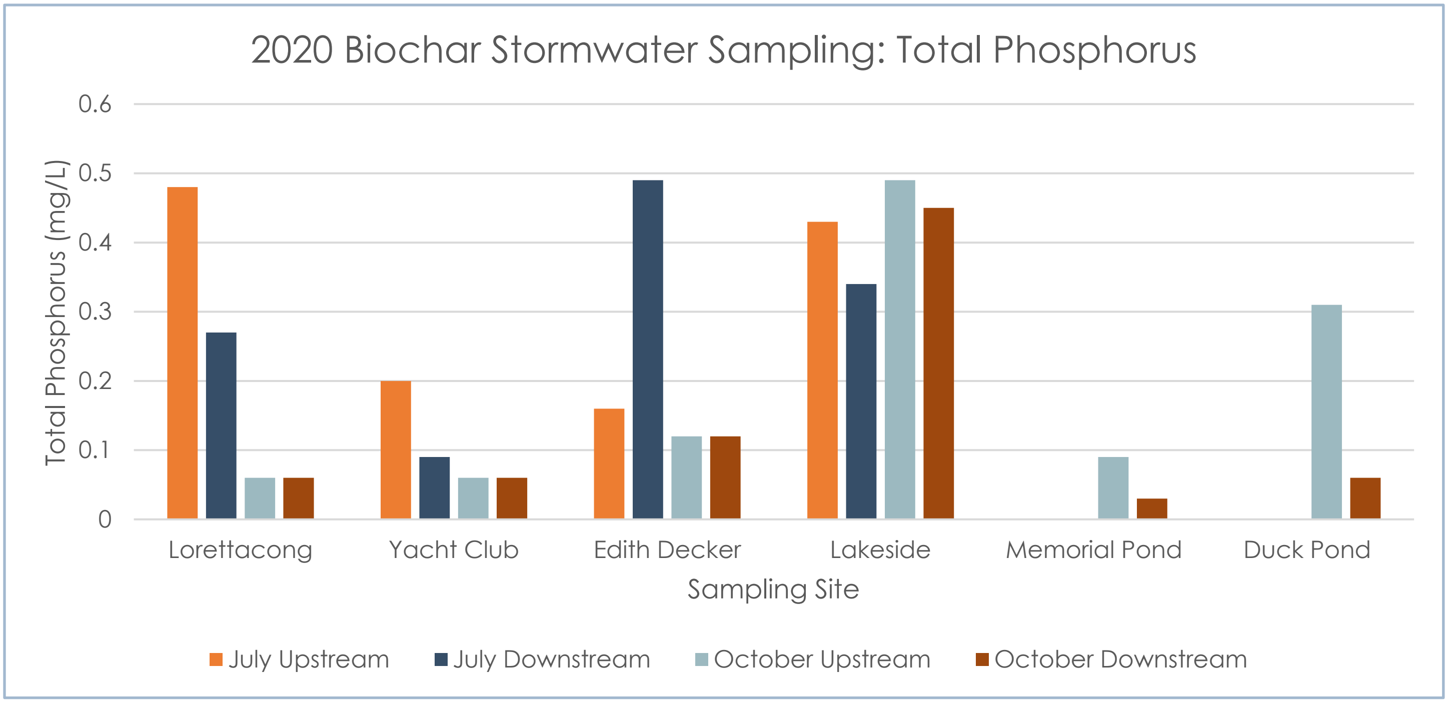


Figure 8.1: Upgradient and down gradient total phosphorus concentrations from two separate sampling events; 10 July 2020 and 29 October 2020.

Stormwater samples for the analysis of TP were collected immediately upgradient and downgradient of four structures with Biochar in 2021, including two ponds and two MTDs (Figure 8.2). The removal rates throughout the season were variable by site and the downstream samples in the MTDs sometimes had higher concentrations; however, this is likely due to mixing with groundwater, which was potentially influenced by septic leachate, and/or backwater influence from Lake Hopatcong. The highest TP removal rate in a pond was 60% in Duck Pond during the second monitoring event in July while the lowest TP removal rate in a pond was 0% in Memorial Pond on 4 June. The highest TP removal rate in an MTD was 50% at the East Shore MTD in July while a 33% increase in TP concentrations was measured downstream of the Yacht Club MTD in June; this was likely influenced by backwater from the lake and/or groundwater influence.

TP results indicate that Biochar placed in streams can provide TP removal rates between 20% – 55%, Biochar placed in ponds can provide TP removal rates between 0% - 81%, and Biochar placed in MTDs can provide TP removal rates between 0% - 50%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates. While some of these removal rates are substantial, it appears as though Biochar provides higher removal rates when placed in ponds due to the extended contact time relative to flowing water in streams. Additionally, it appears as though the TP removal efficiencies dropped well below 10% in the stream sites three months post-installation, indicating that they should be replaced every 2 – 3 months.

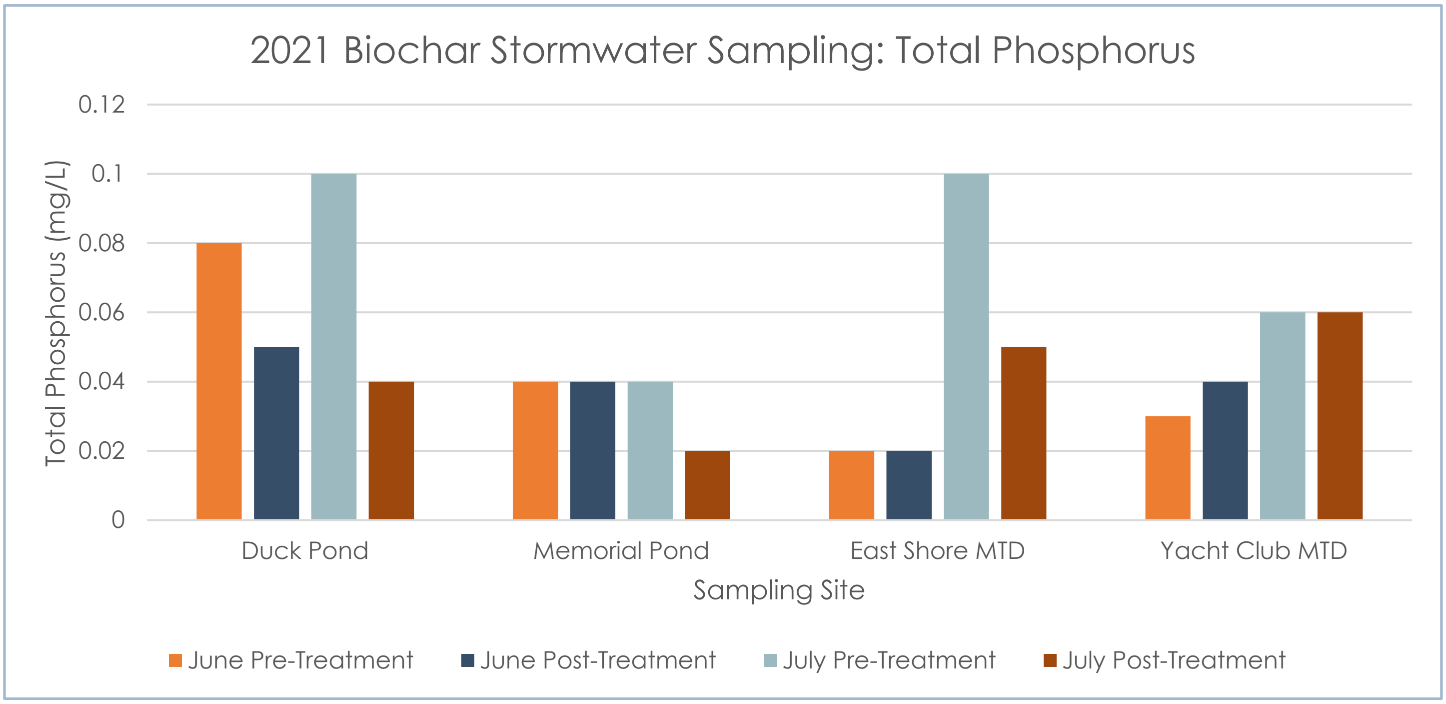


Figure 8.2: Upgradient and downgradient total phosphorus concentrations from two separate sampling events; 4 June 2021 and 1 July 2021.

SOLUBLE REACTIVE PHOSPHORUS

Stormwater samples for the analysis of SRP were collected immediately upgradient and down gradient of all Biochar structures (Figure 8.3). SRP concentrations were reduced at all sites, by varying degrees, during the first stormwater sampling event on 10 July 2020, 8 days after the Biochar was installed. Note that the Biochar in Memorial Pond and Duck Pond was not installed until 31 July 2020. SRP concentrations during the first event were reduced by 24% at Lorettacong Drive, 96% at the Yacht Club, 16% at Edith M Decker, and 2% at Lakeside Blvd.

The second stormwater sampling event occurred on 29 October 2020, approximately three (3) months after the initial Biochar was installed in the streams and two (2) months after the Biochar was installed in the two ponds. SRP reductions downgradient of the four (4) stream sites were minimal during this event, with concentrations decreasing at Lorettacong Drive by 31%. However, the SRP reductions downgradient of the Biochar that was placed near the outlet of two ponds was substantial. SRP concentrations at Memorial Pond and Duck Pond were reduced by 76% and 97%, respectively.

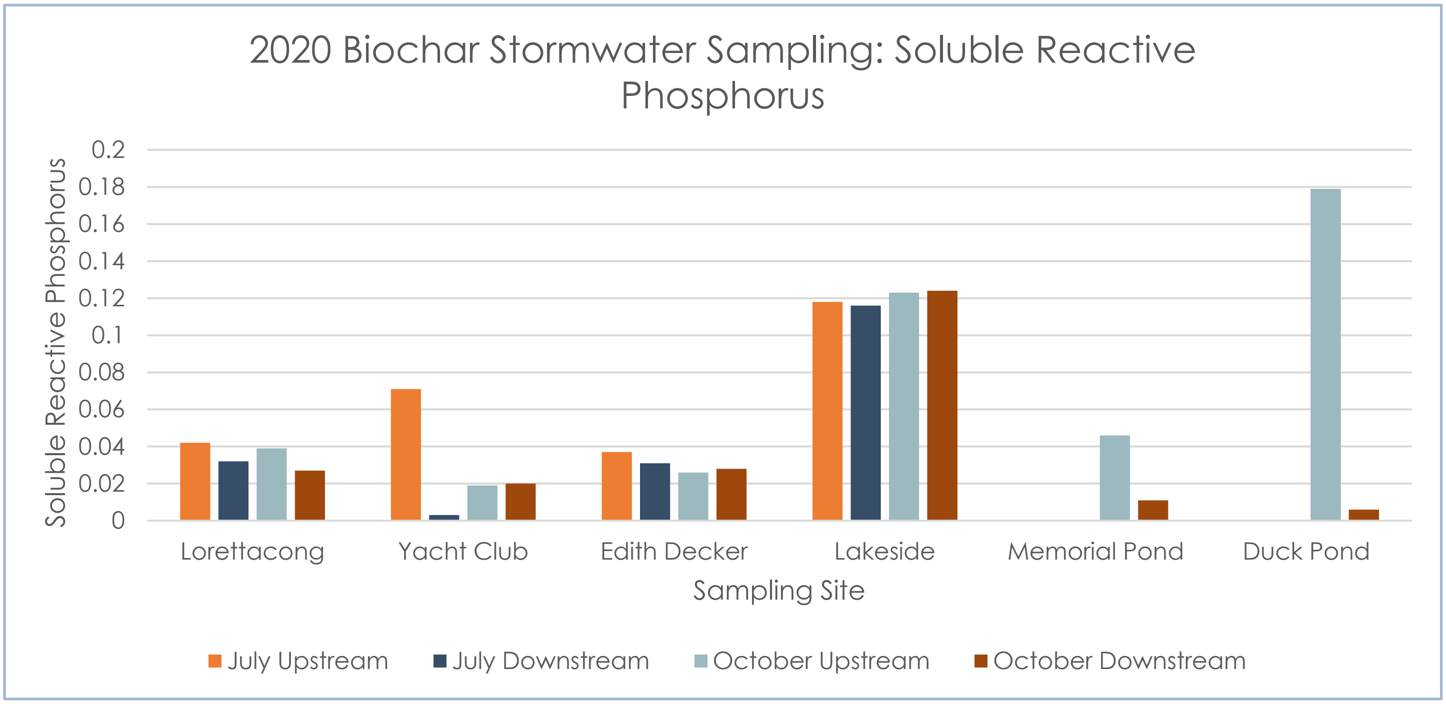


Figure 8.3: Upgradient and down gradient soluble reactive phosphorus concentrations from two separate sampling events; 10 July 2020 and 29 October 2020.

Stormwater samples for the analysis of SRP were collected immediately upgradient and downgradient of four structures with Biochar in 2021, including two ponds and two MTDs (Figure 8.4). The highest SRP removal rate in a pond was 93% in Duck Pond during the second monitoring event in July while the lowest SRP removal rate in a pond was 25% in Memorial Pond on 4 June. The highest SRP removal rate in an MTD was 5% at the East Shore MTD in July while a 43% increase in SRP concentrations was measured downstream of the Yacht Club MTD in June; this was likely influenced by backwater from the lake and/or groundwater influence.

SRP results indicate that Biochar placed in streams can provide SRP removal rates between 2% – 96%, Biochar placed in ponds can provide SRP removal rates between 76% - 97%, and Biochar placed in MTDs can provide SRP removal rates between 0% - 5%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates. Similar to the TP removal rates, it appears as though Biochar provides higher removal rates when placed in ponds due to the extended contact time relative to flowing water in streams. Additionally, it appears as though the SRP removal efficiencies dropped substantially in the stream sites three months post-installation, indicating that they should be replaced every 2 – 3 months.

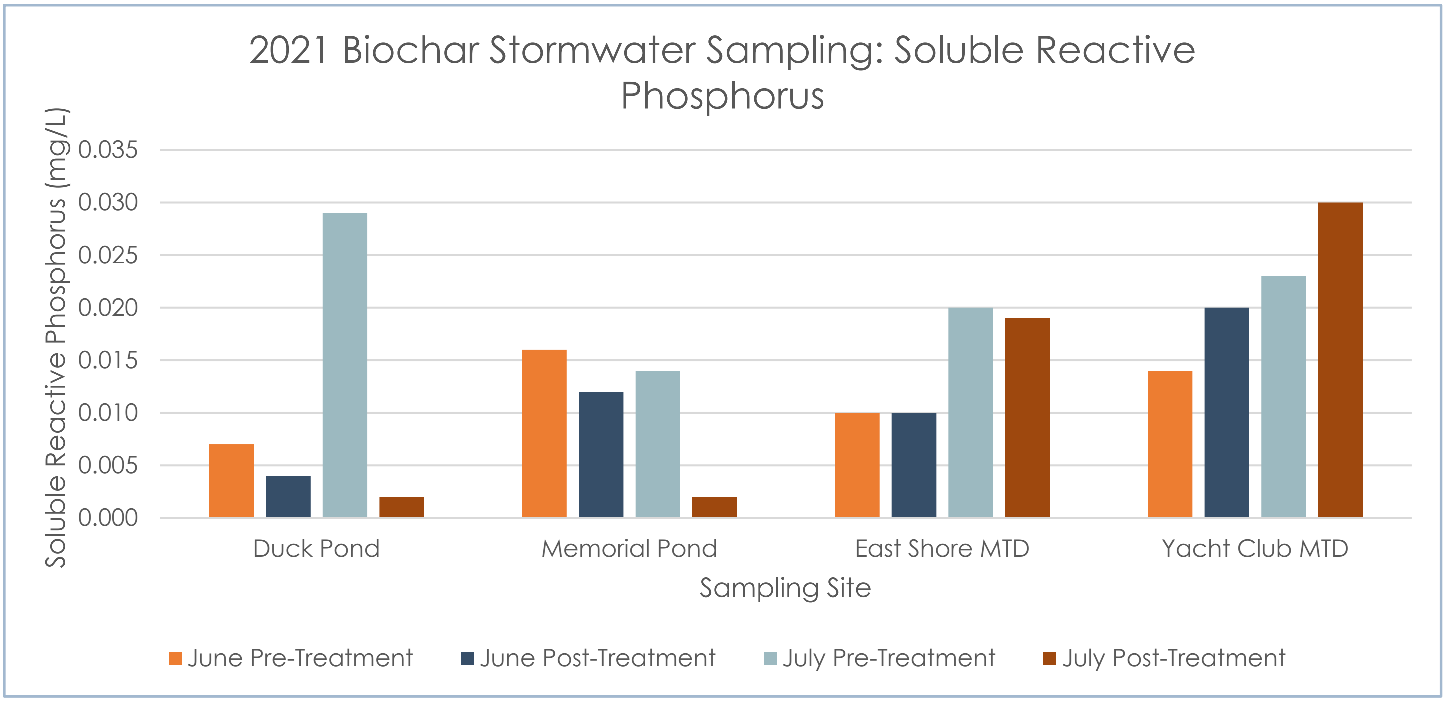


Figure 8.4: Upgradient and downgradient soluble reactive phosphorus concentrations from two separate sampling events; 4 June 2021 and 1 July 2021.

TOTAL DISSOLVED PHOSPHORUS

Stormwater samples for the analysis of TDP were collected immediately upgradient and down gradient of all Biochar structures (Figure 8.5). TDP were variable by site during the first stormwater sampling event on 10 July 2020, 8 days after the Biochar was installed. Note that the Biochar in Memorial Pond and Duck Pond was not installed until 31 July 2020. TDP concentrations during the first event were reduced by 73% at the Yacht Club and 75% at Edith M Decker; removal rates were 0% at the other two sites during this time.

The second stormwater sampling event occurred on 29 October 2020, approximately three (3) months after the initial Biochar was installed in the streams and two (2) months after the Biochar was installed in the two ponds. TDP reductions downgradient of the four (4) stream sites were minimal during this event, with concentrations decreasing at only Lorettacong Drive and Lakeside Blvd. by 25% and 7%, respectively. However, the TDP reductions downgradient of the Biochar that was placed near the outlet of two ponds was substantial. TDP concentrations at Memorial Pond and Duck Pond were reduced by 60% and 94%, respectively.

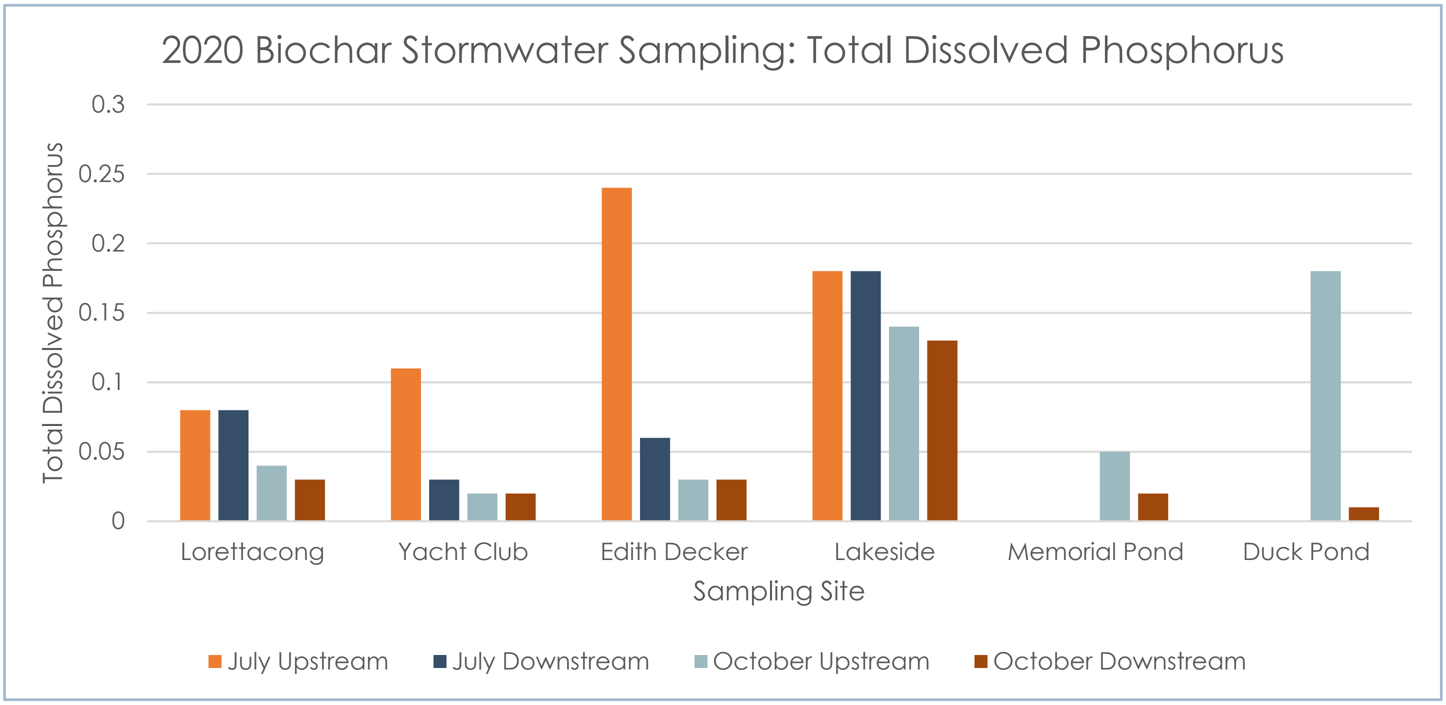


Figure 8.5: Upgradient and down gradient total dissolved phosphorus concentrations from two separate sampling events; 10 July 2020 and 29 October 2020.

Stormwater samples for the analysis of TDP were collected immediately upgradient and downgradient of four structures with Biochar in 2021, including two ponds and two MTDs (Figure 8.6). The highest TDP removal rate in a pond was 75% in Memorial Pond during the second monitoring event in July while the lowest TDP removal rate in a pond was 0% in Duck Pond and Memorial Pond on 4 June; however, upgradient TDP concentrations were already very low on 4 June. The highest TDP removal rate in an MTD was 40% at the Yacht Club MTD in July while a 67% increase in TDP concentrations was measured downstream of the East Shore MTD in July; this was likely influenced by backwater from the lake and/or groundwater influence.

TDP results indicate that Biochar placed in streams can provide TDP removal rates between 0% – 75%, Biochar placed in ponds can provide TDP removal rates between 0% - 94%, and Biochar placed in MTDs can provide TDP removal rates between 0% - 40%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates. Similar to other phosphorus removal rates, it appears as though Biochar provides higher removal rates when placed in ponds due to the extended contact time relative to flowing water in streams. Additionally, it appears as though the TDP removal efficiencies dropped substantially in the stream sites three months post-installation, indicating that they should be replaced every 2 – 3 months.

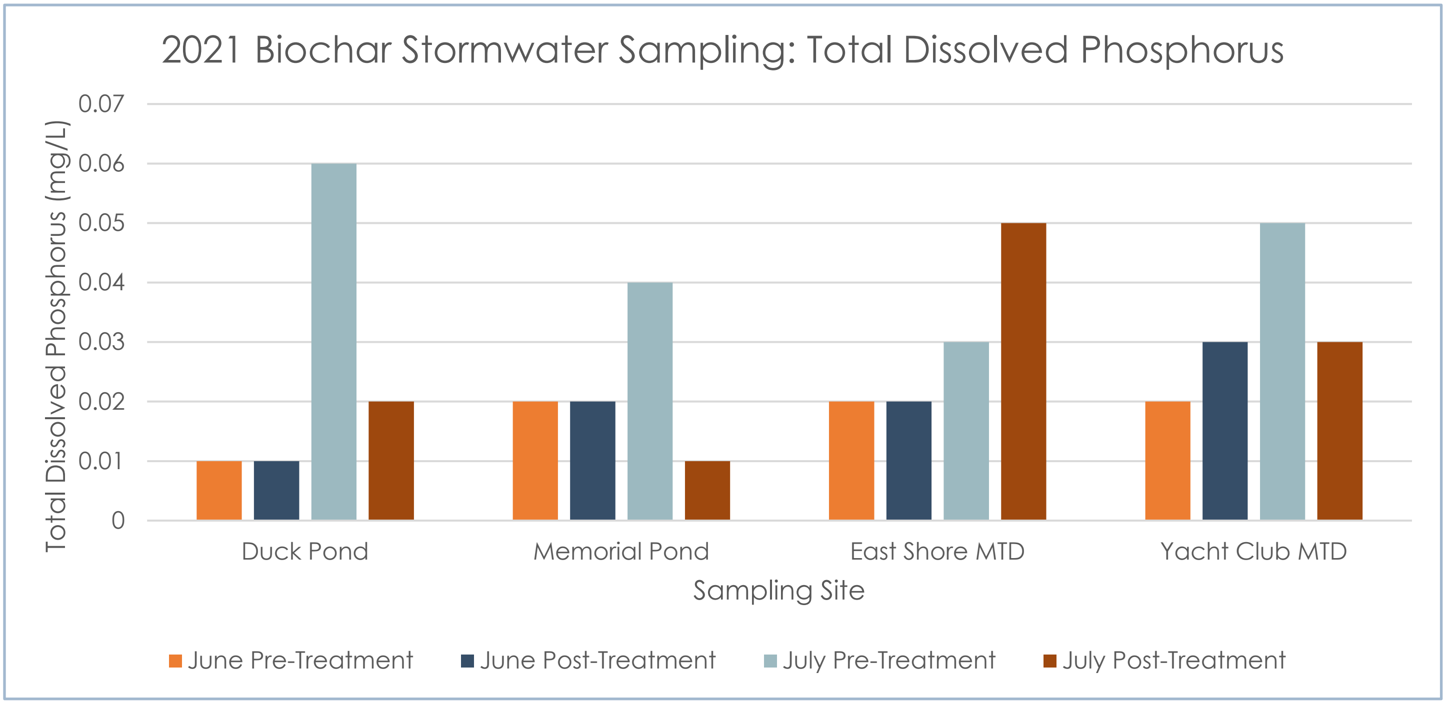


Figure 8.6: Upgradient and downgradient total dissolved phosphorus concentrations from two separate sampling events; 4 June 2021 and 1 July 2021.

SUMMARY

The phosphorus removal rates provided by the Biochar socks varied greatly by parameter and by site but were positive overall. It appears as though contact time between the Biochar and the stormwater is key, with extended contact time resulting in higher removal rates, as shown by the superior removal rates provided by the Biochar socks in the two stormwater ponds. The Biochar socks in the stream sites removed a substantial amount of phosphorus during the first monitoring event, 8 days after they were installed, but provided much less phosphorus removal three months later, indicating they should be replaced or flipped over every 2 – 3 months. Under normal flow conditions in the streams, the socks are likely not inundated. Thus, the water is flowing through the same area of the sock constantly and the Biochar at the "bottom" of the sock (lying on the ground) is getting filled with sediment and nutrients while the top of the sock is likely much cleaner.

While consistent, positive phosphorus removal rates were not evident downgradient of the MTDs, this is likely due to the influence of un-filtered water mixing with the filtered water between the upgradient and downgradient sampling points. As mentioned above, these influences include backwater influence from Lake Hopatcong and potentially septic-influenced groundwater as a result of the high water table. These MTDs are not expected to provide removal rates as high as the pond sites due to a shorter contact time but are expected to provide removal rates similar to the stream sites.

Finally, it is also evident that phosphorus removal rates tend to be higher when the upgradient phosphorus concentrations are elevated. When upgradient phosphorus concentrations are already low, there is less phosphorus per unit volume of water for the Biochar to bind to.

The stormwater results indicate the following about phosphorus removal efficiencies:

TP results indicate that Biochar placed in streams can provide TP removal rates between 20% – 55%, Biochar placed in stormwater ponds can provide TP removal rates up to 81%, and Biochar placed in MTDs can provide TP removal rates up to 50%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates.

SRP results indicate that Biochar placed in streams can provide SRP removal rates up to 96%, Biochar placed in stormwater ponds can provide SRP removal rates between 76% - 97%, and Biochar placed in MTDs can provide SRP removal rates up to 5%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates.

TDP results indicate that Biochar placed in streams can provide TDP removal rates up to 75%, Biochar placed in stormwater ponds can provide TDP removal rates up to 94%, and Biochar placed in MTDs can provide TDP removal rates between up to 40%. As noted above, the MTD sites were likely heavily influenced by un-filtered water and thus is difficult to derive accurate removal rates.

Overall, Biochar shows great potential in removing various forms of phosphorus from stormwater. While the initial results indicate superior removal rates from Biochar placed near the inlet or outlet of a lake or pond, the removal rates in the stormwater streams were still positive, although with greater variability. The key takeaway from this study appears to be that extended contact time results in higher nutrient removal. Thus, if Biochar is to be placed in streams, the Biochar will need to be replaced or potentially flipped or rotated more often, likely every 2 months.

9.0 SUMMARY AND RECOMMENDATIONS

This study offered a unique opportunity to objectively evaluate a variety of innovative, in-lake and watershed management measures designed to prevent, mitigate, and control the development of HABs in Lake Hopatcong. These measures included floating wetland islands (FWIs), installation of three types of aeration systems, application of a nutrient inactivating product (PhosLock), a treatment of a non-copper-based algaecide (GreenClean), the use of a filter media (Biochar) that removes phosphorus and can subsequently be used for mulch and the implementation of the Rutgers rain garden program.

The monitoring that occurred over the course of the 2020 and 2021 seasons, including pre- and post-treatment and/or at treatment and control sites, provided the data necessary to determine the effectiveness of these in-lake and watershed measures to determine if they are applicable to other lakes in New Jersey to combat HABs.

The overall project was a success, with positive results associated with all of the management measures that were implemented. With that being said, none of these management measures are without limitations. The two-year monitoring period associated with the majority of these measures provided the data necessary to parse out the limitations from the best intended use. Most importantly, no HABs occurred in any areas of the lake where these measures were implemented over the past two years.

The following section will summarize the results and conclusions from all of the major management measures implemented in 2020 and 2021. Each summary will include both the best intended use and the major limitations associated with each management measure, based on the data collected as part of this study.

Summary sheets for all management efforts implemented over the course of this study are provided in Appendix X.

PROJECT SUMMARIES

FLOATING WETLAND ISLANDS

The floating wetland islands (FWIs) associated with this project were installed in June 2022. However, based on past studies involving FWIs, the following conclusions can be made:

Limitations: FWIs appear to be less effective in large waterbodies unless a large number of FWIs are installed. FWIs can also detach from their anchors in large systems due to excessive wind and wave action if they are not anchored properly. In addition, regardless of what plant species are selected, the FWIs tend to be most successful in full sunlight. The installation of goose netting is absolutely necessary in order to prevent grazing of the vegetation by Canada geese.

Best Intended Use: FWIs are best used in conjunction with other management measures, such as watershed restoration. However, since FWIs do provide nutrient removal services and are relatively inexpensive, they are a critical component of nutrient reduction and HAB control in many systems. Additionally, they will benefit the fish community by providing habitat and refuge. FWIs tend to be most effective when positioned and anchored in near-shore areas, adjacent to a stormwater pipe, inlet or swale, where the FWI can intercept incoming nutrient loads. Again, the FWI need to be installed in areas that receive full sunlight over the majority of the day.

Conclusion: FWIs are a cost-effective and environmentally friendly complimentary management measure that can lower nutrient concentrations and help prevent the formation of HABs. They can also provide food and refuge habitat for macroinvertebrates and fish.

AERATION SYSTEMS: AIR CURTAIN

The results of the Air Curtain aeration system at Shore Hills Beach Club were positive, as water quality conditions within the treatment zone were favorable all season. The Air Curtain was effective in preventing the accumulation of nuisance particulates and other organic matter from accumulating in the Shore Hills Beach Club marina or swim area throughout the season. Cyanobacteria cell counts remained below the minimum NJDEP HAB Alert Level throughout the season, even as cyanobacteria cell densities increased in other shallow areas across the lake during the peak summer months.

Limitations: The aeration diffusers used for the Air Curtain prevent the establishment of any potential thermal stratification. Thus, Air Curtains should not be used in deeper waters that would otherwise develop a stratification pattern, unless the entire limnetic portion of the target lake is to be destratified. Partially mixing a lake that is deep enough to stratify can result in the increased mixing of internally released phosphorus from the deeper waters.

Best Intended Use: Air curtains are effective in locations similar to Shore Hills Beach Club. Specifically, this includes the deployment of an Air Curtain around the perimeter of a shallow beach, marina, or other public location with the intended goal of preventing the accumulation of cyanobacteria, particulates, plant fragments, or other undesirable debris.

Conclusion: Air Curtains are a cost-effective method of preventing the accumulation of cyanobacteria and other undesirable debris along near-shore areas such as beaches and marinas. They are effective in preventing localized wind-blown cyanobacteria accumulations.

PHOSLOCK

The overall results of the PhosLock applications in Ashley Cove and Landing Channel were exceedingly positive. The mean surface TP concentration of all post-treatment monitoring events in Ashley Cove and Landing Channel was 0.03 mg/L which is the established threshold, as per the TMDL. Most importantly, and as expected with the PhosLock applications, SRP concentrations remained extremely low throughout the entire study period, even as TP concentrations increased. In fact, surface and deep SRP and TDP concentrations remained non-detectable throughout the majority of the 2021 season in both study areas, indicating that the PhosLock applications were effective in reducing the release of dissolved phosphorus from shallow sediments, where there is potential for the mobilization of phosphorus from both chemical and biological processes, into the second year of the study. Most importantly, no HABs or cyanobacteria cell counts above the NJDEP Watch level were measured across all post-treatment events.

While the product is frequently used to strip the water column of dissolved phosphorus, as well as to inactivate phosphorus generated from deep, anoxic sediments, the goal of the PhosLock applications in this study was to inactivate the mobilization of phosphorus from shallow sediments where there is known to be a mobilization of phosphorus from both chemical and biological processes. Thus, the following conclusions are based solely on the results of this study and will not speculate about the use of PhosLock as a nutrient inactivant in the anoxic portion of a lake.

Limitations: PhosLock is more expensive than other nutrient inactivants, such as alum or iron. Based on the study results, there are no technical limitations associated with the application of PhosLock in shallow lake areas. It should be noted that as of 2023 the product PhosLock will not longer be available for purchase in the United States. However, SePRO will have their version of PhosLock available for purchase in 2023, called EutroSORB G. In addition, another nutrient inactivating product, called EutroSORB WC, will be available to inactivate phosphorus in the water column. Yet another product, called EutroSORB SI, will also be available to inactivate phosphorus in the organically-rich, shallow sediments.

Best Intended Use: PhosLock appears to be effective in precluding the release of phosphorus from sediments of shallow, hydraulically secluded areas of a lake. Of particular importance are the soluble reactive phosphorus results from Landing Channel and Ashley Cove which were below the laboratory detection limit throughout the majority of the study period. No HABs were observed in either study area in the two years associated with this study.

Conclusion: Although more expensive than alternative nutrient inactivants, PhosLock appears to be an effective method of precluding HABs by slowing the release of dissolved phosphorus from the sediment of shallow, secluded areas of a lake. While PhosLock will no longer be available in the United States starting in 2023, SePRO does have alternative nutrient inactivating products.

GREENCLEAN

The GreenClean treatment is the one management measure in this study that has essentially inconclusive results due to the limited number of sampling events and the location of the treatment area. The results of the GreenClean treatments were variable by parameter but remained inconclusive overall due to mixed results. The small sample size of only one pre-treatment and one post-treatment monitoring event limits the capability to perform meaningful statistical analyses. Additionally, due to the small size of the treatment zone and the significant mixing that occurs due to its position on the main body of the lake, the GreenClean treatment did not appear to be successful in lowering phycocyanin or chlorophyll-*a* concentrations.

While the results of the GreenClean treatment at Capp Beach were somewhat inconclusive, the treatment appeared to be far more effective at Ashley Cove. Although not originally intended as part of this project, prior to the first PhosLock treatment of 2020 in Ashley Cove, a GreenClean application was conducted to knock down the existing algae biomass that was in Ashley Cove. This application worked extremely well and reduced the filamentous algae in the cove so that the PhosLock could be applied

The following conclusions are based on data from this study as well as GreenClean treatments that were conducted on Lake Mohawk and Upper Lake Mohawk as part of the same NJDEP HABs grant. The data collected at Lake Mohawk and Upper Lake Mohawk were more comprehensive than this data and offer valuable insights into the effectiveness of GreenClean treatments.

Limitations: While the results are limited, the potential release of taste and odor compounds in the treatment zone of Lake Mohawk should be considered when recommending treatments for drinking water reservoirs. GreenClean is supposed to breakdown taste and odor compounds as well as cyanotoxins, however, the limited scope of this study as well as the one at Lake Mohawk, did not provide any evidence to support this statement. GreenClean treatments with the goal of reducing cyanobacteria densities appear to be less successful in waterbodies with a high flushing rate and water movement, such as a beach area situated along the main body of a lake.

Best Intended Use: Based on the GreenClean results from Lake Mohawk and Ashley Cove, it appears that GreenClean may be more appropriate and more cost effective for areas that are not prone to high amounts of flushing or water movement, such as secluded coves or small waterbodies.

Conclusion: Although more expensive than other algaecides, GreenClean appears to be a more environmentally friendly alternative to copper-based algaecides and is more effective in secluded areas with a low flushing rate.

BIOCHAR

Overall, Biochar shows great potential in removing various forms of phosphorus from stormwater. While the initial results indicate superior removal rates from Biochar placed near the inlet or outlet of a lake or pond, the removal rates in the stormwater streams and MTDs were still positive, although with greater variability. The key takeaway from this study appears to be that extended contact time results in higher nutrient removal. Thus, if Biochar is to be placed in streams or MTDs, the Biochar will need to be replaced or potentially flipped or rotated more often, likely every 2 months.

Limitations: Biochar placed in streams or MTDs that have significant flow will provide lower phosphorus removal rates than standing water or slow-flowing streams. However, it is also important to note that stormwater streams and MTDs often have relatively large drainage areas, and while the phosphorus removal rate may not be as significant, the total amount of phosphorus removed on an annual basis can still be significant. It also appears to be difficult to accurately quantify phosphorus removal rates in stormwater MTDs due to factors that can influence the post-treatment results, such as septic and groundwater influence, backwater from the receiving lake, and potential mixing with un-filtered water that may bypass the MTD during periods of heavy flow.

Best Intended Use: Biochar provides the highest phosphorus removal rates in slow-flowing and standing water systems, such as near-shore areas, coves, ponds, and stormwater basins. As noted above, while phosphorus removal rates do not appear to be as high in flowing water systems, Biochar can still remove a significant amount of phosphorus if the Biochar is replaced on a regular basis.

Conclusion: Biochar is a cost-effective method of reducing phosphorus concentrations in stormwater, pond, near-shore areas, and near inlets and outlets of lakes. To remain effective, Biochar needs to be replaced every 2 – 6 months depending on the system.

RECOMMENDATIONS FOR LAKE HOPATCONG

FLOATING WETLAND ISLANDS

Floating wetland islands (FWIs) are constructed of recycled plastic material, are typically planted with native, water loving vegetation and then anchored to the lake bottom. Functionally, these units have been utilized to slow inflow and precipitate sediments. Furthermore, the high surface area of the constructed wetland material and root mass of planted vegetation serve as habitat for bacteria which assimilate and process phosphorus and nitrogen. Nutrient uptake also occurs via direct assimilation from the plants. They also provide habitat for a variety of aquatic organisms and thus attract gamefish species.

The manufacturer of the FWIs typically collects information prior to manufacturing in order to design an area and material density which is optimized for the intention of the installer. These islands can be installed alone, or for more effectiveness, be utilized in conjunction with emergent vegetation, shoreline restoration, or any other in-lake or watershed management measures.

Type:
- Proactive management.

When:
- FWIs are installed and then left in the lake for 10+ years year-round

Where:
- Coves and other hydraulically secluded areas; however, they do required sunlight for the majority of the day
- Stormwater ponds that discharge into Lake Hopatcong, such as Duck Pond or Memorial Pond
- Near the inlets of streams, MTDs, or stormwater ponds to slow inflow rates and reduce nutrient concentrations as they discharge into Lake Hopatcong
- Great in conjunction with other restoration measures, such as Biochar or MTDs
- FWIs are being replaced and installed in Ashley Cove and Landing Channel in 2022
- Other candidates in Lake Hopatcong include River Styx / Crescent Cove, Ingram Cove, the small cove off of Henderson Bay, and the cove south of Weldon Quarry

Pros:
- Environmentally friendly, aesthetically pleasing, and cost-effective
- Provides structure and habitat for a variety of aquatic organisms including young fish. In turn, larger gamefish are also attracted to the structures
- Provides shoreline stabilization when placed along shorelines
- Can slow inflow rates when strategically placed

Cons:
- FWIs can detach from their anchors in large systems due to excessive wind and wave action if not anchored properly
- Do require goose netting to prevent Canada geese from feeding on the vegetation during the first year of installation

AIR CURTAIN AERATION SYSTEM

Air Curtain aeration systems are designed to form a barrier around beaches, marinas, or other high-density nearshore areas. Aeration diffusers are placed on the bottom of the lake, along the perimeter of the protected area, and are supplied with air from a compressor on shore. They are designed to prevent the accumulation of algae, cyanobacteria, plant fragments, and other nuisance debris along designated near-shore areas. The accumulation of cyanobacteria in near-shore areas can otherwise lead to localized cyanobacteria blooms and the development of HABs. The accumulation of plant fragments and other organic matter can lead to nutrient release and low dissolved oxygen levels upon decomposition. However, such near-shore aeration systems primarily function to provide the accumulation of cyanobacteria cells that can lead to a HAB.

Type:
- Proactive management.

When:
- Continuously through the growing season or at least between Memorial Day and Labor Day. Also, holiday weekends when beaches are being used.

Where:
- Installed as barriers around near-shore locations such as beaches, marinas, or other public or high-density areas where people or pets are in contact with the water. This type of aeration is not designed to destratify the entire lake. Thus, the system's need to be designed and sized to function in near-shore aeras, typically in depths less than 10 feet.
- Placing a nanobubble aeration system (ozone optional) in a near-shore location within the protected area of an Air Curtain would have increased benefits. The Air Curtain would prevent the wind-blown accumulation of cyanobacteria or other organic matter into the protected area and the nanobubble system would provide additional oxidation within the protected zone, greatly reducing the risk of bloom formation within the protected area.
- Potential candidates in Lake Hopatcong include the Lake Hopatcong State Park swim beach, Mount Arlington Municipal Beach, or any other beaches or marinas where people recreate during the swimming season.

Pros:
- Prevents the wind-blown accumulation of harmful cyanobacteria along high-density nearshore areas.
- Increase water movement and dissolved oxygen levels along nearshore areas.
- Allows the passage of aquatic organisms, boats, and other watercraft.
- Safe for aquatic wildlife.

Cons:
- Its application is designed for near-shore areas and are not used to conduct whole-lake aeration.
- Requires a stable power source and thus requires funds to cover the cost of this power.
- Will require a certain, although limited, amount of maintenance each type, which typically involves winterization and starting it up in the late spring.

PHOSLOCK

PhosLock is a clay-based, non-aluminum-based nutrient inactivator that has been used in a variety of ways to inactivate phosphorus, making it unavailable for algal growth. PhosLock is not considered an EPA registered pesticide, since it does not directly affect plants or algae, and does not currently require a permit in New Jersey. PhosLock applications are intended to inactivate phosphorus generated from deep, anoxic sediments, as well as shallow sediments where there is a mobilization of phosphorus from both chemical and biological processes. While alum only inactivates inorganic forms of phosphorus, PhosLock can inactivate both inorganic and organic forms of phosphorus. Additionally, cyanobacteria are better adapted at using organic forms of phosphorus compared to other algal groups. Lower dosage rates of PhosLock can also be used to strip the water column of dissolved phosphorus as it sinks to the sediment. The inactivation and reduction of phosphorus concentrations is intended to limit algal growth, with an emphasis on cyanobacteria.

Type:
- Proactive management.

When:
- Can be applied at any time that the lake is not frozen or experiencing an active HAB or phytoplankton bloom. This management technique can be designed to provide years of phosphorus control from one application.
- However, the optimal time for any PhosLock application, whether its to inactivate phosphorus in the sediment or stripping it from the water column, is typically in late spring / early summer (May / June) when dissolved phosphorus concentrations tend to be their highest and prior to the development of cyanobacteria blooms.

Where: :
- Barring any whole lake treatments, would be most effective in more isolated bays / coves and possibly along select near-shore areas. Potential areas may include, but not be limited to, Landing Channel, Ashely Cove, Ingram Cove, sections of River Styx / Crescent Cove and some of the larger coves such as Kings Cove, Byram Cove and Henderson Cove.

Pros:
- Non-aluminum or metal-based
- Can inactivate both inorganic and organic forms of phosphorus
- Effective under anoxic and oxic conditions
- Effective at low pH values
- Does not affect water pH values
- Does not require a buffer
- Safe for aquatic organisms
- Can provide multi-year inactivation of phosphorus in the sediments

Cons:
- More expensive than traditional nutrient inactivants, such as aluminum or iron-based products.
- The product PhosLock will no longer be available in the United States starting in 2023. However, a number of replacement nutrient inactivating products will be available for use over the next 1-2 years. These alternative products include:
  - EutroSORB F (filters for removing phosphorus from flowing waters) and EutroSORB WC (liquid product for stripping phosphorus from the water column) – both products currently available.
  - EutroSORB G (replacement product for PhosLock; targets sediment-bound phosphorus) – available late summer 2022.
  - EutroSORB SI (liquid for sediment phosphorus inactivation in shallow waters) – available sometime in 2023.

GREENCLEAN

GreenClean is an oxidizing algaecide that uses sodium carbonate peroxyhydrate, a form of hydrogen peroxide, as the active ingredient to break down algae cells. GreenClean is an EPA registered algaecide that requires a permit to be filed by a State licensed applicator. The goal of a GreenClean application is to reduce algae and cyanobacteria densities in waterbodies while breaking down and precluding the release of cyanotoxins and taste & odor compounds such as geosmin and MIB.

Type:

- Reactive management.

When:

- As a spot or selective treatment for suspected or confirmed HABs and/or nuisance filamentous algae.

Where:

- This would be best used as a spot treatment at near-shore locations such as beaches, marinas, or other public or high-density areas where people or pets are in contact with the water. This would also be best as a spot treatment at any location where a small or localized cyanobacteria bloom appears. Also, based on the findings of this study, such treatments are substantially more effective in more isolated near-shore areas, like coves or bays, as opposed to near-shore areas more open to the main body of a lake.

Pros:

- Effective in a short period of time and can quickly control nuisance densities of both mat algae and cyanobacteria.
- Does not produce or introduce any toxic materials, such as copper.
- Can also be used to prevent the growth of algae.
- Lower doses may selectively treat cyanobacteria but not green algae.
- **Possibly** effective at reducing both cyanotoxins and taste & odor compounds.

Cons:

- More expensive than copper-based algaecides but does not produce or introduce any toxic materials.
- In contrast to copper-based algaecides, tends to be added on a more routine basis to maximize effectiveness.

BIOCHAR

Biochar is a processed wood material that has a high affinity to adsorb a variety of nutrients, including phosphorus. Biochar can be placed directly in Lake Hopatcong, in streams and stormwater ponds / structures that flow into the lake. The installation of Biochar in any of these systems is intended to reduce nutrient concentrations, with an emphasis on dissolved phosphorus. Reducing dissolved phosphorus concentrations contributes toward limiting nuisance algal growth. Table 9.1 below provides a summary by municipality of all sites that Princeton Hydro recommends continuing to install Biochar on an annual basis. Please note that these are only sites where Biochar was installed as part of this study, and Princeton Hydro recommends installing Biochar in similar sites around the lake to reduce phosphorus concentrations.

Type:
- Proactive management.

When:
- Biochar can be placed into these different systems at any time, but the emphasis should be on the growing season months, between April and October.

Where:
- If installed directly in the lake, Biochar can be placed into floatation balls, sleeves, or cages and tethered along a beach area, swimming line, or where an inlet enters the lake.
- In streams, Biochar can be placed into sleeves or cages and anchored to the streambed or streambank where it can filter phosphorus as the water flows through; however, removal rates are lower in flowing water relative to standing water.
- Biochar can also be placed into sleeves and then installed into stormwater structures, such as Manufactured Treatment Devices (MTDs), where it can filter phosphorus as stormwater flows through the media.

Pros:
- Low product cost.
- Recycled, organic material.
- Biochar can be re-used as a form of mulch for upland landscaping after it is removed from the water.
- Easy installation and maintenance when placed directly in lakes.
- Reduces nutrient concentrations before the water enters the lake if placed in stormwater structures or inlets
- Enhances nutrient filtration capabilities of stormwater structures.

Cons:
- Must be replaced every few months, or at least once per growing season to maintain nutrient removal capabilities.
- Permits may be required for installation in streams.
- Confined Space Certification may be required for installation and maintenance in large stormwater structures.

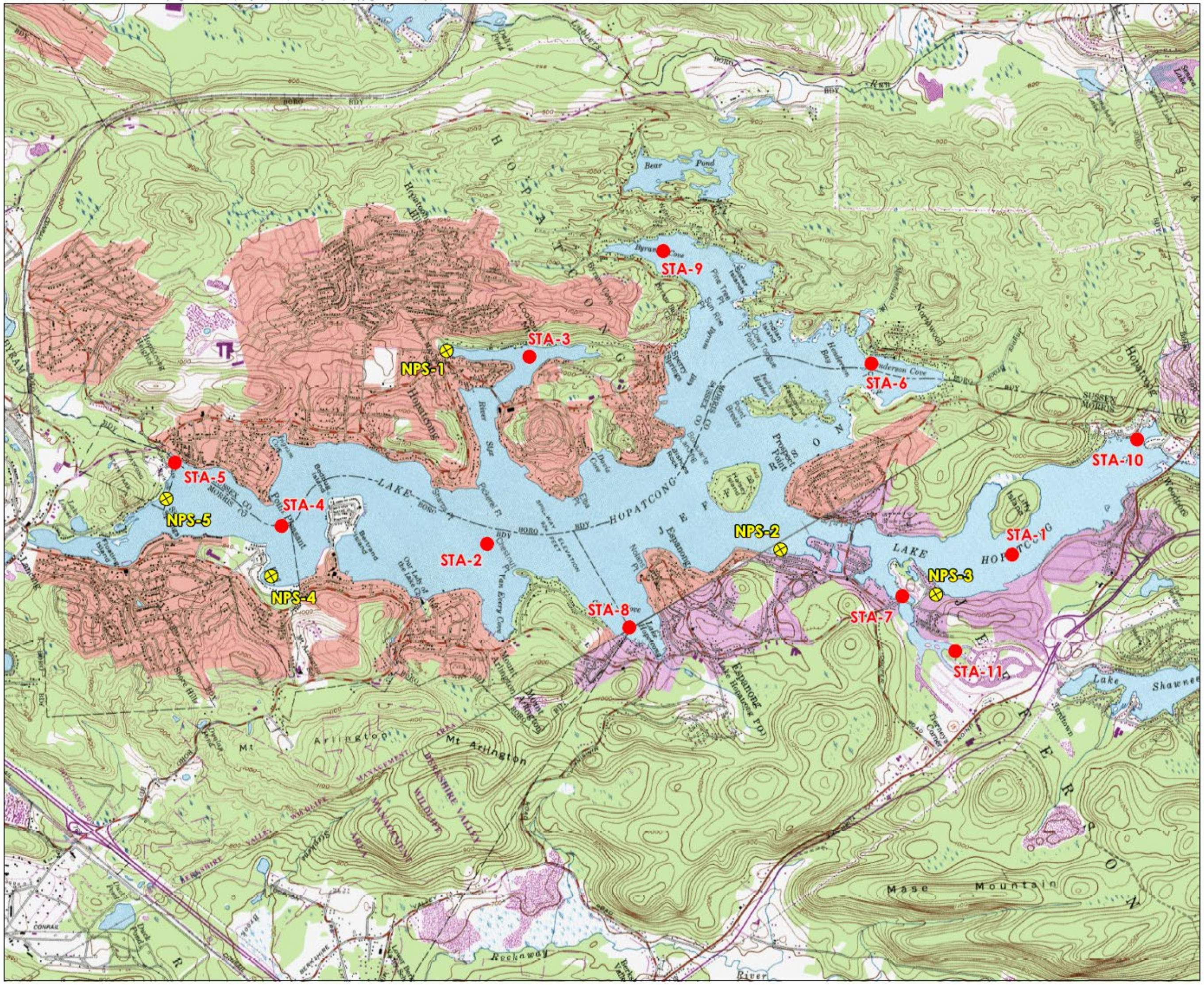
Table 9.1: Summary of Biochar recommendations

Location	Description	Number of Bags	Estimated Costs	Replacement Frequency
Jefferson				
Ashley Cove	Surface water	4	$1000 per round	2-3x per season
Yacht Club Drive - Three Chambered Baffle	MTD	25		1-2x per season
East Shore - Three Chambered Baffle	MTD	25		1-2x per season
Hopatcong				
Aquafilter Units - Crescent Cove	MTD (2)	150 (75 per MTD)	$1,800 per round	1-2x per season
Lakeside Boulevard Ingram Cove Inlet	Stream	6		1-2x per season
Mount Arlington				
Edith M. Decker School	Stream	6	$400 per round	1-2x per season
Memorial Pond	Surface water	12		2-3x per season
Roxbury				
Duck Pond	Surface water	12	$250 per round	2-3x per season

APPENDIX I:

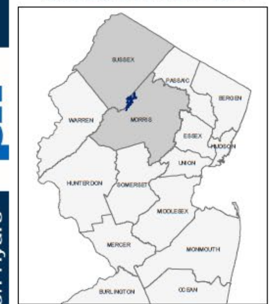
SAMPLING LOCATIONS

File: P:\0003\Projects\0003047\GIS\MXD\SamplingLocations.mxd, May 25, 2010, Drawn by CLP, Copyright Princeton Hydro, LLC



Princeton Hydro

NEW JERSEY COUNTY MAP



PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

N

1 inch = 2,750 feet

0 1,375 2,750 Feet

SOURCES:

1. USGS Topographic Digitial Raster Graphics obtained from Terrain Navigator Pro, Dover and Stanhope, NJ Quadrangles.

Map Projection: State Plane New Jersey (feet) NAD83

FIGURE 1
SAMPLING LOCATIONS

LAKE HOPATCONG
WATER QUALITY SAMPLING
MORRIS AND SUSSEX COUNTIES
NEW JERSEY

Legend

Sampling Stations

- In-Lake
- Near-Shore

APPENDIX II:

QUALITY ASSURANCE PROJECT PLAN

QAPP ADDENDUM FOR LAKE HOPATCONG

SUSSEX AND MORRIS COUNTIES, NEW JERSEY

HUC 14: Lake Hopatcong Sub-watershed - 02040105150020
Grant Identifier: WM20-034; Revision # 4
Submitted for the Evaluation of HAB prevention, mitigation and control in Lake Hopatcong

AUGUST 2021

PREPARED FOR:

THE LAKE HOPATCONG COMMISSION
PO BOX 8515
LANDING, NEW JERSEY 07850

PREPARED BY:

PRINCETON HYDRO LLC
1108 OLD YORK RD, PO BOX 720
RINGOES, NEW JERSEY 08851
(T) 908-237-5660
(F) 908-237-5666
www.princetonhydro.com

SUBMITTED TO:

NEW JERSEY DEPARTMENT OF ENVIROMENTAL PROTECTION
DIVISION OF WATERSHED MANAGEMENT
PO BOX 418
TRENTON, NEW JERSEY 08625-0418

TABLE OF CONTENTS

1.0 PROJECT MANAGEMENT

1.1 TITLE AND APPROVAL SHEET

Project Title: Quality Assurance Project Plan
Evaluation of HAB prevention, mitigation and control in Lake Hopatcong
Sussex and Morris Counties, New Jersey

Grant Identifier: WM20-034

Approvals:

______________________________ Date: __________
Princeton Hydro, LLC, Fred Lubnow, Ph.D., Principal Investigator

______________________________ Date: August 31, 2021
Princeton Hydro, LLC, Jack Szczepanski, PhD, QA/QC Officer

______________________________ Date: __________
Lake Hopatcong Commission, Colleen Lyons, Administrator

______________________________ Date: __________
NJDEP Bureau of Environmental Analysis & Standards, Deborah Kratzer, QAPP reviewer

______________________________ Date: __________
NJDEP Bureau of Environmental Analysis & Standards, Jay Springer, Section Chief

______________________________ Date: __________
NJDEP, Bureau of Quality Assurance and Evaluation Monitoring, Melissa Hornsby, Quality Assurance Officer

1.2 CONTACT INFORMATION

All contact information for associated parties, including Princeton Hydro, Lake Hopatcong Commission, Environmental Compliance Monitoring and NJDEP, can be found in the original In-Lake Monitoring QAPP (May 2021) for Lake Hopatcong dated May 2021. In addition to these parties mentioned in the original QAPP (May 2021), SePRO Research & Technology Campus will be utilized for sediment sample analyses and EMSL Analytical Inc. will be used for T&O compound analysis. All of the personnel listed in the original QAPP (May 2021) and Table 1 below will receive copies of this QAPP addendum (May 2021), and any approved revisions of this plan (August 2021), should they occur.

Table 1: Contact Information		
Title	**Name (Affiliation)**	**Phone Number/E-mail**
SePRO Laboratory Manager	Sam Mason SePRO Research & Technology Campus	(252) 391-8383 samm@sepro.com
SePRO Laboratory QA/QC Officer	Jason Scott SePRO Research & Technology Campus	(252) 391-8383 jasons@sepro.com
EMSL Analytical, Inc Lab Manager	Bin Wang, Ph.D., P.E EMSL Analytical, Inc.	800-220-3675 bwang@emsl.com

LINES OF COMMUNICATION

The lines of communication remain the same to the original QAPP (May 2021), with exception to SePRO and EMSL being added to the Laboratory section alongside Environmental Compliance Monitoring, Inc (ECM).

LABORATORY INFORMATION

In addition to ECM, information for SePRO Research & Technology Campus and EMSL Analytical, Inc. has been provided below.

Name: SePRO Research & Technology Campus	
Address: 16013 Watson Seed Farm Road	
Phone: (252) 437-3282	Contact Name: Sam Mason

Name: EMSL Analytical, Inc; NJ Certified Lab # 03036	
Address: 200 Route 130 North Cinnaminson, NJ 08077	
Phone:	Contact Name:

800-220-3675	Bin Wang, Ph.D., P.E.

1.3 PROJECT OBJECTIVES AND APPROACH

Lake Hopatcong experienced unprecedented harmful algal blooms (HABs) of cyanobacteria over most of the summer season from mid-June well into October in 2019. These HABs resulted in the posting of advisories over large sections of the lake and the closing of all beaches by local/County Departments of Health. These conditions resulted in substantial impacts on the ecological, recreational, and economic resources of the lake and region. These blooms were triggered by some of the highest June total phosphorus (TP) concentrations measured over the last 25 years. These conclusions are based on routine, baseline monitoring of Lake Hopatcong, conducted by the Lake Hopatcong Commission's (LHC) environmental consultant, Princeton Hydro. While prevailing weather conditions contributed toward these elevated TP concentrations, the contributing sources of TP stem from stormwater and septic systems. Long-term, watershed-based measures are currently being explored for Lake Hopatcong, but some more short-term, in-lake/nearshore measures are needed to minimize the local impacts of HABs to protect the lake and the local economy.

Funds were obtained through the NJDEP's HAB Management program to implement a variety of innovative, nearshore management measures to prevent, mitigate, and/or control HABs through habitat modifications, nutrient reduction, and/or by directly killing HABs. Projects have been identified within the two Counties and four municipalities throughout the Lake Hopatcong Watershed (Appendix B). The overall project Goal is to implement these projects and objectively evaluate the relative effectiveness through water quality monitoring. These projects include evaluating various filtering media in two Aqua-Filter stormwater basins, three types of aeration, the nutrient inactivator PhosLock, Floating Wetland Islands, the non-copper algaecide GreenClean, and the use of Biochar to remove phosphorus from nearshore waters.

1.4 DATA QUALITY OBJECTIVES

The data quality objectives (DQOs) of this project follow the same guidelines as presented in the original QAPP (May 2021).

1.5 TRAINING OF FIELD SAMPLING PERSONNEL

Training of field personnel will follow the same guidelines as presented in the original QAPP (May 2021).

1.6 DOCUMENTATION AND RECORDS

Information on the documentation and records for this project can be found in the original QAPP (May 2021).

2.0 SAMPLE COLLECTION PROCEDURES

2.1 FIELD SAMPLING INFORMATION

Where applicable, all sampling procedures shall be in conformance with standard limnological practices and procedures listed in *Standard Methods for the Analysis of Water and Wastewater, 18th Edition* (American Public Health Association, 1992), State protocol (NJDEP, 2005) and/or any comparable US EPA guidance document.

Details on the sampling procedures can be found in sections of the NJDEP Field Sampling Procedures Manual (2005). Specifically, these include Section 5.2.3 - *Surface Water and Liquid Sampling Equipment, Section 5.3.2 – Sediment and Sludge Sampling Equipment* and Sections 6.8.1 and 6.8.2 - *Sample Collection*. For the collection of discrete water samples, Princeton Hydro will utilize either a Kemmerer or a Van Dorn sampler; both devices are listed in the NJDEP Manual More lake-specific details are provided in Section 6.8.2.2.5 – *Lake / Standing Water Sampling*.

Instrumentation used for the collection of field data (dissolved oxygen, temperature, pH and conductivity) shall be properly calibrated in conformance with manufacturer instructions. All sampling sites were chosen to be representative sites and are subject to the approval of the New Jersey Department of Environmental Protection.

STORMWATER SAMPLING

1. As part of a past 319(h) grant application (SFY2005), two large stormwater basins and Aqua-Filters were installed in the parking lot of the Crescent Cove Beach Club. These basins will be cleaned out and the media replaced.

2. All project sites will be located with the use of GPS technology. GPS data will be collected with a hand held GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

3. Once the media is installed, the basins will be sampled during three stormwater events over the course of the 2020 growing season. Sampling will occur immediately upgradient and downgradient of each basin, totaling four sampling locations.

4. Discrete water quality samples will be collected at these four sampling locations at Crescent Cove Beach Club. All discrete water samples will be collected with a laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection.

5. These discrete samples will be analyzed for total phosphorus, soluble reactive phosphorus and total dissolved phosphorus.

AERATION EVALUATION

1. Three different nearshore aeration systems will be installed along three specific beach areas. These Locations and associated aeration types can be found in Table 2 below.

2. Once the three systems are installed, Princeton Hydro will conduct three sampling events within the aerated zones to be conducted in June, July and August 2020.

3. All sampling stations will be located with the use of GPS technology. GPS data will be collected with a hand held GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

4. At each of the three sampling stations a calibrated Surveyor IV Hydrolab or similar device will be used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH and conductivity. Princeton Hydro is State certified for the collection of these four *in-situ* parameters (State ID # 10006). Data will be recorded at 0.5 - 1.0 meter increments beginning at 0.5 meters below the water's surface to within 0.5 meters of each lake's sediment bottom. In addition, water clarity will be measured at each station with a Secchi disk.

5. Prior to any in-lake sampling event the Surveyor IV Hydrolab or similar device will be calibrated as per the manufacturer's specifications. The boat's on-board fathometer will provide guidance as to the total

depth. The meter will be lowered into the water to 0.5 m below the water's surface. Once the readings on the device have equilibrated the *in-situ* measurements (dissolved oxygen, temperature, pH and conductivity) will be recorded. The calibrated line will be lowered at 1.0 meter intervals, and equilibrated measurements will continue to be recorded. At each sampling station the device will be lowered to within 0.5 meters of the bottom.

6. Discrete water quality samples will be collected at the three sampling stations, approximately 0.5 meters below the water's surface. All sub-surface discrete water samples will be collected with a Kemmerer or Van Dorn sampling device or laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection. The sub-surface discrete samples will be analyzed for chlorophyll *a*, microcystins, and phycocyanins by staff scientists.

7. Whole water, sub-surface (0.5 m below surface) samples will be collected for phytoplankton as per the NJDEP Field Sampling Procedures Manual (2005). Analysis via quantification utilizing cell counts (cells/mL) will be performed on these samples and plankton will be identified down to genus or species. The focus will be on cyanobacteria cell count.

Table 2: Station ID

Site ID	Location ID	Location	Coordinates (approximate)	Aeration Type
A1	Shore Hills Beach	195 Mt. Arlington Blvd, Landing NJ	40.9098, -74.6573	Air Curtain System
A2	Mount Arlington Municipal Beach	511 Windemere Ave., Mt. Arlington NJ	40.9291, -74.6391	Nanobubble Oxygen System
A3	Lake Forest Yacht Club	35 Yacht Club Drive, Lake Hopatcong NJ	40.9705, -74.6093	Nanobubble Ozone System

PHOSLOCK SAMPLING AT LANDING

1. Princeton Hydro will conduct a pre- and two post-treatment monitoring events of the area that will be treated with PhosLock. A sampling station will be established in the area where this treatment will take place (Appendix B).

2. All sampling stations will be located with the use of GPS technology. GPS data will be collected with a handheld GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

3. At the established sampling station, a calibrated Surveyor IV Hydrolab or similar device will be used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH and conductivity. Princeton Hydro is State certified for the collection of these four *in-situ* parameters (State ID # 10006). Data will be recorded at 0.5 - 1.0-meter increments beginning at 0.5 meters below the water's surface to within 0.5 meters of each lake's sediment bottom. In addition, water clarity will be measured at each station with a Secchi disk.

4. Prior to any in-lake sampling event the Surveyor IV Hydrolab or similar device will be calibrated as per the manufacturer's specifications. The boat's on-board fathometer will provide guidance as to the total depth. The meter will be lowered into the water to 0.5 m below the water's surface. Once the readings on the device have equilibrated the *in-situ* measurements (dissolved oxygen, temperature, pH and conductivity) will be recorded. The calibrated line will be lowered at 1.0-meter intervals, and equilibrated

measurements will continue to be recorded. At each sampling station the device will be lowered to within 0.5 meters of the bottom.

5. Discrete water quality samples will be collected at the three sampling stations, approximately 0.5 meters below the water's surface. All sub-surface discrete water samples will be collected with a Kemmerer or Van Dorn sampling device or laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection.

6. The sub-surface discrete samples will be analyzed for total phosphorus, soluble reactive phosphorus, total dissolved phosphorus, chlorophyll *a,* microcystins, and phycocyanins

7. Whole water, sub-surface (0.5 m below surface) samples will be collected for phytoplankton as per the NJDEP Field Sampling Procedures Manual (2005). Analysis via quantification utilizing cell counts (cells/mL) will be performed on these samples and plankton will be identified down to genus or species. The focus will be on cyanobacteria cell counts.

8. Sediment samples will be collected at five sampling sites in the Landing PhosLock treatment area. All sediment samples will be collected utilizing an acetate tube or Ponar dredge as per the NJDEP Field Sampling Procedures Manual (2005). These samples will be analyzed by SePRO Research & Technology Campus for P fractionation. These analyses will report total phosphorus (labile, metal oxide, reductant-soluble, organic, apatite and residual) and soluble reactive phosphorus (organic portion).

PHOSLOCK SAMPLING AT ASHLEY COVE

1. Princeton Hydro will conduct water quality monitoring of Ashley Cove four times during both the 2020 and 2021 growing seasons to monitor continued PhosLock treatments. All stations that receive Phoslock applications will receive pre and post treatment sampling A sampling station will be established in the area where this treatment will take place (Appendix B).

2. All sampling stations will be located with the use of GPS technology. GPS data will be collected with a hand-held GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

3. At the established sampling station a calibrated Surveyor IV Hydrolab or similar device will be used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH and conductivity. Princeton Hydro is State certified for the collection of these four *in-situ* parameters (State ID # 10006). Data will be recorded at 0.5 - 1.0 meter increments beginning at 0.5 meters below the water's surface to within 0.5 meters of each lake's sediment bottom. In addition, water clarity will be measured at each station with a Secchi disk.

4. Prior to any in-lake sampling event the Surveyor IV Hydrolab or similar device will be calibrated as per the manufacturer's specifications. The boat's on-board fathometer will provide guidance as to the total depth. The meter will be lowered into the water to 0.5 m below the water's surface. Once the readings on the device have equilibrated the *in-situ* measurements (dissolved oxygen, temperature, pH and conductivity) will be recorded. The calibrated line will be lowered at 1.0-meter intervals, and equilibrated measurements will continue to be recorded. At each sampling station the device will be lowered to within 0.5 meters of the bottom.

5. Discrete water quality samples will be collected at one mid-cove sampling station, approximately 0.5 meters below the water's surface and 0.5 m above the sediment. All sub-surface and bottom water discrete water samples will be collected with a Kemmerer or Van Dorn sampling device or laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP

Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection.

6. The sub-surface (0.5 m below surface) discrete samples will be analyzed for total phosphorus, soluble reactive phosphorus, total dissolved phosphorus, ammonia-N, nitrate-N, total suspended solids and chlorophyll *a*. Bottom water (0.5 m above the sediment) discrete samples will be analyzed for total phosphorus, soluble reactive phosphorus, total dissolved phosphorus, microcystins, and phycocyanins.

7. Whole water, sub-surface (0.5 m below surface) samples will be collected for phytoplankton as per the NJDEP Field Sampling Procedures Manual (2005). Analysis via quantification utilizing cell counts (cells/mL) will be performed on these samples and plankton will be identified down to genus or species. The focus will be on cyanobacteria cell counts.

Table 3: Station ID

Site ID	Location ID	Location	Coordinates (approximate)	Treatment Type
P1	Ashley Cove	Jefferson, NJ	40.9639, -74.6114	PhosLock
P2	Landing	Landing, NJ	40.9060, -74.6633	PhosLock

GREENCLEAN ASSESSMENT

1. Princeton Hydro will conduct pre- and post-treatment monitoring of the area that will be treated with GreenClean. Sampling will be conducted at Capp Beach where this treatment will take place.

2. All sampling sites will be located with the use of GPS technology. GPS data will be collected with a hand held GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

3. At the established sampling area, a calibrated Surveyor IV Hydrolab or similar device will be used to monitor the *in-situ* parameters dissolved oxygen (DO), temperature, pH and conductivity. Princeton Hydro is State certified for the collection of these four *in-situ* parameters (State ID # 10006). Data will be recorded at 0.5 - 1.0-meter increments beginning at 0.5 meters below the water's surface to within 0.5 meters of each lake's sediment bottom. In addition, water clarity will be measured at each station with a Secchi disk.

4. Prior to any in-lake sampling event the Surveyor IV Hydrolab or similar device will be calibrated as per the manufacturer's specifications. The boat's on-board fathometer will provide guidance as to the total depth. The meter will be lowered into the water to 0.5 m below the water's surface. Once the readings on the device have equilibrated the *in-situ* measurements (dissolved oxygen, temperature, pH and conductivity) will be recorded. The calibrated line will be lowered at 1.0-meter intervals, and equilibrated measurements will continue to be recorded. At each sampling station the device will be lowered to within 0.5 meters of the bottom.

5. Discrete water quality samples will be collected at the three sampling stations, approximately 0.5 meters below the water's surface. All sub-surface discrete water samples will be collected with a Kemmerer or Van Dorn sampling device or laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection. The sub-surface discrete samples will be analyzed for chlorophyll *a,* microcystins, phycocyanins, geosmin and MIB.

6. Whole water, sub-surface (0.5 m below surface) samples will be collected for phytoplankton as per the NJDEP Field Sampling Procedures Manual (2005). Analysis via quantification utilizing cell counts (cells/mL) will be performed on these samples and plankton will be identified down to genus or species.

Table 4: Station ID

Site ID	Location ID	Location	Coordinates (approximate)	Treatment Type
G1	Capp Beach	Jefferson, NJ	40.9639, -74.6114	GreenClean 5.0

BIOCHAR ASSESSMENT

1. A series of balls, cages or similar structures will be filled with Biochar (processed wood material that removes nutrients from water) will be installed at Mt. Arlington Beach, Ashley Cove, Landing Channel, Byram Bay Community Club Beach and Hopatcong State Park. However, it should be noted that up to 14 near-shore areas, which includes the beach locations sited above, are being assessed for potential use of Biochar (see project map).

2. Once installed, monitoring will be conducted immediately upgradient and downgradient of Biochar media at each installment site. This sampling will be conducted two times during the 2020 season.

3. All sampling sites will be located with the use of GPS technology. GPS data will be collected with a hand held GPS unit (+/- 3 meters). The resulting coordinates and digital data will be supplied to the Commission as part of the summary report.

Table 5: Station ID for confirmed Biochar installation sites

Site ID	Location ID	Location	Coordinates (approximate)	Treatment Type
B1	Mt Arlington Beach	Mt Arlington NJ	40.9290, -74.6392	Biochar
B2	Landing Channel	Landing NJ	40.9101, -74.6576	Biochar
B3	Ashley Cove	Jefferson NJ	40.9639, -74.6114	Biochar
B4	Byram Bay Community Club Beach	Byram NJ	40.9632, -74.6552	Biochar
B5	Lake Hopatcong State Park	Hopatcong NJ	40.9167, -74.6620	Biochar

4. Discrete water quality samples will be collected at each installment locations in Lake Hopatcong. All discrete water samples will be collected with a laboratory cleaned sample bottle as per Section 5.2.3 - *Surface Water and Liquid Sampling Equipment* of the NJDEP Field Sampling Procedures Manual (2005). All sample containers will be identified with their respective station IDs and also labeled with the date and time of collection.

5. The specific taste and odor parameters that will be lab measured within the lake are Geosmin and MIB. This testing will be conducted by the NJDEP certified analytical laboratory EMSL Analytical Inc (#03036).

6. These discrete samples will be analyzed for total phosphorus, soluble reactive phosphorus and total dissolved phosphorus.

Table 6 – Proposed Sampling Parameters				
Parameter	**Analytical Method**	**Sample Container & Preservation**	**Holding Time**	**Laboratory**
Soluble Reactive Phosphorus	4500-P E and EPA 200.7	1 Quart HDPE bag/bottle, cool to 4°C	48 Hours	ECM
Total Phosphorus	4500-P B-5 and 4500-P E and EPA 200.7	1 Quart HDPE bag/bottle, cool to 4°C	28 Days	ECM
Total Dissolved Phosphorus	4500-P B-5 and 4500-P E	1 Pint plastic, H_2SO_4 added to pH <2, cool to 4°C	28 Days	ECM
Redox (Oxidation-Reduction Potential)	SM 2580 B	Analyzed In-situ	Analyze Immediately	Princeton Hydro
Sediment Phosphorus Fractioning Analysis**	Modified Psenner Sequential Extraction	Plastic Bag	48 hours	SePro
Geosmin**	SM 6040-D	40 mL glass bottle, cool to 4°C sodium omadine (optional)	72 hrs w/o preservation; 7days with preservation	EMSL
MIB**	SM 6040-D	40 mL glass bottle, cool to 4°C sodium omadine (optional)	72 hrs w/o preservation; 7days with preservation	EMSL
Phytoplankton Cell Counts and IDs**	10200 F 1 & 2	100 mL plastic bottle, Lugols solution added, cool to 4°C	ASAP	Princeton Hydro
Microcystins**	Abraxis Test Strip Kit, P/N 520020	Glass sample vials	5 days	Princeton Hydro
Phycocyanin**	Portable Fluorometer	Analyzed in-situ	Analyze Immediately	Princeton Hydro

***** = For Informational Purposes Only and to Inform Advisories, not for regulatory purposes.***

SAMPLE LABELS

A sample label will be affixed to each sample container at the time the samples are collected in the field. The following will be recorded on each label with waterproof ink:

- Sample station location and identification number
- Client/project name
- Date of sample collection
- Time of sample collection
- Name of sample collector
- Type of preservative (if used)

2.2 SAMPLE STORAGE, PRESERVATION AND HOLDING TIMES

Sample containers will be supplied by the laboratory (ECM, EMSL, or SePRO) pre-cleaned and certified to be free of contamination according to the United States Environmental Protection Agency (U.S. EPA) specification for the appropriate methods.

Sampling devices (that are not pre-sterilized and do not contain preservatives/fixing agents) will be rinsed three times with sample water prior to collecting each sample. All samples will be refrigerated or stored on ice (approximately 40°F, do not freeze) and sent to the laboratory immediately at the end of field sampling day for proper storage and preservation.

The sample holding containers, sample preservation methods and maximum holding time for each parameter have been supplied by ECM, EMSL and SePro and are listed in the original QAPP (May 2021).

2.3 CHAIN OF CUSTODY PROCEDURE

For discrete, water and sediment samples (chemical and biological), the sampling containers, preservation, and holding times will follow the specifications in Table 3. Procedures for direct measurements (in-situ water quality) can be found in the original QAPP (May 2021).

Chain of custody procedures will follow those detailed in the original QAPP (May 2021). Copies of both the ECM and SePRO chain of custodies can be found in Appendix A.

3.0 ANALYTICAL REQUIREMENTS

3.1 CHEMISTRY ANALYSES

Chemistry analyses will follow the same guidelines as presented in the original QAPP (May 2021).

3.2 LABORATORY STANDARDS AND REAGENTS

All stock standards and reagents will follow the same guidelines as presented in the original QAPP (May 2021).

4.0 QUALITY OBJECTIVES AND CRITERIA

Summaries of all water quality parameters to be measured and analytical methods to be used are shown in the original QAPP (May 2021). Additional parameters included in this addendum can be found in Table 3. This table was developed in coordination with the independent analytical laboratories; Both Environmental Compliance Monitoring, Inc. (ECM) and SePRO Research & Technology Campus will follow the methods and protocols listed in Table 3. ECM will be responsible for all laboratory analyses except for phytoplankton and zooplankton, which will be identified and enumerated by Princeton Hydro, LLC, and the fractionation analyses performed by SePRO.

Additional information on project detection limits, levels of interest, precision and accuracy for parameters of interest is listed in Table 4. This table was developed in conjunction with Mr. Thomas Grenci of ECM, Inc and Sam Mason of SePRO, and indicates the data quality that is expected for this study.

Table 7 - Information on Detection Limits, Precision and Accuracy for Discrete and Select *In-Situ* Water Quality Parameters

Parameter	Sample Matrix	Project Required Detection Limit	Reporting Level	Level of Interest	Relative Percent Difference*	Percent Recovery*
Total Dissolved Phosphorus*	Water	0.02 mg/L	0.01 mg/L	0.03 mg/L	-9 to 9	88 to 124
Soluble Reactive Phosphorus**	Water	N/A	5.0 î g / L	0.005 mg/L	-20 to 20	99.8 to 100.9
Total Phosphorus**	Water	N/A	10.0 î g /	5.0 mg/L	-20 to 20	88.6 to 110.7
Microcystin***	Water	1.0 î g / L	0.5 î g / L	3.0 î g / L	N/A	N/A
Phycocyanin†	Water	1.0 î g / L	1.0 î g / L	12.0 î g /	N/A	N/A

* As supplied by ECM
** As supplied by SePRO
*** Princeton Hydro will use the Abraxis field test strips, which are read with the Abrascan Dipstick Reader. The generated data are not being used for regulatory use but for educational and management purposes. Additionally, while concentrations of the cyanotoxin can be provided with the Reader, the data is essentially being used to identify the presence/absence of the cyanotoxin. If measurable concentrations of a cyanotoxin are identified, subsequent sampling and laboratory-based analyses (i.e. ELISA) may be required
† Level of interest is based on regression analysis done by both Princeton Hydro and NJDEP, and using the more conservative value that corresponds to 20,000 cells/mL threshold for HAB "Watch" Alert Status.

5.0 CALIBRATION PROCEDURES AND PREVENTATIVE MAINTENANCE

All calibration procedures will follow those detailed in the original QAPP (May 2021).

6.0 DOCUMENTATION, DATA REDUCTION AND REPORTING

All documentation, data reduction and reporting will follow the same guidelines as presented in the original QAPP (May 2021).

REFERENCES

References are presented in the original QAPP (May 2021).

APPENDIX A

SePRO Chain of Custody

SRTC | **SePRO Research & Technology Campus** | **SePRO**

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Company Name:* ______________________ Contact Person:* ______________________

Billing Address:* ____

Telephone:* ______________________ Email Address:* ______________________

Annual? Circle One (YES / NO)

Site Location/State:* ____

*Required fields

Project/Reference Name: ____

SePRO Aquatic Specialist Name: ____

Sampler: ____

Number of samples to be analyzed: ____

Check Payment Method: ☐ PO Number__________ ☐ VISA ☐ MasterCard Card No.__________________ CCV Code:_____ Expiration Date: _____

☐ Check here if you would like us to keep this credit card information on file for future lab analysis orders. Quote No.: ______________

(To establish a secure credit card file for future billing, please contact the SePRO Accounting Department at 317-580-8291).

Sample Location and Identification

Draw a map of water body, to include sample locations by sample identification number as listed on the other side of this form or enclose a copy of a prepared map with this information.

Direct all inquiries about your sampling and SeSCRIPT results to your SePRO Technical Sales Specialist.

Ship samples to:
SePRO SRTC
16013 Watson Seed Farm Road
Whitakers, NC 27891-9114
Email: srtclab@sepro.com
Tel: (252) 437-3282

Field Notes:

COC#:__________ Report #:__________

SRTC — SePRO Research & Technology Campus — SePRO

Algae & Water Quality Analytical Services

SeSCRIPT® Chain of Custody

Water Body Name:__________ City__________ State__________

Water Body Size: (acres)__________ Average Depth: (feet)__________ Date/Time Sample Collected:__________ One form for each water body

Bundle Analysis:

- ☐ Water Quality Baseline Bundle (pH, alkalinity, conductivity, hardness, dissolved oxygen, turbidity, total phosphorus, free reactive phosphorus)
- ☐ Water Quality Baseline Plus Bundle (Baseline Bundle plus chlorophyll a, nitrates, nitrites and total nitrogen)
- ☐ Algae and WQ Baseline Plus Bundle (WQ Baseline Plus Bundle and algae I.D./enumeration)
- ☐ Comprehensive Algae Bioassay (A multi-phase bioassay screening process to evaluate site specific algaecide performance. Also includes the Algae & WQ Baseline Plus analyses. Contact SePRO prior to collection and shipment.)

Individual Analysis:

- ☐ Algae ID††
- ☐ Alkalinity
- ☐ Chloride††
- ☐ Chlorophyll a
- ☐ Conductivity
- ☐ Dissolved Oxygen†
- ☐ Hardness
- ☐ Microbial Bacteria†† (total coliform & E. coli)
- ☐ Nitrates & Nitrites
- ☐ Nitrogen, Total (Kjeldahl)
- ☐ pH
- ☐ Phosphorus, Total (water)
- ☐ Phosphorus, Free Reactive (water)
- ☐ Phosphorus, Total & Free Reactive (water)
- ☐ Phosphorus, Total (sediments)
- ☐ Salinity††
- ☐ Total Dissolved Solids
- ☐ Total Suspended Solids
- ☐ Turbidity

Phosphorus, Fractionning†† (sediments)

- ☐ Level 1 Total & Available P
- ☐ Level 2 SRTC Comprehensive

Algae Infestation:

☐ Low ☐ Moderate ☐ High

Additional description:__________

Water Uses:

☐ Swimming ☐ Fishing ☐ Potable ☐ Irrigation ☐ All listed

Describe algae management history (*if any*):__________

† In order for the lab to generate more accurate D.O. data, it is recommended to preserve the sample immediately after collecting using appropriate reagents. †† This laboratory is not accredited for these tests: Salinity, Chloride, Phosphorus fractioning, Algae ID and Microbial Bacteria.

Client Sample Site I.D. (Required field)	Date Sample Collected (Required field)	Depth Sample Collected (feet)	Sample Location – Identify sites on map (GPS coordinates preferred)	Lab Use Only - Notes
1.				
2.				
3.				
4.				
5.				
6.				

Shipped by:__________ **Date/Time:**__________

To be filled out by laboratory

Received by:__________ **Date/Time:**__________

Sample condition upon receipt: ☐ Good condition ☐ No (explain)__________

Sample temperature upon receipt:__________ **Thermometer ID:**__________

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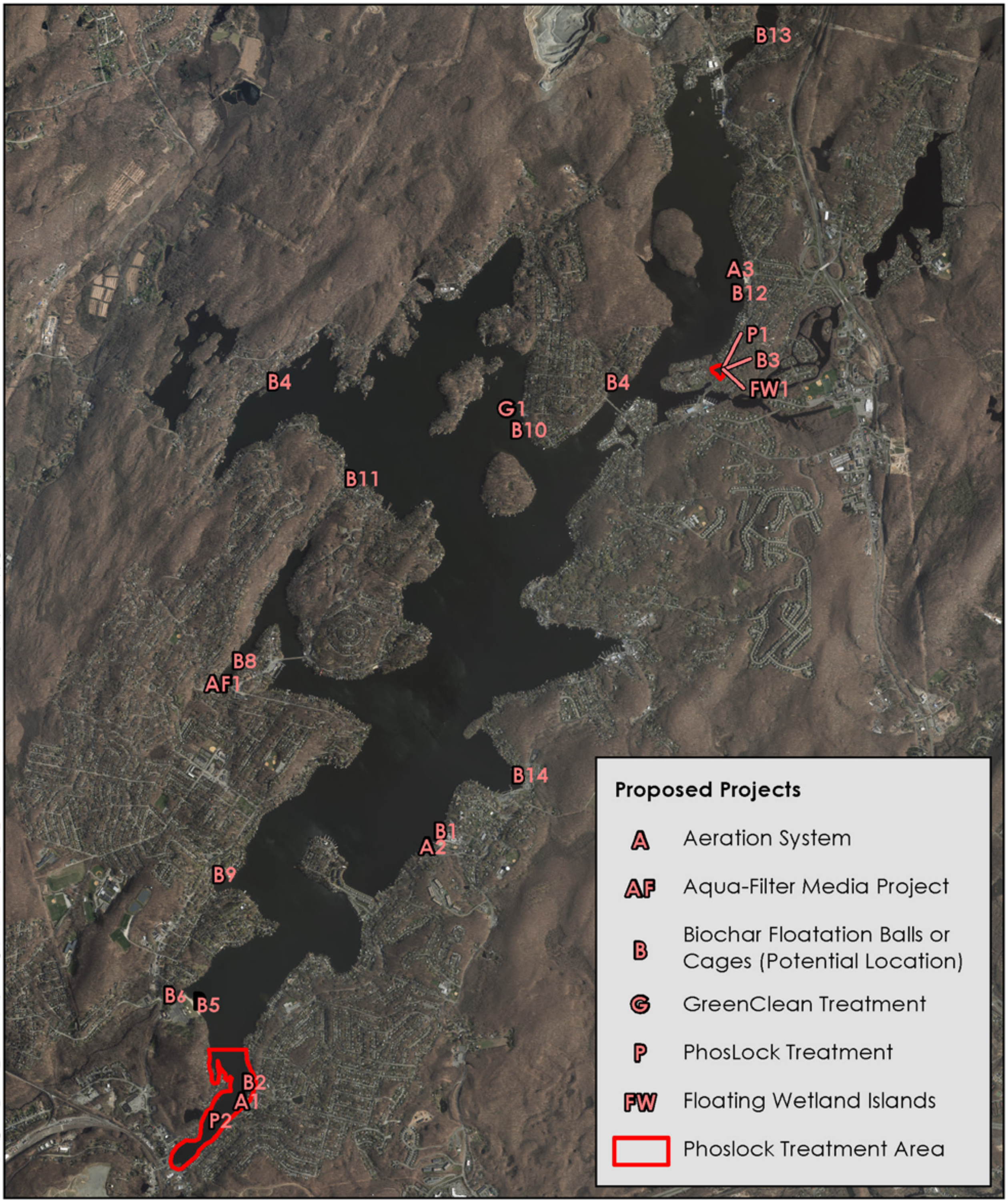
APPENDIX B

Maps



NOTES:
1. Project site locations are approximate.
2. 2015 orthoimagery obtained from NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS).

0 1,750 3,500 Feet

Map Projection: NAD 1983 StatePlane New Jersey FIPS 2900 Feet

FIGURE 2
PROJECT SITE LOCATION MAP

LAKE HOPATCONG
HOPATCONG AND MT. ARLINGTON BOROUGHS
AND JEFFERSON AND ROXBURY TOWNSHIPS
MORRIS AND SUSSEX COUNTIES, NEW JERSEY

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APPENDIX C

Sampling Plan Table

Summary Table: Sampling Plan Details							
Site ID	Location ID	Location	Coordinates (approximate)	Treatment Type	Parameters	Media	Schedule
AF1	Crescent Cove Beach Club	Hopatcong NJ	40.9405, -74.6615	SW Basins & Aquafilters	TP, SRP, TDP	water	3 stormwater samples after BMP implementation in 2020 growing season
A1	Shore Hills Beach	195 Mt. Arlington Blvd, Landing NJ	40.9098, -74.6573	Air Curtain System	Water clarity, DO, temperature, pH and conductivity; Chl a, microcystin, Phycocyanin, plankton counts	water	3 WQ sampling after BMP implementation June, July August of 2020
A2	Mount Arlington Municipal Beach	511 Windemere Ave., Mt. Arlington NJ	40.9291, -74.6391	Nanobubble Oxygen System	Water clarity, DO, temperature, pH and conductivity; Chl a, microcystin, Phycocyanin, plankton counts	water	3 WQ sampling after BMP implementation June, July August of 2020
A3	Lake Forest Yacht Club	35 Yacht Club Drive, Lake Hopatcong NJ	40.9705, -74.6093	Nanobubble Ozone System	Water clarity, DO, temperature, pH and conductivity; Chl a, microcystin, Phycocyanin, phytoplankton cell counts	water	3 WQ sampling events after BMP implementation June, July August of 2020
B1	Mt Arlington Beach	Mt Arlington NJ	40.9290, -74.6392	Biochar	TP, SRP and TDP	water	2 WQ sampling events during the 2020 growing season, each at 1 up- and 1 downgradient site
B2	Landing Channel	Landing NJ	40.9101, -74.6576	Biochar	TP, SRP and TDP	water	2 WQ sampling events during the 2020 growing season, each at 1 up- and 1 downgradient site
B3	Ashley Cove	Jefferson NJ	40.9639, -74.6114	Biochar	TP, SRP and TDP	water	2 WQ sampling events during the 2020 growing season, each at 1 up- and 1 downgradient site
B4	Byram Bay Community Club Beach	Byram NJ	40.9632, -74.6552	Biochar	TP, SRP and TDP	water	2 WQ sampling events during the 2020 growing season, each at 1 up- and 1 downgradient site
B5	Lake Hopatcong State Park	Hopatcong NJ	40.9167, -74.6620	Biochar	TP, SRP and TDP	water	2 WQ sampling events during the 2020 growing season, each at 1 up- and 1 downgradient site
P1	Ashley Cove	Jefferson, NJ	40.9639, -74.6114	PhosLock	Water clarity, DO, temperature, pH and conductivity; TP, SRP, TDP, ammonia-N, nitrate-N, and TSS; phytoplankton cell counts, phycocyanin, Chl a, microcystins	water	4 times during the 2020 and 2021 growing seasons, each (8 total) All stations that receive Phoslock will receive pre and post treatment sampling
P2	Landing	Landing, NJ	40.9060, -74.6633	PhosLock	Water clarity, DO, temperature, pH and conductivity; TP, SRP and TDP; phytoplankton cell counts, phycocyanin, Chl a, microcystins	water	1 pre- and 2 post-treatment each in the 2020 growing season
					P fractionation - TP (labile, metal oxide, reductant-soluble, organic, apatite and residual) and SRP (organic portion)	sediment	1 pre- and 2 post-treatment each in the 2020 growing season at 5 sampling sites (TBD)
G1	Capp Beach	Jefferson, NJ	40.9639, -74.6114, TBD TBD	GreenClean 5.0	Water clarity, DO, temperature, pH and conductivity; phytoplankton cell counts, phycocyanin, Chl a, microcystins, geosmin and MIB	water	1 pre- and 1 post-treatment each in the 2020 growing season at 3 sites (TBD)

APPENDIX III:

ASHLEY COVE – WATER QUALITY DATA

Ashley Cove in-situ 6/5/20								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.5	1.5	0.1	22.4	0.307	8.64	99.6	8.97	Clear, slightly brown water. Dense Milfoil and largeleaf pondweed. Sporadic mat algae on surface and plants
		1.0	20.11	0.332	6.94	76.6	8.28	

Ashley Cove in-situ 9/4/20								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.3	1.3	0.1	22.93	0.329	5.05	58.9	7.47	Brown water, particulates noted. Dense vegetation, both rooted/floating. Milfoil, coontail, Valisneria and largeleaf pondweed.
		1.0	22.66	0.331	2.55	29.6	7.18	

Ashley Cove in-situ 10/9/20								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.2	1.2	0.1	13.95	0.319	5.74	55.7	6.41	Yellow tinted water, rusty tannic color towards bottom. Vegetation noted on bottom. Milfoil and largeleaf pondweed.
		1.0	13.85	0.319	5.73	55.5	6.46	

Ashley Cove in-situ 9/14/21								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.2	1.2+	0.1	23.16	0.341	9.93	119.7	7.88	Very clear water, dense SAV growth including broadleaf pondweed, Eurasian watermilfoil, white water lily, and coontail
		1.0	21.86	0.355	5.14	60.1	7.24	

Ashley Cove in-situ 9/24/21								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.2	1.2+	0.1	20.52	388.6	4.60	52.7	7.22	Very clear water, dense SAV growth including broadleaf pondweed, Eurasian watermilfoil, white water lily, and coontail
		1.0	20.23	323.1	2.60	29.3	7.14	

Ashley Cove in-situ 10/18/21								
DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH	Notes
Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.	
1.2	1.2+	0.1	16.02	340.4	4.16	43.9	7.16	Very clear water, moderate SAV growth including broadleaf pondweed, Eurasian watermilfoil, white water lily, and coontail
		1.0	15.75	341.4	3.84	40.1	7.12	

Ashley Cove: Discrete Data (Surface)								
Date	Station	Chl a	NH3-N	NO3-N	SRP	TDP	TP	TSS
		ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/5/2020	AC-S	3.2	0.02	0.07	0.001	0.01	0.02	5
9/4/2020	AC-S	13.0	0.005	0.03	0.001	0.02	0.04	5
10/9/2020	AC-S	13.0	0.005	0.11	0.003	0.02	0.04	2
9/14/2021	AC-S	15.0	0.01	0.05	0.001	0.01	0.03	1
9/24/2021	AC-S	23.0	0.02	0.01	0.001	0.01	0.03	3
10/18/2021	AC-S	6.3	0.005	0.1	0.001	0.005	0.02	1

Ashley Cove: Discrete Data (Deep)				
Date	Station	SRP	TDP	TP
		mg/L	mg/L	mg/L
6/5/2020	AC-D	0.002	0.01	0.03
9/4/2020	AC-D	0.001	0.02	0.05
10/9/2020	AC-D	0.002	0.005	0.02
9/14/2021	AC-D	0.001	0.001	0.04
9/24/2021	AC-D	0.001	0.005	0.03
10/18/2021	AC-D	0.001	0.005	0.02

Ashley Cove: Cyanobacteria and Clarity Metrics						
Date	Station	Phycocyanin	Chl a	Cyano Cell Count	Microcystin	Secchi Depth
		ug/L	ug/L	cells/mL	ppb	meters
6/5/2020	Ashley Cove	3	6	2384	1 ppb	1.5
9/4/2020	Ashley Cove	10	12	12970	Negative	1.3
10/9/2020	Ashley Cove	3	6	0	Negative	1.2
9/14/2021	Ashley Cove	3	n.s.	0	Negative	1.3
9/24/2021	Ashley Cove	2	n.s.	2156	Negative	1.3
10/18/2021	Ashley Cove	4	n.s.	0	Negative	1.3

*Please note that *in-situ* chlorophyll *a* data wasn't collected in 2021 due to an issue with the fluorometer

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		**Sampling Date: 6/5/20**		**Examination Date: 6/9/20**	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	**1**	**Chlorophyta**	**1**	**Cyanophyta**	**1**
Cymbella	51	*Chlamydomonas*	609	*Dolichospermum*	2384
		Crucigenia	51		
Chrysophyta		*Eudorina*	203	**Cryptomonads**	
Uroglena	1572	*Coelastrum*	254	*Cryptomonas*	1065
Sites:	**1**	**Comments: Microcystins: 1 ppb**			
Total Phytoplankton genera/ Cells per mL	6189				
Total Cyanobacteria Cells per mL	2384				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		**Sampling Date: 9/4/20**		**Examination Date: 9/9/20**	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	**1**	**Chlorophyta**	**1**	**Cyanophyta**	**1**
Synedra	440	*Chlamydomonas*	440	*Dolichospermum*	5935
		Chlorella	989	*Pseudanabaena*	1209
Chrysophyta		*Scenedesmus*	1539	*Merismopedia*	1759
Dinobryon	989	*Crucigenia*	440	*Aphanizomenon*	4067
		Haematococcus	110	**Cryptomonads**	
Pyrrhophyta		*Coelastrum*	879	*Cryptomonas*	1759
Gymnodinium	110	*Staurastrum*	110		
Sites:	**1**	**Comments: Microcystin: Negative**			
Total Phytoplankton genera/ Cells per mL	20775				
Total Cyanobacteria Cells per mL	12970				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		Sampling Date: 10/9/20		Examination Date: 10/12/20	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	1	Chlorophyta	1	Cyanophyta	1
Synedra	80	*Crucigenia*	640		
Navicula	80				
Chrysophyta					
Dinobryon	961				
				Cryptomonads	
Euglenophyta				*Cryptomonas*	881
Trachelomonas	80				
Sites:	1	Comments: Microcystin: Negative			
Total Phytoplankton genera/ Cells per mL	2722				
Total Cyanobacteria Cells per mL	0				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		Sampling Date: 9/14/21		Examination Date: 10/9/21	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	1	Chlorophyta	1	Cyanophyta	1
Synedra	118	*Golenkinia*	39		
Navicula	79				
Chrysophyta					
Mallomonas	39				
				Cryptomonads	
Euglenophyta				*Cryptomonas*	236
Trachelomonas				*Chroomonas*	275
Sites:	1	Comments: Microcystin: Negative			
Total Phytoplankton genera/ Cells per mL	786				
Total Cyanobacteria Cells per mL	0				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		**Sampling Date: 9/24/21**		**Examination Date: 10/9/21**	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	**1**	**Chlorophyta**	**1**	**Cyanophyta**	**1**
Synedra	45	*Chlorella*	45	*Merismopedia*	2156
Navicula	45				
Dinoflagellates					
Ceratium	45				
				Cryptomonads	
Euglenophyta				*Cryptomonas*	90
Trachelomonas				*Chroomonas*	180
Sites:	**1**	**Comments: Microcystin: Negative**			
Total Phytoplankton genera/ Cells per mL	2606				
Total Cyanobacteria Cells per mL	2156				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Ashley Cove		**Sampling Date: 10/18/21**		**Examination Date: 10/19/21**	
Site 1: Surface grab					
Phytoplankton					
Bacillariphyta	**1**	**Chlorophyta**	**1**	**Cyanophyta**	**1**
		Chlamydomonas	98		
		Chlorella	49		
Dinoflagellates					
				Cryptomonads	
Euglenophyta				*Cryptomonas*	146
Trachelomonas	49			*Chroomonas*	1174
Sites:	**1**	**Comments: Microcystin: Negative**			
Total Phytoplankton genera/ Cells per mL	1516				
Total Cyanobacteria Cells per mL	0				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

APPENDIX IV:

AQUA-FILTER – STORMWATER DATA

Aqua-Filter with Biochar: Stormwater Sampling, 2021					
Date	**Site**	**Treatment**	**SRP**	**TDP**	**TP**
			mg/L	**mg/L**	**mg/L**
6/4/2021	Crescent Cove North	Pre-Treatment	0.020	0.02	0.03
		Post-Treatment	0.019	0.02	0.03
	Crescent Cove South	Pre-Treatment	0.024	0.02	0.03
		Post-Treatment	0.013	0.02	0.02
7/1/2021	Crescent Cove North	Pre-Treatment	0.019	0.05	0.05
		Post-Treatment	0.020	0.04	0.05
	Crescent Cove South	Pre-Treatment	0.026	0.04	0.14
		Post-Treatment	0.027	0.05	0.10
8/23/2021	Crescent Cove North	Pre-Treatment	0.078	0.08	0.12
		Post-Treatment	0.063	0.06	0.11
	Crescent Cove South	Pre-Treatment	0.057	0.07	0.10
		Post-Treatment	0.065	0.07	0.11
9/2/2021	Crescent Cove North	Pre-Treatment	0.052	0.07	0.10
		Post-Treatment	0.068	0.08	0.10
	Crescent Cove South	Pre-Treatment	0.064	0.08	0.10
		Post-Treatment	0.056	0.07	0.10
10/26/2021	Crescent Cove North	Pre-Treatment	0.084	0.10	0.14
		Post-Treatment	0.083	0.10	0.15
	Crescent Cove South	Pre-Treatment	0.077	0.09	0.11
		Post-Treatment	0.081	0.10	0.11

APPENDIX V:

AIR CURTAIN – WATER QUALITY DATA

Evaluation of Aeration System Sites, 5/19/21										
Station	**DEPTH (meters)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**	**Phycocyanin**	**Notes**
	Total	**Secchi**	**Sample**	**°C**	**mS/cm**	**mg/L**	**% Sat.**	**S.U.**	**µg/L**	
Shore Hills: Treatment	1.8	1.8+	0.1	22.12	0.444	10.97	128.10	9.26	3	Aeration system installed and running.
			1	21.58	0.455	11.26	130.90	9.28		
			1.5	21.39	0.457	11.32	130.60	924.00		
Shore Hills: Control	1.7	1.7+	0.1	22.20	0.429	11.22	131.30	9.28	3	Clear / slght brown water with few particulates. No surface scums
			1	21.83	0.434	11.62	134.00	9.28		
			1.5	21.23	0.436	12.55	145.10	9.41		

Evaluation of Aeration System Sites, 6/29/21										
Station	**DEPTH (meters)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**	**Phycocyanin**	**Notes**
	Total	**Secchi**	**Sample**	**°C**	**mS/cm**	**mg/L**	**% Sat.**	**S.U.**	**µg/L**	
Shore Hills: Treatment	1.8	1.8+	0.1	26.00	0.448	7.40	93.14	7.41	5	Noticeably less floating particulates in the treatment area behind the air curtain.
			1	25.87	0.447	7.39	92.90	7.42		
			1.5	25.71	0.447	7.66	95.22	7.42		
Shore Hills: Control	1.7	1.7+	0.1	26.13	0.448	7.31	92.44	7.22	4	Minor accumulation of suspended particulates in the water column.
			1	25.76	0.444	7.53	94.70	7.28		
			1.5	25.59	0.443	7.47	93.38	7.31		

Evaluation of Aeration System Sites, 7/27/21										
Station	**DEPTH (meters)**			**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**	**Phycocyanin**	**Notes**
	Total	**Secchi**	**Sample**	**°C**	**mS/cm**	**mg/L**	**% Sat.**	**S.U.**	**µg/L**	
Shore Hills: Treatment	1.8	1.1	0.1	26.78	0.445	7.63	98.50	7.66	13	Slight green water but no surface streaks and less particulates than the control zone.
			1	26.79	0.444	7.60	98.00	7.66		
			1.5	26.80	0.445	7.59	97.90	7.65		
Shore Hills: Control	2.0	1.1	0.1	26.95	0.412	7.83	101.30	7.70	13	Cloudy green water with the accumulaton of fine particulates along the surface.
			1	26.88	0.405	7.77	100.50	7.70		
			1.5	26.66	0.402	7.65	98.50	7.67		

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 5/19/21**			**Examination Date: 5/27/21**		
Site 1: Shore Hills Treatnent			**Site 2: Shore Hills Control**					
Phytoplankton								
Bacillariphyta	**1**	**2**	**Chlorophyta**	**1**	**2**	**Cyanophyta**	**1**	**2**
Fragilaria		P	*Chlorella*	*P*	P	*Coelosphaerium*		480
			Pediastrum	*P*	C			
			Scenedesmus	*P*	P			
			Staurastrum	*P*	P	**Cryptomonads**		
						Cryptomonas		R
Dinoflagellates								
Ceratium		R				**Euglenophyta**		
						Euglena sp.	*P*	P
						Trachelomonas	*P*	P
Sites:	**1**	**2**	**Comments: Microcystin tests were Negative**					
Total Phytoplankton Genera	6	10						
Total Cyanobacteria Cells per mL	0	480						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 6/29/21**			**Examination Date: 6/30/21**		
Site 1: Shore Hills Treatnent			**Site 2: Shore Hills Control**					
Phytoplankton								
Bacillariphyta	**1**	**2**	**Chlorophyta**	**1**	**2**	**Cyanophyta**	**1**	**2**
Tabellaria		P	*Lagerheimia*		R	*Aphanocapsa*	*946*	813
			Pediastrum	*P*	R	*Pseudanabaena*	*7429*	
			Scenedesmus	*R*		*Merismopedia*		678
			Sphaerocystis	*P*	P	**Cryptomonads**		
			Staurastrum	*R*		*Cryptomonas*	*C*	C
Chrysophyta								
Dinobryon	*P*	P	**Dinoflagellates**			**Euglenophyta**		
			Ceratium	*P*	R	*Phacus*	*R*	
						Trachelomonas	*R*	R
Sites:	**1**	**2**	**Comments: Microcystin tests were Negative**					
Total Phytoplankton Genera	11	10						
Total Cyanobacteria Cells per mL	8375	1491						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 7/27/21**			**Examination Date: 12/20/21**		
Site 1: Shore Hills Treatnent			**Site 2: Shore Hills Control**					
Phytoplankton								
Bacillariphyta	**1**	**2**	**Chlorophyta**	**1**	**2**	**Cyanophyta**	**1**	**2**
Asterionella	*C*		*Akinstrodesmus*	*P*	P	*Aphanizomenon*	*2329*	2885
Fragilaria	*P*	P	*Coelastrum*	*R*	R	*Coelosphareium*	*10191*	3607
Melosira	*C*	C	*Crucigenia*	*R*	R	*Dolichospermum*	*3785*	8655
Synedra	*C*	P	*Eudorina*	*P*	P	*Microcystis*	*291*	1082
Tabellaria	*P*	C	*Gleotila*	*P*	P			
			Nephrocytium	*P*	P	**Cryptomonads**		
			Pediastrum	*P*	P	*Cryptomonas*		R
Chrysophyta			*Quadrigula*	*R*				
			Scenedesmus	*C*	P	**Euglenophyta**		
			Selenastrum	*P*		*Euglena sp.*	*P*	P
			Staurastrum	*P*	P			
			Tetradesmus	*P*	R			
Sites:	**1**	**2**	**Comments: Microcystin tests were Negative**					
Total Phytoplankton Genera	22	20						
Total Cyanobacteria Cells per mL	16596	16229						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

APPENDIX VI:

LANDING CHANNEL – WATER QUALITY DATA

Landing Channel: Pre-Treatment Monitoring - 6/12/20								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	2.0	1.5	0.1	23.59	0.455	5.93	70.1	7.40
			1.0	23.47	0.457	5.89	69.5	7.24
			1.5	23.21	0.459	5.93	69.6	7.21
ST-5	1.4	1.4	0.1	22.97	0.437	7.66	89.5	7.52
			1.0	22.38	0.436	6.58	76.0	7.44

Landing Channel: Post-Treatment Monitoring - 6/24/20								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	2.1	1.9	0.1	26.93	0.467	7.62	95.1	7.50
			1.0	26.59	0.469	7.62	94.5	7.47
			1.8	26.14	0.464	7.73	95.1	7.54
ST-5	2.7	1.5	0.1	25.88	0.452	6.64	81.3	7.67
			1.0	25.24	0.445	6.24	75.5	7.56
			2.0	24.62	0.444	6.22	74.4	7.50
			2.5	24.34	0.445	5.78	68.8	7.42

Landing Channel: Post-Treatment Monitoring - 7/22/20								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	1.9	1.0	0.1	28.75	0.452	9.33	120.2	8.37
			1.0	28.67	0.452	9.61	123.7	8.35
			1.5	28.24	0.45	7.41	94.8	7.79
ST-5	1.2	1.1	0.1	28.12	0.446	8.82	112.5	8.17
			1.0	28.06	0.446	8.88	113.0	8.10

Landing Channel: Post-Treatment Monitoring - 9/23/20								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	2.0	1.2	0.1	15.76	0.442	10.15	102.4	7.91
			1.0	15.73	0.442	10.09	101.8	7.97
			1.5	15.69	0.442	10.07	101.5	7.99
ST-5	3.1	1.1	0.1	16.72	0.439	10.16	104.6	8.00
			1.0	16.71	0.439	10.12	104.2	8.01
			2.0	16.60	0.439	10.14	104.2	8.01
			2.5	16.54	0.439	10.04	103.0	8.05

Landing Channel: Post-Treatment Monitoring - 5/19/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	1.7	1.7+	0.1	22.20	0.429	11.22	131.3	9.28
			1.0	21.83	0.434	11.62	134.0	9.28
			1.5	21.23	0.436	12.55	145.1	9.41
ST-5	2.5	2.2	0.1	18.75	0.434	11.25	122.4	8.83
			1.0	18.58	0.433	11.35	123.7	8.76
			2.0	17.75	0.429	11.13	119.4	8.49

Landing Channel: Post-Treatment Monitoring - 6/9/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	1.7	1.7+	0.1	25.00	0.425	7.96	99.4	7.66
			1.0	24.29	0.423	7.83	96.4	7.63
			1.5	23.62	0.425	8.56	104.0	7.71
ST-5	3.2	2.6	0.1	24.56	0.418	9.17	113.6	7.94
			1.0	24.35	0.418	9.23	114.1	7.91
			2.0	22.56	0.419	9.45	112.1	7.83
			3.0	20.56	0.420	6.20	70.8	7.47

Landing Channel: Post-Treatment Monitoring - 7/13/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	1.7	1.3	0.1	25.82	0.422	7.74	97.1	7.53
			1.0	25.83	0.422	7.74	96.8	7.54
			1.5	25.82	0.422	7.66	96.1	7.52
ST-5	3.2	1.4	0.1	25.82	0.420	8.90	111.9	7.94
			1.0	25.76	0.420	8.87	111.8	7.91
			2.0	25.70	0.419	8.68	109.4	7.83
			3.0	25.64	0.421	8.55	107.6	7.47

Landing Channel: Post-Treatment Monitoring - 8/17/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	2.0	1.0	0.1	25.71	0.435	7.88	98.9	7.60
			1.0	25.74	0.433	7.74	97.1	7.60
			1.5	25.62	0.432	7.70	96.4	7.58
ST-5	1.2	1.0	0.1	25.45	0.432	6.95	86.8	7.46
			1.0	25.84	0.429	6.64	83.6	7.44

Landing Channel: Post-Treatment Monitoring - 9/14/21								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
Landing	1.7	1.3	0.1	23.72	0.178	9.53	115.9	8.22
			1.0	22.98	0.420	9.85	118.1	8.36
			1.5	22.67	0.419	10.00	119.1	8.40
ST-5	2.4	1.3	0.1	22.19	0.408	9.20	108.5	7.95
			1.0	22.12	0.408	9.16	107.8	8.00
			2.0	22.07	0.408	8.90	104.7	7.95

Landing Channel: Discrete Data (Surface)					
Date	Station	Chl a	SRP	TDP	TP
		μg/L	mg/L	mg/L	mg/L
6/12/2020	Landing Channel	5.2	0.001	0.020	0.03
	ST-5 Control	9.4	0.001	n.s	0.03
6/24/2020	Landing Channel	4.0	0.001	0.005	0.02
	ST-5 Control	n.s.	n.s.	n.s	n.s.
7/22/2020	Landing Channel	26.0	0.001	0.040	0.05
	ST-5 Control	22.0	0.001	n.s	0.03
9/23/2020	Landing Channel	n.s.	0.004	0.020	0.03
	ST-5 Control	17.0	0.001	n.s.	0.03
5/19/2021	Landing Channel	2.4	0.002	0.010	0.03
	ST-5 Control	2.7	0.001	n.s.	0.01
6/9/2021	Landing Channel	6.6	0.001	0.010	0.02
	ST-5 Control	2.5	0.001	n.s.	0.01
7/13/2021	Landing Channel	30.0	0.001	0.010	0.03
	ST-5 Control	16.0	0.001	n.s.	0.02
8/17/2021	Landing Channel	15.0	0.001	0.010	0.03
	ST-5 Control	12.0	0.001	n.s.	0.04
9/14/2021	Landing Channel	11.0	0.001	0.005	0.03
	ST-5 Control	14.0	0.001	n.s.	0.03

Landing Channel: Discrete Data (Deep)				
Date	Station	SRP	TDP	TP
		mg/L	mg/L	mg/L
6/12/2020	Landing Channel	0.002	0.020	0.04
6/24/2020	Landing Channel	0.001	0.010	0.02
7/22/2020	Landing Channel	0.001	0.050	0.08
9/23/2020	Landing Channel	0.001	0.020	0.03
5/19/2021	Landing Channel	0.001	0.01	0.03
6/9/2021	Landing Channel	0.001	0.01	0.02
7/13/2021	Landing Channel	0.001	0.005	0.06
8/17/2021	Landing Channel	0.001	0.01	0.03
9/14/2021	Landing Channel	0.001	0.005	0.03

Landing Channel: Cyanobacteria and Clarity Metrics						
Date	Station	Phycocyanin	Chl *a*	Cyano Cell Counts	Microcystin	Secchi Depth
		µg/L	µg/L	mg/L	ppb	meters
6/12/2020	Landing Channel	3	4	5969	Negative	1.5
6/24/2020	Landing Channel	3	9	1624	Negative	1.9
7/22/2020	Landing Channel	22	16	63230	n.s.	1
9/23/2020	Landing Channel	10	9	26214	Negative	1.2
5/19/2021	Landing Channel	3	n.s.	480	Negative	1.7
6/9/2021	Landing Channel	4	n.s.	874	Negative	1.7
7/13/2021	Landing Channel	14	n.s.	299	Negative	1.3
8/17/2021	Landing Channel	16	n.s.	22842	Negative	1
9/14/2021	Landing Channel	6	n.s.	25268	Negative	1.3

Phytoplankton and Zooplankton Community Composition Analysis					
Sampling Location: Hopatcong		**Sampling Date: 6/12/20**		**Examination Date: 6/17/20**	
Site 1: Landing Surface					
Phytoplankton					
Bacillariphyta	**1**	**Chlorophyta**	**1**	**Cyanophyta**	**1**
Navicula	43	*Chlorella*	171	*Dolichospermum*	298
Tabellaria	554	*Chlamydomonas*	43	*Aphanizomenon*	5287
Asterionella	640	*Crucigenia*	298	*Pseudanabaena*	384
Chrysophyta		*Gloeotila*	171	**Cryptomonads**	
Sites:	**1**	**Comments:**			
Total Phytoplankton genera/ Cells per mL	7889				
Total Cyanobacteria Cells per mL	5969				
		Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)			
		Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare			

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			Sampling Date: 6/24/20			Examination Date: 6/26/20		
Site 1: Landing Surface			Site 2: ST-5 Surface					
Phytoplankton								
Bacillariphyta	**1**	**2**	**Chlorophyta**	**1**	**2**	**Cyanophyta**	**1**	**2**
Navicula	*49*		*Chlorella*	*148*	337	*Dolichospermum*	*1624*	562
Cymbella	*49*		*Chlamydomonas*	*98*	225	*Aphanizomenon*		2756
Fragilaria		450	*Pediastrum*	*788*	900			
Synedra		169	*Gloeotila*	*98*	1237	**Cryptomonads**		
Stephanodiscus		56	*Scenedesmus*	*591*	225	*Cryptomonas*	*394*	619
Chrysophyta			*Pandorina*	*197*				
Dinobryon	*689*	225	*Eudorina*	*394*	450			
			Haematococcus	*98*	112			
			Ankistrodesmus	*49*				
			Treubaria		46			
Sites:	**1**	**2**	**Comments: Microcystin tests were Negative at both stations**					
Total Phytoplankton genera/ Cells per mL	5266	8369						
Total Cyanobacteria Cells per mL	1624	3318						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			Sampling Date: 7/22/20			Examination Date: 7/23/20		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**	**2**	**Chlorophyta**	**1**	**2**	**Cyanophyta**	**1**	**2**
Fragilaria	*675*		*Akinstrodesmus*	*771*		*Aphanizomenon*	*34892*	
Melosira	*771*		*Chlamydomonas*	*289*		*Aphanocapsa*	*6843*	
Synedra	*96*		*Chlorella*	*1446*		*Dolichospermum*	*12338*	
Tabellaria	*1157*		*Cosmarium*	*193*		Lyngbya	4338	
			Scenedesmus	*771*		*Woronchinia*	*4819*	
Chrysophyta			*Sphaerocystis*	*5301*				
			Staurastrum	*96*		**Cryptomonads**		
						Chroomonas	*289*	
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton genera/ Cells per mL	75085	0						
Total Cyanobacteria Cells per mL	63230	0						
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 9/23/20**			**Examination Date: 9/24/20**		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Navicula			*Chlorella*	*200*		*Dolichospermum*	*9505*	
Melosira	*200*		*Haematococcus*	*200*		*Aphanizomenon*	*12807*	
Fragilaria	*400*		*Ankistrodesmus*	*100*		*Pseudanabaena*	*3902*	
Synedra	*2802*		*Staurastrum*	*200*		**Cryptomonads**		
Stephanodiscus			*Scenedesmus*	*600*		*Cryptomonas*	*300*	
Chrysophyta			*Eudorina*	*800*				
Dinobryon	*100*					**Euglenophyta**		
						Euglena	*100*	
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	32216							
Total Cyanobacteria Cells per mL	26214							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 5/19/21**			**Examination Date: 5/27/21**		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Fragillaria	*64*		*Chlorella*	*224*		*Coelosphaerium*	*480*	
			Scenedesmus	*128*				
						Cryptomonads		
						Cryptomonas		
Chrysophyta								
						Euglenophyta		
						Euglena	*32*	
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	928							
Total Cyanobacteria Cells per mL	480							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 6/9/21**			**Examination Date: 6/11/21**		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Synedra	*44*		*Pediastrum*	*874*		*Aphanizomenon*	*874*	
			Schroederia	*44*				
						Cryptomonads		
						Cryptomonas	*88*	
Chrysophyta								
						Euglenophyta		
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	1924							
Total Cyanobacteria Cells per mL	874							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 7/13/21**			**Examination Date: 7/23/21**		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Melosira	*1198*		*Akinstrodesmus*	*75*		*Dolichospermum*	*299*	
Synedra			*Brachiomonas*	*3*				
			Chlamydomonas	*37*				
			Chlorella	*225*		**Cryptomonads**		
			Coelastrum	*562*		*Cryptomonas*	*299*	
Chrysophyta			*Crucigenia*	*599*				
			Dicellula	*13*		**Euglenophyta**		
			Eudorina	*25*				
			Pediastrum	*19*				
			Scenedesmus	*14*				
			Sphaerocystis	*460*				
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	3828							
Total Cyanobacteria Cells per mL	299							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			Sampling Date: 8/17/21			Examination Date: 8/20/21		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Melosira	*3710*		*Akinstrodesmus*	*371*		*Aphanizomenon*	*12720*	
Synedra	*742*		*Chlorella*	*265*		*Dolichospermum*	*1378*	
Tabellaria	*212*		*Crucigenia*	*423*		*Lyngbya*	*8744*	
			Dicellula	*847*		**Cryptomonads**		
			Goolenkinia	*105*		*Cryptomonas*	*371*	
Chrysophyta			*Scenedesmus*	*635*				
			Schroederia	*53*		**Euglenophyta**		
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	30576							
Total Cyanobacteria Cells per mL	22842							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			Sampling Date: 9/14/21			Examination Date: 10/9/21		
Site 1: Landing Surface								
Phytoplankton								
Bacillariphyta	**1**		**Chlorophyta**	**1**		**Cyanophyta**	**1**	
Synedra	*505*		*Scenedesmus*	*786*		*Aphanizomenon*	*14038*	
			Chlorella	*112*		*Dolichospermum*	*11230*	
			Gleotila	*1123*				
			Staurastrum	*505*		**Cryptomonads**		
						Cryptomonas	*168*	
Chrysophyta								
						Euglenophyta		
						Trachelomonas	*56*	
Sites:	**1**		**Comments: Microcystin tests were Negative**					
Total Phytoplankton genera/ Cells per mL	28523							
Total Cyanobacteria Cells per mL	25268							
			Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)					

APPENDIX VII:

CAPP BEACH – WATER QUALITY DATA

Capp Beach: *In-Situ*						
Date	Secchi	Temperature	Specific Conductance	Dissolved Oxygen		pH
	(m)	°C	mS/cm	mg/L	% Sat.	S.U.
8/12/2020	0.8	28.28	0.367	8.40	107.6	7.88
8/17/2020	1.1	26.25	0.419	9.09	112.0	7.77

CAPP Beach: Cyanobacteria and Clarity Metrics						
Date	Station	Phycocyanin	Chl a	Cyano Cell Count	Microcystin	Secchi Depth
		ug/L	ug/L	cells/mL	ppb	meters
8/12/2020	B2	23	20	60297	Negative	0.8
8/17/2020	B2	31	26	n.s.	Negative	1.1

APPENDIX VIII:

BIOCHAR FEASIBILITY STUDY

BIOCHAR FEASIBILITY STUDY

MORRIS AND SUSSEX COUNTIES, NEW JERSEY

MAY 2020

PREPARED FOR:

LAKE HOPATCONG COMMISSION
ATTN: RON SMITH, COMMISSONER
P.O. BOX 8519
LANDING, NJ 07850
973-601-7801

PREPARED BY:

PRINCETON HYDRO, LLC
1108 OLD YORK ROAD, SUITE 1
P.O. BOX 720
RINGOES, NJ 08551
908-235-5660

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INTRODUCTION

This document provides a summary of the field investigations into the potential locations along the shoreline of Lake Hopatcong for the installation of Biochar, a processed wood product that has a high affinity for removing pollutants from water. For Lake Hopatcong we are particularly interested in the Biochar's ability to remove phosphorus from water, since elevated phosphorus concentrations favor the growth of cyanobacteria. In turn, high amounts of cyanobacteria have the potential to produce Harmful Algal Blooms (HABs), which result in negative impacts on the ecology, recreation, health and economy of local lake communities.

The field work for this Biochar project was conducted on 10 and 17 of April 2020. Note the work for this investigation is covered under the HAB grant provided to the Lake Hopatcong Commission by the NJDEP (WM20-034). The purpose of this document was to identify and prioritize locations for the installation of Biochar around Lake Hopatcong.

BOROUGH OF HOPATCONG

LAKESIDE BOULEVARD / HOLIDAY DRIVE DRAINAGE STREAM

Site Description: There is a small drainage stream located off of Holiday Drive that receives runoff from the surrounding neighborhood and discharges into Ingram Cove; the stream had water flowing during the site visit and typically has some flow from the small creek that drains to it. Extensive erosion was observed along both banks during the site visit. Excessive sedimentation was occurring along the streambed and the inlet of this drainage stream in Ingram Cove and was probed in the past for sediment accumulation; sediment deposition was measured at approximately 2.5 feet compared to approximately only 0.5 feet a few feet away from where the stream enters the cove. There is a double catch basin on the corner of Lakeside Boulevard and Holiday Drive that receives the runoff from the small waterway and thus drains directly to the drainage stream.

Potential Locations:

In-stream directly where the water flows out of the pipe (Figure 1a).
In stream at the mouth of the stream right before the lake, anchored to a tree (Figure 1b).
Directly where the stream empties into Ingram Cove (Figure 1c).
In the catch basin on street (Figure 1d).
Anchored in swim area of Ingram Cove.

Figure 1a

Figure 1b

Figure 1c

Figure 1d

SOUTHERN END OF CRESCENT COVE (BELL AVENUE)

Site Description: Bell avenue is a steep street that runs perpendicular to Crescent Cove, with no swales or other vegetative structures in place to capture or treat stormwater. There are at least four outflow pipes in the southern end of Crescent Cove that drain runoff from Bell Avenue, Crescent Road, and the area surrounding the Lakeside Boulevard and River Styx Road intersection. The main outlet pipes are located on the southern end of the Cove, where Bell Avenue intersects Crescent Road. As such, these two structures would be the ideal locations for the installation of biochar but the cove would benefit from the installation in each of the outlet structures if possible. The following section provides descriptions of each of the 4 sites, starting from the east on the corner of Crescent Road and moving west towards Bell Ave:

Potential Locations:

Small outlet structure and only one manhole visible on the road; likely drains water from the steep part of Crescent Road and the River Styx Road cross section (Figure 2a). No catch basins visible on Crescent Road and thus may be located too far from the Cove.

Bigger outlet structure with concrete outlet; likely drains water from flatter portion of Bell Ave/Crescent Road. There is a manhole located in the middle of the street and catch basin across the street. There is also a pump house directly across the street (Figure 2b).

Major storm inlet that drains water from the steep portion of Bell Ave, both surface and sub-surface runoff. There is a manhole in the middle of the road and multiple catch basins located in a row up Bell Ave. This appears to be the major inlet of this portion of Crescent Cove and should be included for biochar (Figure 2c).

Big storm grate on Crescent Road; receives sub-surface runoff from the modified drainage stream across the street after the runoff dips under Crescent Road. The catch basin was extremely filled in during the site visit. The outlet structure associated with this storm grate could not be located from the road during the site visit; it is possible it connects with the major storm inlet (Figure 2c) before emptying into the cove (Figure 2d).

Figure 2a

Figure 2b

Figure 2c

Figure 2d

WITTEN PARK DRAINAGE STREAM

Site Description: There is a drainage stream located in Witten Park that receives runoff from the surrounding neighborhood through two outfall pipes before discharging into Byram Bay. Extensive erosion was observed along both banks during the site visit, including bank scouring and severe undercutting. Both streambanks were void of any vegetation along the entire reach, and the entire park was comprised of mostly loose dirt and gravel. Both outfall pipes are located a few feet higher in elevation than the stream, and the water travels down scattered rocks before entering the main channel. The bigger pipe located just above the main stream is the primary inlet and had a small flow of water during the time of the site visit; a neighbor came out during the site visit and confirmed that the pipe always has water flowing and that the drainage stream flows heavily during periods of rain. There are catch basins located on the intersection of Maxim Drive and Hudson Avenue that empty into each of the two stormwater pipes.

Potential Locations:

In-stream directly where the water flows out of the pipe (Figure 3a).
In stream at the mouth of the stream right before the lake, anchored to fence (Figure 3b).
In-stream in the middle anchored to a tree (Figure 3c).
In the catch basin on street (Figure 3d).

Figure 3a

Figure 3b

Figure 3c

Figure 3d

BYRAM BAY COMMUNITY CLUB

Site Description: The Byram Bay Community Club is located on a steep slope, surrounded by a lot of large rocks in Ingram Cove. The Community Club has a small swim area that drops off in depth rather quickly, a steep boat launch area and a dock that extends approximately 15 meters into the lake. During the summer months, a swim line approximately 30 meters in length extends from the dock area across to the large rocks. Additionally, a small stream that drains part of the surrounding community travels under the Community Club before emptying into the lake near the waterslide; the stream is located on the surface before dipping below the surface at the start of the site property on the west side. A large catch basin is located in the parking lot of the community club that would be an ideal location for the installation of biochar.

Potential Locations:

In the catch basin located in the parking lot (Figure 4a, b).
Attached to the swim line or anchored in a nearby area (Figure 4c).
Attached to the end of the dock (Figure 4d).

Figure 4a

Figure 4b

Figure 4c

Figure 4d

BOROUGH OF ROXBURY

HOPATCONG STATE PARK BEACH

Site Description: The Hopatcong State Park Beach is located in the northeast corner of the State Park and has approximately 200 meters of beach shoreline (Figure 5a). The beach is flanked by approximately 75 meters of a grassy shoreline that lacks a vegetative buffer on the southeast side and by the boat launch on the northwest side. There are also three 10-meter rock jetties along the beach area; one on the southeast side of the beach and two on the northwest side by the boat launch. A swim line will be placed along the swim area of the beach during the summer months.

Potential Locations:

- Swim Line
- Along rock jetties (Figure 5b).
- Along concrete bulkhead located next to the beach (Figure 5c).

Figure 5a

Figure 5b

Figure 5c

HOPATCONG STATE PARK CATCH BASINS

Site Description: In addition to the Hopatcong State Park Beach, the next best location on site for the installation of biochar are in the storm drains that drain to the beach area. Three separate series of catch basins were observed near the beach area: a series of catch basins from the parking lot down to the shoreline on the southeast side of the beach near the playground, one deep catch basin just downstream of the rain garden near the parking lot, and one catch basin in the grass area just north of the bathrooms. Any remaining storm drains that were observed on the northwest side of the park likely drain to the Musconetcong River and would have little to no impact on Lake Hopatcong. The series of catch basins near the playground likely receives the majority of the parking lot stormwater and would be the ideal location for the installation of biochar.

Potential Locations:

- Series of 3 catch basins on southeast side of park between parking lot and beach (Figure 6a).
- 1 deep catch basin downstream of the rain garden (Figure 6b).
- 1 catch basin on the grass just NW of the bathrooms (Figure 6c).

Figure 6a

Figure 6b

Figure 6c

SHORE HILLS BEACH CLUB

Site Description: Shore Hills Beach Club is a narrow beach club located on Mt. Arlington Drive. The Beach Club contains a beach/swim area that is approximately 100 meters in length. The swim area is secluded from Landing Channel in Lake Hopatcong by a cement dock that contains boat slips on the opposite side (Figure 7a). The Beach Club also contains a boat launch and approximately 80 boat slips across the property. The property currently contains a small aeration unit that is located within the swim area. Landing Channel on the opposite side of the docks as the swim area contains large rocks which are all marked by buoys. The owner of the club mentioned that he did not prefer to have the biochar located in the swim area; it would likely be difficult to attach to the docks as they mostly all contain boat slips. There is a double catch basin on Mt. Arlington Drive that could be a potential installation location.

Potential Locations:

Located on the opposite side of the swim area, anchored near one of the buoys that mark the location of the rocks (Figure 7b).
In the double catch basin on Mt. Arlington Drive.

Figure 7a

Figure 7b

BOROUGH OF MOUNT ARLINGTON

EDITH M. DECKER ELEMENTARY SCHOOL

Site Description: There is a small stream that runs along the front of the site school, between the parking lot and Howard Blvd. The stream travels through a culvert and under Howard Blvd. before discharging into Lake Hopatcong down the street. There are two large catch basins located between the parking lot and the stream in front of the school; these catch basins drain back to the stream before it enters the culvert. There is also a curbside storm drain and multiple smaller catch basins on the side of the parking lot that drain to the same location as the stream. Thus, the stream receives runoff from the stream itself, the school property, and a portion of Howard Blvd.

Potential Locations:

Attached to the grate on the culvert (Figure 8a).
Inside the catch basins on the street (Figure 8b).

Figure 8a

Figure 8b

MT. ARLINGTON BEACH CLUB

Site Description: There is a stream just uphill from the beach that runs through a culvert before it travels under the parking lot, eventually discharging into the lake adjacent to the beach. There is a curbside storm drain on the opposite side of the parking lot from where the stream enters the culvert that could be a potential location for the in. An investigation into the hydrology of the stream and associated discharge into Lake Hopatcong revealed that this stream drains a substantial portion of the upstream neighborhood. The beach contains approximately 30 meters of shoreline and a dock extends approximately 47 meters into the lake from the shoreline; it is currently unknown if there will be a swim line in place during the summer months.

Potential Locations:

Attached along the dock on the left side of the property (Figure 9a).
Anchored to the potential swim line or somewhere in the swim area (Figure 9b).
In the catch basin located in the parking lot (Figure 9c, d).

Figure 9a

Figure 9b

Figure 9c

Figure 9d

BOROUGH OF JEFFERSON

CAPP BEACH

Site Description: Capp Beach is a small beach area located at the end of Maine Street and has approximately 40 meters of shoreline (Figure 10a). The beach is flanked by a dock that sticks out approximately 20 meters into the shoreline on the north side and a small rock jetty on the south side. It is possible that the swim area will have a swim line during the summer months, but none was visible during the site visit.

Potential Locations:

Swim line.
Attached to the dock (Figure 10b).
Along the small jetty next to beach on the south side (Figure 10c).

Figure 10a

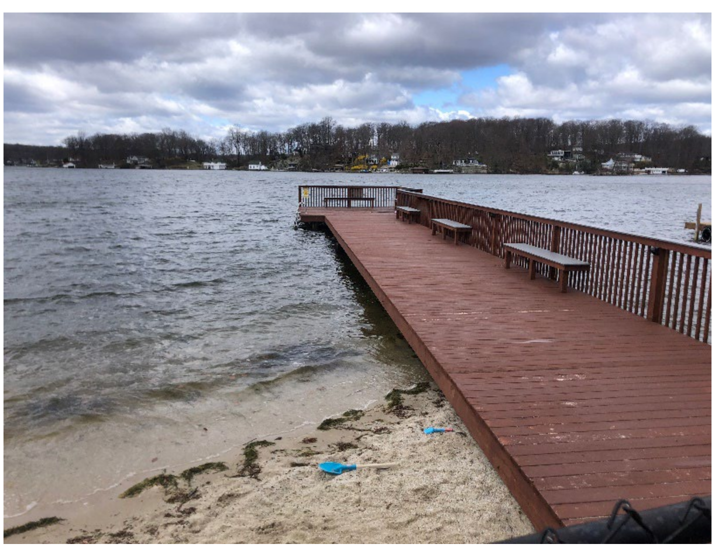


Figure 10b

Figure 10c

BRADY ROAD / NORTH LAKESIDE AVENUE (BEEBE MARINA)

Site Description: There is a small stream on the west side of Brady Road that travels underground and into a catch basin in the parking lot on the west side of the Brady Road and North Lakeside Avenue intersection. Water from this catch basin then travels under Brady Road, through a double catch basin located on the corner of Brady Road and North Lakeside Avenue, and into Lake Hopatcong. This double catch basin likely receives a considerable volume of stormwater, Including from the small stream, the surrounding roads and the parking lots of the restaurants across the street. Thus, the double catch basin would be an ideal location for the installation of biochar.

Potential Locations:

Directly in double catch basin that drains the small stream and surrounding neighborhood stormwater (Figure 11a).

Figure 11a

LAKE WINOA OUTLET AT LORETTACONG DRIVE

Site Description: An un-named stream between the outlet of Lake Winoa and Lake Hopatcong flows under Lorettacong Drive and into Lake Hopatcong. The erosion in the stream upgradient of Lorettacong Drive is extensive and is likely contributing a substantial nutrient and sediment load to Lake Hopatcong. If biochar could be stabilized in the shallower, concrete channelized portion of the stream just downgradient of Lorettacong Drive, it would be ideal. There are rocks, trees, and the concrete that are potential locations to stabilize biochar to, although this section likely receives elevated discharge rates during storm events. If this is not feasible, anchored biochar in the lake itself just after there the stream enters the lake would be ideal.

Potential Locations:

In-stream, directly downgradient of Lorettacong (potentially anchor to the rocks of the side concrete walls) (Figure 12a, b).
Further downstream in Lake Hopatcong (anchored to bottom) (Figure 12c).

Figure 12a

Figure 12 b

Figure 12c

LAKE FOREST YACHT CLUB

Site Description: Lake Forest Yacht Club is located along Yacht Club Drive and consists mainly of a beach area, a marina, and a secondary row of boat-slips along a narrow channel on the opposite side of the beach. The beach area consists of approximately 110 meters of beach shoreline. During the summer months, a row of floating docks approximately 120 meters in length is set up from the north end of the beach to the south end, creating a barrier between the swim area and the lake proper; a sediment curtain a few meters in length is set up under these floating docks. The boat-slip area in the narrow channel consists of approximately 85 meters of unbuffered shoreline. The parking lot is located between the beach area and the boat slips and has three catch basins that drain to the narrow channel. Additionally, a stormwater outlet pipe is located in the northeast corner of the narrow channel that drains a small stream and stormwater from some of the surrounding neighborhood.

Potential Locations:

Along Swim docks (Figure 13a).
Directly where the major stormwater pipe enters the small cove by the boat slips (Figure 13b).
In catch basins that drain parking lot runoff (Figure 13c).

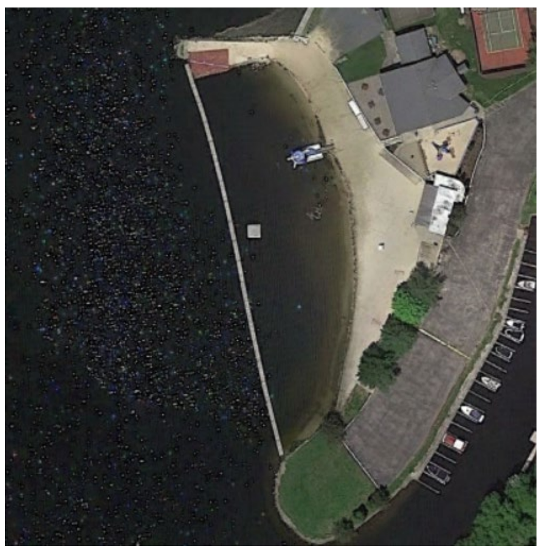


Figure 13a

Figure 13b

Figure 13c

RECOMMENDATIONS

Based on a review of the locations that were assessment as part of this study, as well as extensive conversations with the manufacturer of the material (Biochar Now), Princeton Hydro has developed a set of recommendations on which sites should be considered for this HAB study. Note these recommendations are based on several factors:

1. The ease in quantifying the amount of phosphorus being removed by the Biochar (based on sampling logistics and contact time with the Biochar; the longer the water has contact with the Biochar the higher the amount of phosphorus removal).
2. Ensuring that there is at least one project site in each municipality.
3. Trying a variety of Biochar techniques and particle sizes (along a beach area, the point where the water immediately enters the lake and within existing stormwater infrastructure).

While the original Scope of Work for the HAB grant requires a minimum of four locations to be assessed for Biochar, we have selected six primary projects. The two additional primary sites are specifically to install the Biochar in two Three-Chambered Baffle Box Manufactured Treatment Device (MTD) stormwater structures that were installed in Jefferson Township as part of a US EPA Targeted Watershed Grant, awarded to the Lake Hopatcong Commission. These two stormwater structures were designed to accommodate some type of filter media. Past studies have shown that installing filter media in these two structures, one located along East Shore Road, the other located along Yacht Club Drive, were effective at increasing the capacity of these structures to remove phosphorus. However, the cost of the media as well as the issues with the material breaking down in the structure, made it difficult for the Township to continue to use these media on a long-term basis. Thus, we would like evaluate the effectiveness of the using Biochar in these two existing stormwater structures. Also, the other project sites assessed in the report should be considered for future installations of Biochar, depending on the results of these initial projects. Finally, it should be noted, while not described in this report, Biochar will also be used in one of the AquaFilter stormwater structures in the Borough of Hopatcong as well as Ashley Cove.

PRIMARY PROJECT SITES FOR BIOCHAR

1. **Outlet of Duck Pond (Township of Roxbury):** Would like to install the Biochar sausages in Duck Pond around the outlet. Should have plenty of contact time and will be easy to collect samples to assess the phosphorus removal rates. Maybe some additional sausages in the outlet stream itself.

2. **Lakeside Blvd / Holiday Drive (Borough of Hopatcong):** Install some Biochar sausages or a cage just below the stormwater pipe and/or along the swimming lane.

3. **Edith M. Decker Elementary School (Borough of Mt. Arlington):** Install some Biochar sausages just below the culvert under Howard Blvd.

4. **Lake Winoa Outlet at Lorettacong Drive (Township of Jefferson):** Possibly install / anchor some Biochar sausages immediately down gradient of Lorettacong Drive.

5. **East Shore Road MTD (Township of Jefferson):** Possibly install some Biochar in the lagoon or channel immediately upgradient of the MTD.

6. **Yacht Club Drive MTD (Township of Jefferson):** Possibly install some of the courser Biochar material directly within the MTD.

SECONDARY PROJECT SITES FOR BIOCHAR

1. **Outlet of Memorial Pond (Borough of Mt. Arlington):** Install some Biochar sausages in Duck Pond around the outlet.

2. **Lake Forest Yacht Club (Township of Jefferson):** Just below the stormwater pipe that enters a small cove on the other side of the beach

APPENDIX IX:
BIOCHAR STORMWATER DATA

Biochar: Stormwater Sampling, 2020					
Date	Site	Stream Side	SRP	TDP	TP
			mg/L	mg/L	mg/L
7/10/2020	Lorettacong Drive	Pre-Treatment	0.042	0.08	0.48
		Post-Treatment	0.032	0.08	0.27
	Yacht Club	Pre-Treatment	0.071	0.11	0.2
		Post-Treatment	0.003	0.03	0.09
	Edith M Decker	Pre-Treatment	0.037	0.24	0.16
		Post-Treatment	0.031	0.06	0.49
	Lakeside	Pre-Treatment	0.118	0.18	0.43
		Post-Treatment	0.116	0.18	0.34
10/29/2020	Lorettacong Drive	Pre-Treatment	0.039	0.04	0.06
		Post-Treatment	0.027	0.03	0.06
	Yacht Club	Pre-Treatment	0.019	0.02	0.06
		Post-Treatment	0.02	0.02	0.06
	Edith M Decker	Pre-Treatment	0.026	0.03	0.12
		Post-Treatment	0.028	0.03	0.12
	Lakeside	Pre-Treatment	0.123	0.14	0.49
		Post-Treatment	0.124	0.13	0.45
	Memorial Pond	Pre-Treatment	0.046	0.05	0.09
		Post-Treatment	0.011	0.02	0.03
	Duck Pond	Pre-Treatment	0.179	0.18	0.31
		Post-Treatment	0.006	0.01	0.06

Biochar: Stormwater Sampling, 2021					
Date	Site	Treatment	SRP	TDP	TP
			mg/L	mg/L	mg/L
6/4/2021	Duck Pond	Pre-Treatment	0.007	0.01	0.08
		Post-Treatment	0.004	0.01	0.05
	Memorial Pond	Pre-Treatment	0.016	0.02	0.04
		Post-Treatment	0.012	0.02	0.04
	East Shore MTD	Pre-Treatment	0.010	0.02	0.02
		Post-Treatment	0.010	0.02	0.02
	Yacht Club MTD	Pre-Treatment	0.014	0.02	0.03
		Post-Treatment	0.020	0.03	0.04
7/1/2021	Duck Pond	Pre-Treatment	0.029	0.06	0.1
		Post-Treatment	0.002	0.02	0.04
	Memorial Pond	Pre-Treatment	0.014	0.04	0.04
		Post-Treatment	0.002	0.01	0.02
	East Shore MTD	Pre-Treatment	0.020	0.03	0.1
		Post-Treatment	0.019	0.05	0.05
	Yacht Club MTD	Pre-Treatment	0.023	0.05	0.06
		Post-Treatment	0.030	0.03	0.06

APPENDIX X:

PROJECT SUMMARY SHEETS

PhosLock (Nutrient Inactivation)

Description: PhosLock is a clay-based, non-aluminum-based nutrient inactivator that has been used in a variety of ways to inactivate phosphorus, making it unavailable for algal growth. PhosLock is not considered an EPA registered pesticide, since it does not directly affect plants or algae, and does not currently require a permit in New Jersey.

Goal of Management Measure: PhosLock applications are intended to inactivate phosphorus generated from deep, anoxic sediments, as well as shallow sediments where there is a mobilization of phosphorus from both chemical and biological processes. PhosLock can also be used to strip the water column of dissolved phosphorus as it moves towards the sediment. The inactivation and reduction of phosphorus concentrations is intended to limit the availability of phosphorus.

Advantages:

- Non-aluminum or metal-based.
- Effective under anoxic and oxic conditions.
- Effective at low pH values.
- Does not affect water pH values.
- Does not require a buffer.
- Safe for aquatic organisms.
- Can inactivate both inorganic and organic forms of phosphorus.
- Can provide multi-year inactivation of phosphorus in the sediments.

Limitations:

- More expensive than traditional nutrient inactivants, such as aluminum or iron-based products.
- Starting in 2023 PhosLock will no longer be available in the US; however, an alternative product with the same formulation will be available by the manufacturer, SePRO, and is named EutroSORB G.

Permits: There are currently no permits required in New Jersey specifically for PhosLock applications. However, treatments equal to or larger than 80 acres will more than likely trigger the need for a NJ Pollutant Discharge Elimination System (NJPDES) permit.

Range of Costs: Specific treatment costs would vary based on the type of treatment (sediment vs. stripping), dosage rates and mode of application. However, including product and labor a PhosLock treatment is preliminarily estimated to cost between $1,000 and $2,500 per acre.

Biochar (Lentic Systems; Standing Waters)

Description: Biochar is a processed wood material that has a high affinity to adsorb a variety of nutrients, including phosphorus. Biochar can be placed into floatation balls, sleeves, or cages and tethered along a beach area, swimming line in stormwater ponds, or where an inlet enters the lake.

Goal of Management Measure: The installation of Biochar sleeves in lentic systems is intended to reduce nutrient concentrations, with an emphasis on dissolved phosphorus. Thus, Biochar is a nutrient management measure.

Maintenance: Biochar sleeves need to be replaced every few months to maintain efficient nutrient removal rates. Such replacement rates may vary between 3 and 6 months; however, for standing waters 6 months seems to be an appropriate replacement rate. Once removed, the material can then be used as mulch for upland landscaping.

Advantages:

- Low product cost.
- Recycled, organic material.
- Biochar can be re-used as a form of mulch after it is removed from the water
- Easy installation and maintenance for homeowners and volunteers.

Limitations:

- Must be replaced every few months, or at least once per growing season to maintain nutrient removal capabilities.
- While it can be purchased in bulk and sleeves be built, it is recommended purchasing the sleeves pre-made to avoid dealing with issues such as particles in the air while handling the material.

Permits: No permits are typically required for the installation in standing waters.

Range of Costs: The cost of the Biochar and the sleeve, in bulk, is about $11 per sleeve (3-4 ft long and 8" in diameter). However, pre-made Biochar sleeves cost approximately $25 to $30 per sleeve. Neither of these cost estimates includes shipping of the product, material to anchor / install the Biochar or the labor for installation and retrieval of the material.

Biochar (Stormwater Structures)

Description: Biochar is a processed wood material that has a high affinity to adsorb a variety of nutrients, including phosphorus. Biochar can be placed into sleeves and then installed into stormwater structures, such as Manufactured Treatment Devices (MTDs), where it can remove phosphorus as stormwater flows through the media.

Goal of Management Measure: The installation of Biochar sleeves in stormwater structures is intended to reduce stormwater nutrient concentrations, with an emphasis on dissolved phosphorus, before the water discharges into the receiving pond lake, stream or other waterway. Thus, Biochar is a nutrient management measure.

Maintenance: In stormwater structures, Biochar sleeves need to be replaced every 3 to 5 months to maintain efficient nutrient removal rates. Biochar sleeves should be replaced approximately every three months in stormwater structures that receive significant storm-related flows. Once removed, the material can then be used as mulch for upland landscaping.

Advantages:

- Low product cost.
- Recycled, organic material.
- Biochar can be re-used as a form of mulch after it is removed from the water
- Enhances the capacity of stormwater structures to remove nutrients from the flowing stormwater.

Limitations:

- Must be replaced every few months, or at least once per growing season to maintain nutrient removal capabilities.

- Confined Space Certification may be required for installation and maintenance in certain, large stormwater structures.
- May need to evaluate varying particle sizes of Biochar and the MTD design to avoid any potential localized flooding associated with the structure.

Permits: Typically, no permits are required.

Range of Costs: The cost of the Biochar and the sleeve, in bulk, is about $11 per sleeve (3-4 ft long and 8" in diameter). However, pre-made Biochar sleeves cost approximately $25 to $30 per sleeve. Neither of these cost estimates includes shipping of the product, material to anchor / install the Biochar or the labor for installation and retrieval of the material.

Biochar (Lotic Systems; Flowing Waters)

Description: Biochar is a processed wood material that has a high affinity to adsorb a variety of nutrients, including phosphorus. Biochar can be placed into sleeves or cages and anchored to the streambed or streambank where it can remove phosphorus as the water flows through.

Goal of Management Measure: The installation of Biochar sleeves in flowing systems is intended to reduce nutrient concentrations, with an emphasis on dissolved phosphorus, before the water discharges into the receiving pond or lake. Thus, Biochar is a nutrient management measure.

Maintenance: For flowing waters, Biochar sleeves need to be replaced every 2 to 5 months to maintain efficient nutrient removal rates; the removal frequency is based on the magnitude of the pollutant load and the base / storm flows. For example, Biochar sleeves should be replaced approximately every 2-3 months in streams that experience higher flows. Once removed, the material can then be used as mulch for upland landscaping.

Advantages:

- Low product cost.
- Recycled, organic material.
- Biochar can be re-used as a form of mulch after it is removed from the water
- Reduces nutrient concentrations before the water discharges into the receiving pond or lake.

Limitations:

- Must be replaced every few months to maintain nutrient removal capabilities.
- Permits may be required.
- There have been instances where the installed sleeves have been displaced during large / severe storm events.
- While it can be purchased in bulk and sleeves be built, it is recommended purchasing the sleeves pre-made to avoid dealing with issues such as particles in the air while handling the material.

Permits: Any work proposed within a State open water (Freshwater Wetlands Protection Act) and/or regulated water (Flood Hazard Area Control Act) requires approval via permit(s) that are specific to each Act.

Range of Costs: The cost of the Biochar and the sleeve, in bulk, is about \$11 per sleeve (3-4 ft long and 8” in diameter). However, pre-made Biochar sleeves cost approximately \$25 to \$30 per sleeve. Neither of these cost estimates includes shipping of the product, material to anchor / install the Biochar or the labor for installation and retrieval of the material.

Air Curtain

Description: Air Curtain aeration systems are designed to form a barrier of moving water around beaches, marinas, or other high-density nearshore areas. Aeration diffusers are placed on the bottom of the lake, along the perimeter of the protected area, and are supplied with air from a compressor on shore.

Goal of Management Measure: Air Curtains are designed to prevent the accumulation of algae, cyanobacteria, plant fragments, and other nuisance debris along the designed area. The accumulation of cyanobacteria in near-shore areas can otherwise lead to elevated cell counts. The accumulation of plant fragments and other organic matter can lead to nutrient release and low dissolved oxygen levels upon decomposition.

Advantages:

- Prevents the wind-blown accumulation of harmful cyanobacteria along high-density nearshore areas.
- Increases water movement and dissolved oxygen levels along nearshore areas.
- Allows the passage of boats and other watercraft.
- Safe for aquatic wildlife.

Limitations:

- Prevents the establishment of thermal stratification. Thus, Air Curtains should not be used in deeper waters that would otherwise develop a stratification pattern unless the entire limnetic portion of the target lake is to be destratified (in such as case a different type of aeration is required).
- Needs a reliable and safe source of electricity close to the shoreline.
- Annual costs associated with power and routine maintenance.

Permits: NJDEP does not specifically have a permitting process for the installation of an aeration system. However, any shoreline compressor housing units would need to consider any potential wetlands, flood hazard and riparian zones, and would potentially require a Freshwater Wetlands Permit and/or a Flood Hazard Permit. However, most Air Curtains intended for relatively small areas such as a beach or marina should not require a permit.

Range of Costs: Highly dependent on the area targeted for treatment. Capital costs are expected to start around $15,000 to $25,000. Costs can be substantially higher if a nearshore source of power is not readily available.

Nanobubble Aeration

Description: Nanobubble aeration systems utilize extremely small gas bubbles to oxygenate a waterbody. Due to their extremely small size and minimal buoyancy relative to traditional aeration systems, nanobubbles remain stable in the water for longer periods of time rather than traveling directly to the water surface and bursting, providing superior oxygenation.

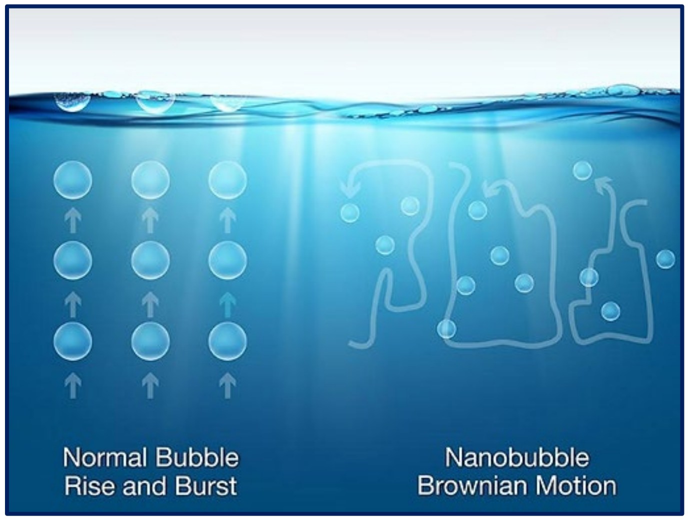
Goal of Management Measure: Nanobubble aeration systems are designed to saturate the water with significantly more oxygen than traditional aeration systems. In turn, this should decrease foul odors, increase the breakdown of organic matter in the water column (such as cyanotoxins and taste & odor compounds) and along the bottom of the lake, disrupt the formation of algae blooms, and promote beneficial bacteria growth.

Advantages:

- Nanobubbles remain suspended in the water longer than bubbles from traditional aeration systems.
- High surface area of bubbles per volume of water relative to bubbles from traditional aeration systems increases gas (oxygen) transfer to water.
- Suppose to provide a higher degree of oxidation of organic matter relative to standard aeration.

Limitations:

- More expensive than traditional aeration systems.
- Needs a reliable and safe source of electricity close to the shoreline.
- Annual costs associated with power and routine maintenance.



Source: Nanobubble Systems

Permits: NJDEP does not specifically have a permitting process for the installation of an aeration system. However, any shoreline compressor housing units would need to consider any potential wetlands, flood hazard and riparian zones, and would potentially require a Freshwater Wetlands Permit and/or a Flood Hazard Permit. However, most nanobubble systems intended for relatively small areas such as a beach or cove should not require a permit.

Range of Costs: Highly dependent on the area targeted for treatment. Capital costs are expected to start around $25,000 to $35,000. Costs can be substantially higher if a nearshore source of power is not readily available.

Nanobubble Aeration with Ozone

Description: Nanobubble aeration systems utilize extremely small gas bubbles to oxygenate a waterbody. Infusing the nanobubbles with ozone, a safe disinfecting and sanitizing gas, greatly increasing the oxidation power of the aeration system. Due to their extremely small size and minimal buoyancy relative to traditional aeration systems, nanobubbles remain stable in the water for longer periods, which also allows the ozone to remain stable for extended periods of time.

Goal of Management Measure: Nanobubble aeration systems with ozone are designed to provide the same aeration benefits associated with regular nanobubble systems, with additional oxidation and sanitization properties provided by ozone gas. The ozone nanobubbles offer the ability to degrade organic and inorganic pollutants and chemicals that may be present in the waterbody, which may include cyanotoxins and taste & odor compounds.

Advantages:

- Superior oxidation potential relative to traditional aeration or nanobubble systems.
- The nanobubbles allow the ozone to remain stable in the water for extended periods of time.
- Ozone provides the ability to degrade pollutants and chemicals such as cyanotoxins and taste & odor compounds.

Limitations:

- More expensive than traditional aeration systems.
- Needs a reliable and safe source of electricity close to the shoreline.
- Annual costs associated with power and routine maintenance.

Permits: NJDEP does not specifically have a permitting process for the installation of an aeration system. However, any shoreline compressor housing units would need to consider any potential wetlands, flood hazard and riparian zones, and would potentially require a Freshwater Wetlands Permit and/or a Flood Hazard Permit. However, most nanobubble systems intended for relatively small areas such as a beach or cove should not require a permit.

Range of Costs: Highly dependent on the area targeted for treatment. Capital costs are expected to start around $25,000 to $35,000. Costs can be substantially higher if a nearshore source of power is not readily available.

Floating Wetland Islands

Description: Floating wetland islands (FWIs) are constructed of recycled plastic material and are planted with a variety of native wetland vegetation. The plants are rooted in peat or other soil matrix, which eventually grow through the matrix material and into the water column where they assimilate nutrients to support vegetative growth. The high surface area of the constructed wetland material and root mass of planted vegetation serve as habitat for bacteria and other microbial life, which further assimilate and process phosphorus and nitrogen.

Goal of Management Measure: The main goal associated with the implementation of FWIs is the reduction of nitrogen and phosphorus concentrations in the water. Incorporating these nutrients into the FWI vegetation and microbial community reduces the nutrient pool in the water column. Additionally, the development of this microbial community underneath the FWI attractive a variety of aquatic life, including macroinvertebrates, small fish and, in turn, game fish.

Advantages:

- Environmentally friendly, aesthetically pleasing, and cost-effective.
- A green management measure in reducing nutrient concentrations.
- Provides structure and habitat for a variety of aquatic organisms including young fish. In turn, larger gamefish are also attracted to the structures.
- Provides shoreline stabilization when placed along shorelines.
- Can slow inflow rates when strategically placed.

Limitations:

- FWIs can detach from their anchors in larger systems due to excessive wind and wave action if not anchored properly.
- In some cases, FWIs may need to be tethered to the shoreline as well as anchored.
- Goose netting needs to be installed and maintained for at least one full growing season to prevent grazing of the planted vegetation by Canada geese. Once the plants are well established, the geese will leave the FWIs alone.

Permits: Typically, no permits are required.

Range of Costs: An estimated range of cost for the purchase, transport, planting, and installation of four (4) approximately 110 square foot FWIs is between $25,000 and $35,000. The assistance of volunteers in the planting and anchoring / installation of the FWI can reduce costs.

GreenClean

Description: GreenClean is an oxidizing algaecide that uses sodium carbonate peroxyhydrate, a form of hydrogen peroxide, as the active ingredient to break down algae cells. GreenClean is an EPA registered algaecide that requires a permit to be filed by a State licensed applicator. Treatments can only be done by licensed and experienced applicators

Goal of Management Measure: Reduce algae and cyanobacteria densities in waterbodies. The product is also supposed to break down and preclude the release of cyanotoxins as well break down taste & odor compounds such as geosmin and MIB.

Advantages:

- Does not contain copper like many traditional algaecides which remain in the sediments and can bioaccumulate in the environment.
- Completely breaks down into water and oxygen upon decomposition.
- Reported to breakdown cyanotoxins and taste & odor compounds.
- Begins to work immediately upon application and releases oxygen into the water.
- Effective in coves, small waterbodies, or any area with limited water exchange.

Limitations:

- Limited success with cyanobacteria control in areas with a high flushing rate and high degree of water exchange, such as a beach area situated along the main body of a lake.
- More expensive product cost than standard copper-based algaecides.
- Licensed applicators need to be well versed in how to safely handle and use the product.

Permits: Requires an Aquatic Pesticide Permit to be filed by a New Jersey State licensed applicator.

Range of Costs: While the actual cost of a treatment with GreenClean will depend on the targeted algae and dosage rates, the area being treated and the number of required treatments, a very preliminary estimate of cost is approximately between $450 and $650 per acre per treatment event.