YEAR 2022 SUMMARY REPORT
RESTORATION OF WHITE POND'S WATER QUALITY

<u>RESTORATION METHOD</u>: PASSIVE HARVESTING, SUSTAINABLE REMOVAL AND COMPOSTING OF CYANOBACTERIA USING THE A-POD TECHNOLOGY
(U.S. Patent No. 10,745.879)

"Before" Photograph: White Pond, August 26, 2021 taken by Higgins Environmental Associates, Inc.

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HEA

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1 .0 INTRODUCTION

This report serves to summarize Higgins Environmental Associates, Inc. (HEA's) activities, data and findings for ecological restoration services completed in Year 2022 at White Pond in Concord, Massachusetts. This work was completed by HEA under contract to the Town of Concord, in accordance with HEA's Proposal No. 10220 (revised February 11, 2022).

Ecological restoration focused on improving water quality and controlling health risks to people, pets and wildlife associated with cyanobacteria also referred to as harmful algae blooms (HABs) or blue green algae (BGA) collectively "cyanoHABs" and their excess nutrients, cyanotoxins and carbon in White Pond. Ecological restoration work was completed by passively harvesting and removing cyanoHABs from White Pond using a technology called the A-Pod (U.S. Patent No. 10,745,879). HEA's field assessments and research for use of the A-Pods began at White Pond in July 2021, under contract to the National Science Foundation (NSF).

To assist in HEA's evaluation and for the benefit of Concord, HEA has also included some information for NSF work completed in Years 2021 and 2022 at White Pond. The remainder of this report is broken down by section to aid the reader in understanding work completed and results achieved.

1.1 Historic CyanoHAB Impacts on Surface Water Quality of White Pond

Historical water quality information including presence/absence of cyanoHAB scums and water clarity have been regularly recorded since the 1980s by the Friends of White Pond, the White Pond Advisory Committee and others including consultants to the Town of Concord, academia and Massachusetts agencies charged with water quality assessments. CyanoHAB scums have been documented as being present in White Pond since the 1980s. From 2015 to 2021, Concord's Health Department posted No-Contact Advisories at White Pond due to frequent cyanoHAB events occurring above Massachusetts health guidelines. In year 2022, HEA utilized the A-Pod technology to control health risk drivers (primarily cyanoHAB scums) while also removing the larger biovolume, suspended biomass of cyanoHABs below the water surface. In Year 2022, Massachusetts health guidelines for cyanoHABs were not exceeded and no-contact advisories were not posted by Concord's Health Department. Historically, and as confirmed by more recent investigations by HEA and the Town, cyanoHABs are primarily of the genus Microcystis sp. with lessor and sometimes competing occurrences of Dolichospermum sp.. Both types of cyanoHABs can contain cyanotoxins that can negatively affect the health of people, pets and wildlife.

The cover page of this report includes a photograph taken by HEA on August 26, 2021 of dense cyanoHAB surface and near surface accumulations. This cyanoHAB accumulation was visibly apparent over approximately 50 percent of the pond surface from the center of the pond to the northern, eastern and western shores. Initially as part of our NSF work and later under contract to Concord, HEA documented elevated cyanoHAB biomass extending over the entire water body column (surface to 64 feet deep) and water body area-volume based on vertical assessment multiparameter sonde transects throughout the pond. Additional information on cyanoHABs is provided with other sections of this report.

2.0 SUMMARY OF PASSIVE HARVESTING AND REMOVAL OF CYANOHABs USING THE A-POD TECHNOLOGY

2.1 The A-Pod Technology Process

The A-Pod technology can be used actively or passively to trap, concentrate and permanently remove cyanoHABs, their toxins and nutrients from fresh, estuarine and marine waters. The following annotated photographs taken at White Pond in October 2021 during HEA's NSF work depicts and helps to explain the A-Pod process.

The A-Pod was the third ecological restoration apparatus and process invented by Mr. Higgins of HEA. The first two (the P-Pod and S-Pod) are intended to extract or biodegrade contaminants and nutrients from in-place sediment or to remove targeted areas of soft sediment, respectively. Each of these patented apparatuses and processes are portable, scalable and can operate with minimal carbon footprint or disturbance to non-target areas or sensitive resources. More information is provided at www.higginsenv.com and at P-Pod Technologies, LLC's website at www.ppodtech.com

2.2 2021-2022 Significant Ecological and Health Milestones Achieved

As documented by information (field data and laboratory testing results) provided with this report, significant ecological restoration milestones were achieved in 2022 for White Pond as follows:

- ❑ An estimated 388.5 dry to moist pounds of cyanoHABs and suspended solids were permanently and sustainably removed from White Pond and biodegraded on land in a controlled manner.

❏ A fifty one percent (51 %) reduction in cyanoHAB biovolume (e.g., cyanoHAB biomass by water body volume) was achieved for White Pond from October 2021 to October 2022.

❏ Board of Health restrictions or advisories for water contact were not required or issued in Year 2022 when a total of four A-Pods were in-place and functioning to control and remove cyanoHABs and cyanotoxin health risks.

❏ Water clarity improved to a Year 2022 (May to November) median of 24.2 feet versus the historic 30-year (1987-2017, typically June to August) median of 19.6 feet.

❏ The phosphorus concentration in cyanoHAB solids removed from 2021 to 2022 decreased by 44%; the biogeochemically-active nutrient sulfur decreased by 27%; and total nitrogen increased by 211% in cyanoHABs removed over time which corresponded to a 285% (maximum of 0.5 mg/L) increase in total nitrogen concentration of surface water outside the A-Pod Trap and collection area from June to October 2022. This total nitrogen concentration (0.5 mg/L) in ambient water of White Pond is within the low to moderate range (less than 1 mg/L) for nitrogen noted previously by the ESS Group (ESS 2015, 2016-2017). U.S. EPA 2014 has a recommended criteria limit of 0.36 mg/L for total nitrogen in lakes and pond.

❏ CyanoHAB scums in White Pond decreased in occurrence and extent during ecological restoration using the A-Pods and were not present from September to December 2022 when open water phycocyanin (PC, a measure of cyanoHAB biomass) concentrations were 1.7 Relative Fluoresence Units (RFUs) or less, **Chart 1 - Years 2021-2022 Benefit of CyanoHAB Removal**.

❏ Cyanotoxins in open surface waters of White Pond, outside of the A-Pod, were non-detectable by laboratory analysis of samples collected by HEA in Year 2022.

❏ HEA documented the presence of "benthic meadows" of beneficial benthic macroalgae (Nitella) and moss from depths of approximately 5 to 45 feet throughout the pond. Walden Pond has similar benthic meadows. These would serve as a sink for nutrients and as habitat for benthic fauna.

❏ HEA documented a predominantly clockwise water flow in White Pond with shallow (top 4 feet) water velocities between 6 to 8 feet per minute. Water flow eddies were documented in areas of shallow bathymetric and shoreline structure changes.

HEA was able to meet and speak with many people from Concord and other towns that were using White Pond for boating, swimming and fishing. HEA was also able in part, to assess White Pond's water quality relative to Walden Pond. We would like to take this opportunity to thank Concord and residents around White Pond that shared their knowledge of the pond, kept watch over the A-Pods, and that provided space for our small Jon boat and some gear.

3.0 ASSESSMENTS AND FINDINGS

HEA's assessments at White Pond began on July 16, 2021 as part of A-Pod field performance and cyanoHAB evaluation research supported by NSF. In 2021, HEA conferred with the Town of Concord's Division of Natural Resources, Health Director and the White Pond Advisory Committee to discuss our proposed NSF work and any concerns, conditions or requirements they might have for our research and use of A-Pods at White Pond. On August 18, 2021, the first A-Pod was placed in White Pond just south of the town beach (far eastern side of pond). This A-Pod was then moved to a northern cove (referred to as Thoreau's Cove) on August 30, 2021. A-Pod field operation research was completed by October 20, 2021 which included the removal and land-based controlled composting of approximately 100 dry-moist pounds of CyanoHABs and suspended solids. In addition to removal of cyanoHABs, the A-Pod process removes similar water-suspended solids such as pollen and fragments of plant matter (pine needles, leaves, detached benthic algae fragments and similar).

In Year 2022, HEA provided ecological restoration services to the Town of Concord for White Pond under HEA's Proposal No. 01220 (revised on February 11, 2022). Year 2022 field work took place between May 5th to December 5th. Ongoing NSF supported research took place separately during this time as well. Field sampling locations and other pertinent features such as the location of A-Pods and water current patterns are depicted on **Figure 1 - Year 2022 Field Information**. A bathymetric map (depth to bottom contours) is depicted on **Figure 2 - MassWildlife Bathymetric Map for White Pond**. A summary of field data collected by HEA and previously by others (1987-2017) is provided on **Table 1 - Years 2021 to 2022 Monthly Field Data Summaries for White Pond - Emphasis on CyanoHAB data**. Information on U.S. pounds of cyanoHABs and suspended solids removed from White Pond and reduction in cyanoHAB biovolume and health risks is depicted on **Chart 1 - Years 2021-2022 Benefit of CyanoHAB Removal**. HEA also completed sampling and laboratory analysis of surface water for nutrients, PC and cyanotoxins as summarized on **Table 2 - Surface Water Sampling Results**. HEA also collected samples for laboratory analysis of cyanoHAB solids, the benthic meadow macroalgae, and sediment (discrete, vertical profile and transect) in White Pond as summarized on **Table 3 - Recovered HAB and Sediment Sample Results**. Laboratory datasheets for samples collected as part of HEA's contract with the Town of Concord are attached. For the benefit of Concord and other readers of this report, HEA has also attached charts of monthly sonde vertical profile transect data for cyanoHABs, temperature, dissolved oxygen, turbidity, pH and oxidation-reduction potential of White Pond's surface water.

The following sections outline assessment methods and findings by HEA in Year 2022 while working for Concord and as pertinent for findings from our NSF research work.

3.1 Shallow and Vertical Sonde Profiling

<u>Material, Methods and Equipment Utilized</u>:

Shallow and vertical profile testing of water quality at White Pond were completed using an In-Situ AquaTroll 500 sonde fitted with probes for measurement for pH, temperature, dissolved oxygen, blue-green algae phycocyanin (BGA-PC); oxidation-reduction potential, turbidity, depth, barometric pressure, hydrostatic pressure, conductivity, salinity, resistivity, density, total dissolved solids, and recording of longitude and latitude for each sonde sampling location.

Vertical profile sonde surveys were completed (in Year 2021 with a 30 foot cable and in Year 2022 with a 100 foot cable) within each of White Pond's three primary deep basins (East, Center and West Holes), **Figure 1**, supplemented by lateral north to south offset vertical depth sonde surveys to evaluate overall water body volume water quality of White Pond. Sonde measurements in survey mode are collected and recorded every few seconds. Sonde snapshots were also collected in discrete areas of the pond, most often within and around A-Pods. Sonde survey records were then reviewed, processed to correct for variation in readings due to different cable lengths between 2021 and 2022 and to remove water quality sonde results when the sonde probe entered soft bottom sediments.

Sonde probes are factory-calibrated and field checked by HEA for consistency of readings between field use by using reference standards, deionized water blanks and a field benchmark (at White Pond, HEA used a closed container filled with pond water kept in the shade within a boat) to check for field variance of a fixed sample (the container of water) from one survey event to the next. The only sonde-related variance HEA noted was associated with change out of the sonde cable from year 2021 (30 foot cable) to year 2022 (100 foot cable). A cable correction factor for the cyanoHAB probe (BGA-PC) was determined and applied to correct PC data based upon direct field comparison of sonde PC results at the same locations (three), day and time using each cable to a depth of 30 feet. Similar cable correction factors could be applied to other sonde parameters but this report of findings focuses on changes in cyanoHAB biomass (in PC) and biovolume (PC over White Pond's water volume) during ecological restoration work using the A-Pods to passively remove cyanoHABs, their cyanotoxins and nutrients.

<u>Sonde PC Data</u>:

Vertical sonde monthly data records and charts of cyanoHAB data measured in PC are summarized on **Table 1 - Years 2021-2022 Monthly Field Data Summaries for White Pond Restoration with A-Pods - Emphasis on CyanoHAB Data**, on **Chart 2 - Years 2021-2022 Monthly White Pond CyanoHAB Population Variance** and on **Chart 3 - October Years 2021-2022 Changes in CyanoHAB Biomass and Biovolume (PC) in White Pond**. Sonde snapshot data (similar to taking a photograph) represent discrete samples and were often collected at and around A-Pods and from the field benchmark station. HEA also collected sonde snapshots at the same time and location as surface water sampling for laboratory analysis in June, August and October 2022 as summarized on **Table 1** and **2**.

<u>Sonde Findings for PC</u>:

While **Chart 2** is busy with data including surveys completed by HEA for our NSF work it does show a tight pattern and range of cyanoHAB population variance by month with notable decreases and some heterogeneity in cyanoHAB PC biomass and biovolume occurring as cyanoHABs were removed over time from White Pond using the A-Pods. Vertical sonde surveys at each of the deep holes and at north to south offsets documented that cyanoHAB biomass and biovolume did not vary much during each individual month's sonde survey. However, from one month to the next, there were readily apparent cyanoHAB PC biomass and biovolume changes due most likely to either seasonal growth of the cyanoHAB populations with increasing sunlight and temperatures (maximum growth typically in late June to early August) and reductions in PC due to removal of cyanoHABs with the A-Pods. By October of years 2021 and 2022, cyanoHAB removal events for each year using the A-Pods were essentially complete (in November 2022, an additional 20 dry-moist pounds of cyanoHABs were removed before removing the A-Pods on November 22, 2022). In year 2021, the A-Pod (just one) was removed on October 20th. Surface water and cyanoHAB solid samples for laboratory analysis were also collected in the month of October, **Table 2** and **3**. As such, for comparative purposes, HEA chose to use cyanoHAB PC results from October 2021 compared to October 2022 to evaluate changes in overall cyanoHAB biomass and biovolume in White Pond as this was the similar end of season data which took into account: 1) a similar lifecycle phase for cyanoHABs (typical October sunlight and temperature ranges); and 2) substantial completion of cyanoHAB removal events each year using the A-Pods. Water temperature in the top 30 feet (limit of year 2021 sonde cable) from October 7, 2021 to October 12, 2022 varied by approximately 5 degrees Fahrenheit, not a significant difference relative to cyanoHAB growth conditions, and temperatures below 30 feet would likely have been very similar from 2021 to 2022. A correction factor for temperature readings between cable lengths (30 to 100 feet) was not warranted as differences in temperature (top 30 feet, same time and locations) were within 0.06 degrees Celsius. HEA has attached charts (Charts 4 through 9) of monthly sonde vertical profile data including temperature for Year 2022 and for October 7, 2021 (Chart 5).

By October of each year (2021 to 2022), the A-Pod had removed part of each years' respective cyanoHAB population. **Chart 3** is used to more clearly depict the October 2021 to October 2022 51% reduction in cyanoHAB biomass and biovolume during HEA's ecological restoration work using the A-Pods. From year 2021 to year 2022, while not significant numerically, sonde survey results indicate increasing cyanoHAB variance with decreasing PC concentrations near the surface and increasing and decreasing PC concentrations with depth. When sonde PC data appeared to be visually skewed, as noted on **Charts 2** and **3** by the thin, deep and more concentrated layer of cyanoHAB in October and November, HEA assessed PC variance by calculating the data sets median, mean and standard deviation and determined skewness to be nominal (no more than approximately 0.6). If the data was significantly skewed (or asymmetric), the value for skewness would have been greater than approximately 2 to 3 (positive or negative) of a normal, non-skewed distribution (0). HEA interprets the temporary deep, thin layer of cyanoHABs to be an interval where cyanoHABs are coalescing together at the expense of upper and lower depth cyanoHAB biomass intervals due to changes in biogeochemical conditions. These biogeochemical conditions also occurred at depth intervals consistent with changes in oxidation-reduction potential, turbidity, and dissolved oxygen concentration of less than 2 mg/L. Additional discussion of this biogeochemical-cyanoHAB condition would seem to be beyond the scope of this summary report but HEA remains available to discuss this further if requested. The reader may also want to review sources noted in **Section 6.0 References and Sources** in particular, papers by Caraco, Cole and Likens (1991) and (1992); and, Cottingham, et. al. (2015) for more information.

For October 2021 to October 2022 PC biovolume comparisons using sonde PC biomass data results, HEA conservatively assumed that the overall water body of White Pond which fluctuates seasonally was unchanged. Based on monthly depth to pond bottom sediment measurements in the East Hole, as noted on **Table 1**, surface water elevations of White Pond fluctuated by upwards of 3.9 feet in year 2022. Water body surface elevations, are indicators of overall water body volume which fluctuates due to evaporation, precipitation and ground water baseflow (positive or negative). May 2022 water levels were the same as in October 2022, 61.9 foot depth to bottom sediment on both monthly readings. The lowest water level occurred in September 2022 when the depth to bottom sediments were measured at 58.7 feet. The highest water level occurred in July with a depth to bottom sediment measurement of 62.6 feet. Based on photographic and field observations during HEA's work at Thoreau's Cove with the A-Pod, year 2022 fall (September to October) water levels were notably lower (less water body volume) than in the fall (September to October) of year 2021. The difference, a drop in surface water elevation of approximately 3 feet was visually apparent based on receding water levels and exposure of shore structures and features during fall of year 2022 compared to fall of year 2021. HEA's calculated 51% reduction in cyanoHAB (PC) biovolume from October 2021 to October 2022 is conservative (e.g, there was less cyanoHAB PC biomass in October 2022 even with a reduction in overall water body volume compared to October 2021).

For the benefit of Concord and others reviewing this report, HEA has attached charts of monthly sonde vertical survey data for cyanoHABs, temperature, dissolved oxygen, turbidity, pH and oxidation-reduction potential. While HEA's assessment has focused on changes in cyanoHAB in PC, based upon our review of other sonde probe reading results, removal of cyanoHABs without adding other physical or chemical substances to the pond was a beneficial ecological restoration activity for White Pond and it's water quality and reduction of health risks posed by historic cyanoHAB conditions.

3.2 Surface Water Sampling and Analysis

Material, Methods and Equipment Utilized:

In accordance with HEA's Proposal, three rounds of sampling and laboratory analysis of surface water from White Pond were completed in year 2022 using a discrete water sampler (4 foot depth sample interval profile and within the A-Pod Trap itself). Each sampling round included three sample locations designated as: "WP-Trap" sample (within the A-Pod trap); a "WP-In" sample (within the A-Pod collection member area but outside the trap; and a "WP-Out" sample (center of the pond). The WP-Trap samples were collected after mixing (homogenizing) of the trap's contents. WP-In and WP-Out samples were collected using a discrete sampler from 4 feet below the water surface. Surface water samples were placed directly upon sampling into pre-preserved, laboratory-supplied containers, cooled to less than 4 degrees Celsius, and kept under chain of custody documentation through laboratory analysis. Each sample was submitted for laboratory analysis for the nutrients: Nitrate and Nitrite as Nitrogen, Total Nitrogen, Kjeldahl Nitrogen, total phosphorus, total organic carbon, total iron, total sulfur; and, phycocyanin (PC) and cyanotoxin (after identifying the predominant type of cyanobacteria). Field sonde snapshots were taken at each sampling location to obtain a field PC reading to compare to laboratory PC results.

Field and Laboratory Data:

Field and corresponding laboratory PC data are summarized on **Table 1 - Years 2021 to 2022 Monthly Field Data Summaries for White Pond Restoration with A-Pods - Emphasis on CyanoHAB Data** and laboratory results for year 2022 samples are summarized on **Table 2 - Surface Water Sample Results**. Laboratory data sheets for surface water samples from year 2022, under contract to the Town of Concord, are attached for reference.

Surface Water Sample Findings:

White Pond cyanoHABs were predominantly Microcystis sp. with lesser occurrence or dominance by Dolichospermum sp. In year 2022, cyanotoxins were at low (0.11 ug/L) to non detectable concentrations in open water ("In" and "Out") samples and were present at low concentrations (up to 0.802 ug/L) within the A-Pod ("Trap") samples collected by HEA. Laboratory results for nutrients were not remarkable or interpreted as indicative of eutrophic (nutrient-rich) conditions in White Pond. HEA's results for surface water are reasonably consistent with prior work by others (ESS Group, William Walker et al) which indicated that White Pond is borderline between mesotrophic and oligotrophic (nutrient-poor). However, the total nitrogen concentration of water samples from June 2022 to October 12, 2022 increased steadily by 83 to 135% (Trap and In samples, respectively) and by 285% in the open water "Out" sample but was still within the range reported previously by others (ESS Group, 2015, 2016-2017).

3.3 Sediment Sampling and Analysis

Material, Methods and Equipment Utilized:

Sediment quality assessments and sampling (total of nine samples for this report) were collected using a gravity-core sampler or for very fine, easily disturbed sediments (top 2 inches) a discrete water sampler was used on November 7, 2022. Sediment samples were cooled to less than 4 degrees Celsius upon sampling, frozen back at the office and kept under chain of custody documentation through laboratory analysis.

Laboratory analysis of sediment included the nutrients: total organic carbon; iron, nitrogen (total, nitrate and nitrite as N, and Kjeldahl N), phosphorus and sulfur. Seven sediment samples were collected from the top 2 to 6-inches of soft sediment and two samples were collected at depth (4 to 8 inches and from 16 to 24 inches) below a 0 to 2 inch sample interval location designated as "SED3-WP5". The SED3-WP5 sample was an intact vertical profile sediment core sample collected from the deepest basin (East Hole) that was then divided into discrete sample intervals (0-2 inches; 4-8 inches and 16-24 inches) with depth below the sediment surface. Five of the sediment sample locations were from the eastern-most deep basin (East Hole) and two were collected on a transect from the center and western basin respectively, **Figure 1** and **Table 3**.

Field and Laboratory Data:

Sample results including reference to sampling location and sampling depths are summarized on **Table 3 - Recovered HAB and Sediment Sample Results**. Laboratory data sheets for sediment samples are attached for reference. Based on field observations, soft sediments consisted of a light grey-brown, organic-rich silt with visible layering of sediment in core samples. Organic detritus including plant fragments and even some fish scales were noted on the surface of some sediment samples. Based in microscopic analysis of one sediment sample (top 2 inches, November 7th), the sediment sample was light green in color and microbially-active with bacteria and micro-invertebrates or similar sized microbial organisms. Upon aging at the office under ambient, natural lighting, this sample became brown in color within one week.

Sediment Sample Findings:

From November 2021 to November 2022, sediment sample laboratory results from the top 2-inches of sediment, documented a decrease in phosphorus of 12%; an increase of sulfur by 15%; and a substantial increase in total nitrogen of 682% (8,840 mg/kg). In their 2015 report, the ESS Group documented an average (composited) sediment sample result for nitrogen of 1,000 mg/kg. HEA's sediment results for nitrogen varied from 229 mg/kg in August 2021 to 22,400 mg/kg in August 2022. Physical and microscopic evaluation of the November 2022 sediment sample (total nitrogen concentration of 8,840 mg/kg) collected from the top 2 inches of very fine, detrital sediment documented a high proportion of green-colored detritus (likely algae, plant matter and cyanoHABs). Total nitrogen concentrations also appear to correlate with variation in total organic carbon content sample results for sediment, **Table 3**. HEA interprets the wide range in total nitrogen concentrations of sediment to inclusion of varying proportions of nitrogen-rich organic matter (fish wastes, benthic algae, plant fragments and cyanoHABs). Another source of nitrogen could be related to use of the pond by waterfowl. However, during HEA's field work (2021-2022), waterfowl were only rarely observed, which is unusual, other than a few cormorants, shore birds (herons), an eagle and ospreys. Waterfowl can be a significant source of external nutrient loading for nitrogen, phosphorus and sulfur to surface water and sediment in other water bodies.

HEA's vertical profile sediment sample (SED3-WP5) collected in November 2021 had a pattern of sediment phosphorus data consistent with a mesotrophic to oligotrophic water body (e.g., uniform concentration with depth below 6 inches and slight decrease in upper (top 2 inches) sediments (Carey and Rydin, 2011). Phosphorus results in the top 6 inches of other sediment samples collected by HEA ranged from 580 mg/kg in July 2021 to 2,410 in August of 2022. Like nitrogen, phosphorus results appear to correlate with variations in total organic carbon results. The sediment vertical profile core sample (SED-WP5) also had increasing total nitrogen concentrations with depth of up to 1,680 mg/kg. If the same logic applies to nitrogen as to phosphorus concentration patterns with sediment depth (Carey and Rydin, 2011), then nitrogen results would also be consistent with a mesotrophic to oligotrophic water body.

Sediment results greater than 10 inches (26 centimeters) deep from HEA's in-place gravity core sediment sample (SED3-WP5) were likely deposited approximately 200 to 1,500 years ago (Stager, Harvey and Chimileski, 2020).

Sediment results for the biogeochemically-active nutrient sulfur ranged between 2,370 mg/kg (July 2021) to 11,400 mg/kg in November 2022. Sulfur results from samples in November 2021 and November 2022 increased by 15% (9,870 mg/kg versus 11,400 mg/kg). To some extent, the variance in sulfur content could also relate to the presence of organic-rich detritus but sulfur concentrations did not appear to correlate as well with total organic carbon content of sediment samples as did total nitrogen or phosphorus. In addition, unlike vertical profile data (sample SED3-WP5) results for phosphorus and nitrogen, there was approximately twice as much sulfur in the upper two inch layer of sediment compared to deeper intervals. A similar pattern was noted for the nutrient iron including less of an apparent correlation with total organic carbon content of sediment than nitrogen or phosphorus.

HEA did not observe hydrous iron minerals in oxic or anoxic sediments of White Pond. If present, the anoxic forms of hydrous iron-phosphorus minerals (including the minerals strengite and vivianite) would occur within the anoxic sediment-pore water space of buried sediment. Hydrous iron minerals (oxic and anoxic) can be significant natural sinks for the nutrients iron and phosphorus (up to 40,000 milligrams per kilogram). Additional information on this topic is provided in a separate presentation by HEA at www.ppodtech.com on lake iron nodules and the impact by sulfur and also in a paper by Hansel, C., Lentini, C., Tang, Y. et al. (2015).

3.4 CyanoHAB Sampling and Analysis

Material, Methods and Equipment Utilized:

CyanoHAB samples were collected directly from cyanoHAB solids concentrated within the A-Pod trap area and allowed to air-dry in bulk for three days to a moist to dry consistency before sampling and laboratory analysis. CyanoHAB samples were then collected by compositing several grab samples of the bulk volume of cyanoHABs removed from the A-Pod trap. The amount of cyanoHABs recovered and sampled were also weighed out in U.S. pounds, as summarized on **Table 1**. Remaining cyanoHAB solids removed from the A-Pods were biodegraded/composted on land in a controlled manner.

HEA also collected a sample of benthic algae (Nitella) on September 14, 2021 as a reference sample for this type of benthic macroalgae. The benthic algae sample was collected as a grab sample off the sediment surface in approximately 30 feet of water to the south of Thoreau's Cove.

CyanoHAB and the benthic algae were submitted for the same laboratory analysis as surface water and sediment samples with the exception being that the benthic algae sample (September 14, 2021) and cyanoHAB solids (October 14, 2021) were submitted for total nitrogen only, rather than a breakout of nitrogen forms (inorganic and organic). As living organic matter, the total nitrogen results for both benthic algae and cyanoHAB solids should be primarily organic (kjeldahl) nitrogen. CyanoHAB and benthic algae samples were frozen upon sampling and kept under chain of custody documentation through laboratory analysis.

Field and Laboratory Data:

Field PC and corresponding laboratory PC and cyanotoxin data for cyanoHAB solids are summarized on **Table 1**. Laboratory results for nutrient content are summarized on **Table 3 - Recovered HAB and Sediment Sample Results**. Laboratory data sheets for cyanoHAB samples are attached for reference. Based on field observations, cyanoHAB solids and the benthic algae samples were cyan (blue-green) in color for the cyanoHABs and a dark green color for the benthic algae. The benthic algae sample had no visual evidence of die-off or stress (i.e., yellowing or rotted segments). A total of 388.5 pounds of cyanoHABs and other suspended solids (pollen, and fragments of benthic algae, leaves and pine needles) were removed from October 2021 through November 2022 using the A-Pods in passive cyanoHAB harvesting mode.

CyanoHAB and Benthic Algae Sample Findings:

Laboratory results for cyanoHABs recovered from October 2021 to October 2022 (the last laboratory sample in year 2022) had a decrease in the nutrients: phosphorus of 44% (from 3,630 mg/kg to 2,040 mg/kg); and sulfur of 27% (3,690 mg/kg versus 2,690 mg/kg). The nutrient nitrogen (as total nitrogen) removed with cyanoHABs over time increased dramatically, based on laboratory results, by 211% from 5,860 mg/kg in October 2021 to 18,200 mg/kg in October 2022. CyanoHABs are nitrogen-fixers and can acquire this nutrient from atmospheric sources and diffusion into water as well as from sediment and surface water.

3.5 Bathymetric and Hydrologic Assessments

Material, Methods and Equipment Utilized:

HEA completed multi-frequency, dual channel sonar and chart plotter surveys to characterize and map water body bathymetry, bottom-habitats and water body volume. Physical grab samples were used to assess and confirm benthic strata (hard and soft sediments) and flora (benthic macroalgae). Shallow, top 8 feet of the water column assessments for benthic flora on sediment were made visually from HEA's small Jon boat. Hydrologic drogues, made by HEA, were used to assess natural water current patterns and velocity at varying depths in White Pond. Some hydrologic drogues, set at varying depths, contained global position system (gps) trackers. Numerous other drogues were set at varying depths and times of year 2022 on transects across the pond and tracked by a boat-mounted gps every hour or so to evaluate water current patterns across and around the pond at varying depths. Water current velocity measurements for depth intervals of: top 2-feet; 4 feet; and, 10 feet were made by tracking the distance-time of travel for drogues set at these depths. A-Pod collection member arms extending into White Pond also provided a direct visual and physical indication of the magnitude and direction of water flows at depths of up to 8 feet (main A-Pod).

Field Data and Findings:

HEA's White Pond bathymetric survey map is complete but due to issues with software, HEA has not yet been able to download and include a map version with this report. However, bathymetric survey results viewed on the sonar/chart plotter directly are consistent with bathymetry for White Pond depicted by the Massachusetts Division of Fisheries and Wildlife (MassWildlife), **Figure 2**. HEA's soft bottom substrate for benthic macroalgae (Nitella primarily) occurred within a depth interval between approximately 5 to 45 feet deep all around the pond. Fresh water moss was visually observed at shallow depths (3 to 8 feet) around the pond except in areas of shallow sediment disturbance (swim and wading areas). The occurrence of the extensive benthic meadows in White Pond are consistent with those of Walden Pond which occur a water depth range of 20 to 43 feet (as documented by USGS, and Stager, et. al., 2020). At White Pond, soft sediments in the absence of benthic algae meadows were present from 45 to 64 feet in deep basins (East Hole, Center Hole and Western Hole) noted on **Figures 1** and **2**. Based on gravity core penetration depths for sediment samples collected by HEA, soft sediments are approximately two feet thick in the deepest basin, East Hole, off the town beach. When actively developed as the season progressed, benthic meadows were thick enough to prevent collection of soft sediments with the gravity corer at depths shallower than 45 feet. Similar gravity core penetration difficulties were noted by others within the depth range of healthy benthic meadows at Walden Pond. HEA estimates based on thickness of benthic algae retrieved with grab samples that benthic meadows may be upwards of two feet thick at the peak of their growth season (July to October). This may also be apparent from sonar surveys once we are able to upload and process that information. HEA will provide this updated bathymetric map as a supplement to this report when available.

Water currents and patterns were assessed by HEA using multiple hydrologic drogues deployed within the top

2 feet, at 4 feet and at 10 feet below the water surface with movements tracked over time. Water velocity measurements were taken as distance-time of travel for drogues at differing depths. Water currents and strength were also noted by changes in A-Pod collection members. The direction and pattern of shallow water (top 4 feet) current flow at White Pond was primarily clockwise, **Figure 1**. HEA's deeper hydrologic drogues (at 10 feet) showed only nominal (a few feet) of movement during our field assessments to date. However, even the deeper drogues to 10 feet documented water currents at depth but flow velocity was much lower than upper water column currents. Although not shown on **Figure 1**, water flow patterns also radiated outward from the center section of the pond (e.g., top 4 feet flowed towards the shores, and then began the often clockwise pattern of primary flow around the pond which is depicted on **Figure 1**. These flow patterns and characteristics are not unique or uncommon to small or large water bodies as they relate to the interaction of a water body's internal conditions and forces (bathymetry, frictional forces, turbulence, shoreline morphology, water pressure, density and essential incompressibility of water) with external forces (wind direction, duration-strength and fetch, and coriolis effect on large water bodies). The patented A-Pod technology uses these common natural water current flows and patterns to passively and sustainably trap and remove suspended solids like the cyanoHABs. **Figure 1** also depicts water current eddies, depicted as spirals, noted by HEA during our hydrologic assessments (2021-2022). Eddies are formed when primary water currents are altered by shoreline morphology changes, structures such as some docks, and changes in shallow water bathymetric relief patterns.

3.6 Water Clarity and Benthic Flora

<u>Material, Methods and Equipment Utilized</u>:

Visual assessments and photographic documentation were completed for benthic algae, sediment, surface water and cyanoHAB conditions. In addition to sonde turbidity measurements, water clarity was measured around noon on calm days using a secchi disc without the use of a view scope. Discrete samples of sediment and benthic flora were collected using either the gravity corer, a discrete water sampler, or by using a small fluke-style anchor (for benthic flora only).

<u>Field Data and Findings</u>:

HEA had a maximum secchi disc water clarity reading of 32.6 feet (approximately 10 meters) on October 12, 2022 near the conclusion of our Year 2022 restoration work. The year 2022 median secchi disc water clarity was determined to be 24.2 feet (May to November) versus the 1987-2017 year historic median of approximately 19.6 feet (approximately 6 meters, typically measured between June and August of each year). Turbidity sonde data, provided as an attached chart, were generally low and indicative of high water clarity. Seasonally (July to December) at depths of approximately 45 plus feet, turbidity increased (from approximately 1 to 8 nephelometric units (NTUs)). This increase in turbidity at depth also corresponded to the thin layer of more concentrated cyanoHAB PC noted later in the season (September to early November) at approximately 48 to 51 feet. Benthic flora consisted primarily of a macroalgae (Nitella) from depths of 5 to 45-47 feet around the pond. At depths greater than 45 feet, the recovered benthic flora was yellowed and not as dense coverage wise on the sediment bottom. HEA's determination of benthic flora is based on visual assessment and comparison of field samples with published photographic images. Nitella and fresh water moss are not invasive species and would provide both beneficial cover, forage and nutrients to micro- and macroinvertibrates, zooplankton and insects, natural nutrient cycling and production of oxygen during photosynthesis. Macroinvertibrates, zooplankton and insects would in turn provide forage for fish and other aquatic invertebrates and crustaceans (such as crayfish).

4.0 DISCUSSION OF FINDINGS FROM JULY 2021 TO DECEMBER 2022

As part of ecological restoration activities from August 2021 to December 2022 to improve the water quality of White Pond, HEA has utilized a cyanoHAB harvesting and removal technology, called the A-Pod, to passively trap (harvest), concentrate and permanently remove approximately 388.5 dry to moist U.S. pounds of cyanoHAB and similar suspended solids (pollen, and fragments of leaves, pine needles and macroalgae) from White Pond. The A-Pod technology is a physical collection, concentration and separation process for permanently removing suspended solids in water (i.e., cyanoHABs and similar). At White Pond, the A-Pods were used in passive mode, leveraging natural water body currents to trap and remove cyanoHABs without the use of chemicals, biologic substances, physical alterations such as dredging or covering of sediment.

Historically, White Pond has had visibly apparent cyanoHAB surface scums and blooms since the 1980s. In August 2021 (report cover photograph), HEA documented the presence of visibly-dense cyanoHAB scums and suspensions over approximately 50% of the pond. Until use of the A-Pods in 2022, these cyanoHAB events had created unhealthy conditions warranting closure and posting of signs by Concord around White Pond to restrict or limit water contact or use by people and pets.

CyanoHABs at White Pond have recently, and historically, been identified as either the strains Microcystis sp. or Dolichospermum sp.. These types of cyanoHABs are known to contain cyanotoxins that can have severe acute (death) to chronic (liver and neurological) damage to people, pets and wildlife via ingestion (typically the acute risk pathway), and/or inhalation of water-borne cyanoHAB aerosols and direct water contact (the more chronic health risk pathways).

From July 2021 through December 2022, HEA collected a significant amount of temporal and spatial data on cyanoHABs, surface water, sediment and benthic macroalgae in White Pond. Field and laboratory data findings and results are summarized in **Section 3.0** of this report. Based upon numerous vertical sonde PC profiles on an east to west transect (at each of the three deep basins) and at north and south offsets, cyanoHAB biomass as measured in PC was fairly uniform (almost normally distributed) from close to the water surface to the depth of sediment at each survey location and laterally between vertical survey offset locations taken during each monthly sonde survey. As such, PC results are also representative of cyanoHAB biovolume for White Pond during each monthly sonde survey. PC as both cyanoHAB biomass and biovolume did vary from one month to the next with seasonal changes (i.e. influence of sunlight and temperature) and removal of cyanoHABs using the A-Pods. HEA interprets sonde PC profiles for cyanoHABs at White Pond as being consistent with a high water clarity, oligotrophic to slightly mesotrophic water body.

Based upon HEA's review and analysis of data, use of the A-Pods has so far conservatively achieved a 51 percent reduction in both cyanoHAB biomass and biovolume in White Pond from August 2021 to October 2022. An additional 20 pounds of dry to moist cyanoHABs were also removed in November 2022 after HEA's October 2021 to October 2022 evaluation timeframe. Water clarity also improved as cyanoHABs were removed; the year 2022 secchi-disc median water clarity of 24.2 feet was greater than the 30-year (1987 to

2017) median of 19.6 feet (6 meters).

Use of the A-Pods and removal of cyanoHABs has also documented reductions in the nutrient content of cyanoHABs (for phosphorus and sulfur) and from the upper two inches of soft sediment (for phosphorus) from deep basins over time (November 2021 to November 2022). HEA's assessment findings have also documented variability in some sediment and surface water nutrient concentration over time, notably for nitrogen and sulfur. Sediment data for the nutrients nitrogen and phosphorus follow a stratigraphic pattern with depth consistent with an oligotrophic to mesotrophic water body (Carey and Rydin, 2011). Sediment concentrations for iron and sulfur were greatest in upper sediments and decreased in concentration with depth. Soft sediments deeper than 10 inches (26 centimeters) in deep basins at White Pond are likely greater than 200 years old (Stager et.al., 2020). HEA can discuss our findings regarding nutrients profiles and patterns in cyanoHABs, surface water and sediment in more detail if requested. In **Section 6.0**, we have provided additional references and sources of information that may be of interest for some readers.

In summary, excess and available nutrients at White Pond are contained primarily within the suspended cyanoHABs themselves, the benthic macroalge (Nitella) and within the top several inches of soft sediment. CyanoHABs are able to access and reduce excess nutrient concentrations in upper sediment layers by their evolutionary ability to utilize changes in biogeochemical conditions in water and sediment. However, based on results to date (2021-2022), excess concentrations of the biogeochemically active nutrient and pollutant sulfur in upper soft sediments of White Pond may remain at concentrations beyond what the cyanoHABs and A-Pod process can sustainably remove. HEA has provided recommendations in **Section 5.0** in this regard.

5.0 RECOMMENDATIONS

Based upon our findings to date, HEA recommends the following:

1. In Year 2023, continued use of two A-Pods to remove cyanoHABs and their cyanotoxins and excess nutrients. A-Pods are already constructed and ready to use at White Pond. Recovered cyanoHABs should be composted as in year 2022. Supporting assessments similar to year 2022 should be completed and include vertical sonde surveys on transects and offsets at White Pond and include Walden Pond as a reference location. A sufficient number of cyanoHAB solid, sediment and surface water samples should be collected over time and at various locations to support an evaluation for the nutrients (carbon, iron, nitrogen, phosphorus and sulfur), characterization of the type(s) of cyanoHABs, PC and cyanotoxin content. Sediment sampling should begin early in the season in addition to later in November.

2. Based on HEA's field observations, review of historical information, sampling and laboratory analytical results, and findings for patterns of nutrients in White Pond, HEA recommends that the Town of Concord consider including the biogeochemically-active macronutrient sulfur into any existing or upcoming guidance for promoting judicious use of similar nutrients or alternate practices that use less nutrients including sulfur by Concord's businesses, municipal services and residents. Sulfur is a component of many common residential and commercial use products and practices including within detergents, water quality additives, lawn care products and fertilizers.

3. The benthic meadows of macroalgae and fresh water moss at White Pond are fairly unique and not often reported in other water bodies of New England. Similar meadows, but not as extensive by depth have been documented at Walden Pond as well. Concord should consider evaluating and developing an understanding of why these meadows exist and ways to either maintain them or slowly reduce their occurrence (if their presence is related to a source of excess nutrients that itself can be reduced or removed). At present, they are a large sink (this term means not otherwise not available beyond the "sink") for nutrients that would otherwise be available to cyanoHABs, other forms of algae and cyanobacteria or macrophytes, including invasive species. The occurrence of these benthic meadows at both Walden and White Ponds and how their presence is related to nutrient availability (sources) and retention, sediment characteristics and water quality should be determined. It was interesting to note that these benthic meadows were present at shallower depths at White Pond than Walden and at both ponds, were not present at significant densities on soft sediments with depth. Their occurrence was also a good indicator of the significant depth of the photic zone at both ponds.

4. Excess sulfur may remain in the upper layer of soft sediment in deep basins following A-Pod and cyanoHAB removal activities. Removal of the top several inches of very soft, easily disturbed sediment in the eastern basin, and possibly the central and western basin (additional sediment sampling warranted) is something Concord should consider. This layer (top 2-inches) of sediment contained elevated sulfur concentrations; twice the concentration of underlying and much older sediments. Based on chronological dating of sediment at White Pond (Stager et. al, 2020), the source of this excess sulfur in the upper layer of sediment may be from air-borne deposition (dry and wet) during the Industrial Revolution and burning of coal starting in the mid-1800s as well as more recent land use changes, erosion and climate change. Removing these legacy impacts, notably the excess sulfur, would further restore the environmental health of White Pond. At present, the excess sulfur in the top two inches of soft sediment can have a dramatic effect on the natural biogeochemical cycling, deposition and binding of nutrients and related water quality that many people are just not aware of given the timeframe (past 200 years) and ongoing persistence of these historic pollutant impacts. Based on historical records, Henry David Thoreau (1817-1862) may have observed the beginning of these now legacy pollutant and sulfur impacts remaining in White Pond {i.e., that Thoreau (circa 1854) noted White Pond's water quality as extremely clear (30-33 foot water clarity) but had a green color (Stager et al 2020)}.

   If interested in removing more of these historic pollutants from White Pond, HEA would recommend use of the A-Pod's sister technology, the S-Pod or the P-Pod. The S-Pod is designed and patented for removal of easily disturbed, soft sediments at depth such as occurs at White Pond. The P-Pod is designed and patented to extract excess nutrients or to degrade contaminants from in-place sediments - without sediment removal or disturbance. More information on these technologies are provided at www.ppodtech.com Either technology would be a relatively low cost, sustainable approach with minimal disturbance to the pond, pond users or the environment.

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ATTACHMENTS

Laboratory Data Sheets - Under Separate Cover - Concord's Year 2022 CyanoHAB solids, Sediment and Surface Water samples. As a courtesy, HEA has included laboratory data sheets and results for samples included on summary tables in this report but completed under HEA's NSF work.

FIGURES

YEAR 2022 SUMMARY REPORT
RESTORATION OF WHITE POND'S WATER

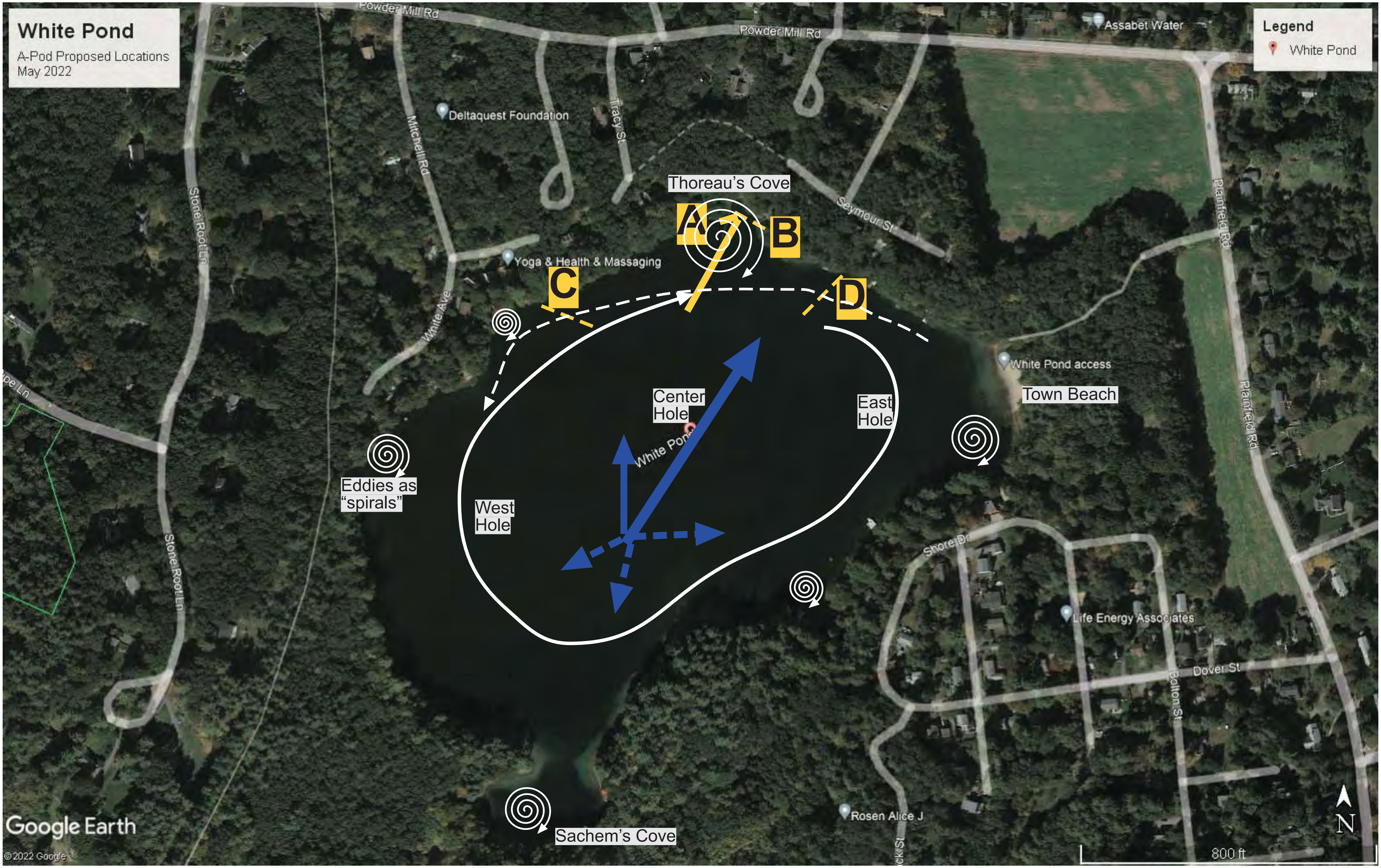


Figure 1 - Year 2022 Field Information

Prepared on January 9, 2023 by Higgins Environmental Associates, Inc.
Reference: 2021 Google Earth image
Locations and dimensions are for illustrative purposes only.

KEY:

Primary A-Pod Location "A". Main extension is 300 feet long

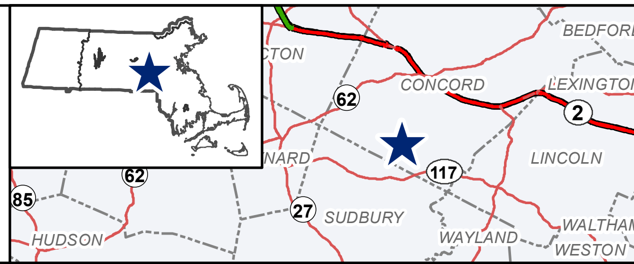
Secondary A-Pod Locations "B", "C" and "D" primarily for scums. Each Section is 180 feet long.

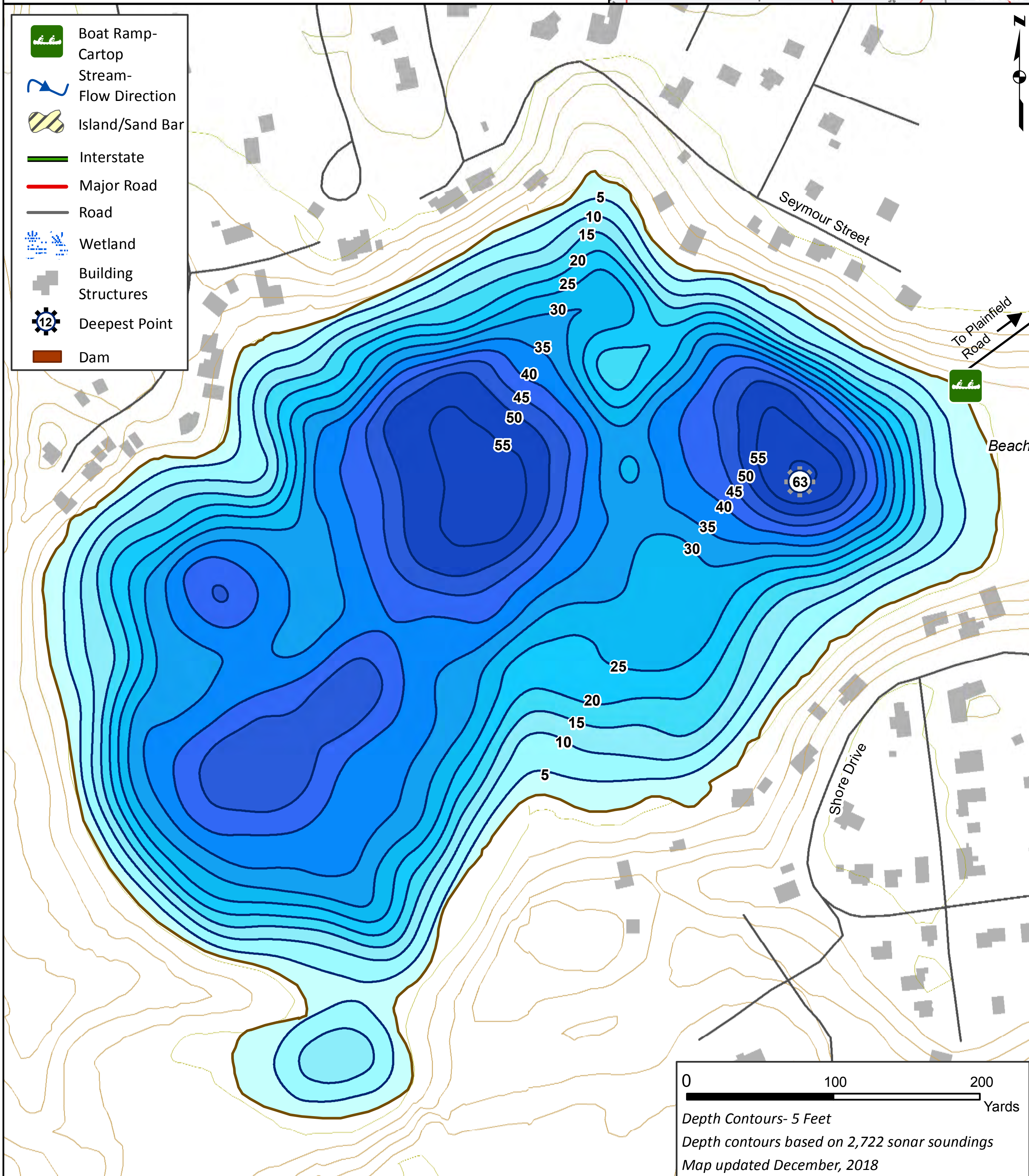
Blue Arrows are Wind Directions: White are water currents

Higgins Environmental Associates, Inc.
Environmental Science and Hydrogeology

White Pond

40 Acres
Concord
Concord River Watershed
Coordinates: 71°23'14" W 42°25'44" N
USGS Quad: Maynard





TABLES

YEAR 2022 SUMMARY REPORT
RESTORATION OF WHITE POND'S WATER

TABLE 1 - YEARs 2021 to 2022 MONTHLY FIELD DATA SUMMARIES FOR WHITE POND RESTORATION with A-Pods - EMPHASIS ON CYANOHAB DATA

White Pond Monthly Records	Cyanobacteria Data Pounds Recovered (pounds)	Maximum Field BGA-PC A-Pod Trap	A-Pod Trap lab PC and Cyanotoxins Lab PC	Lab Cyanotoxins	Average Field BGA-PC Open Water - Biovolume	Open Water lab PC and Cyanotoxins Lab PC	Lab Cyanotoxins	Water Clarity (Secchi depth in Feet)	Depth to Sediment Deepest Basin	HAB Scums In Pond?
Units of Measurement	U.S Pounds	RFUs	ug/L	ug/L	RFUs	ug/L	ug/L	Feet		Visual
1987-2014 Data (by others)	None	Not Measured	Not Appicable	Not Applicable	Not Measured	Not Measured	Not Measured	Median of 6 Meters(19.6ft)		Yes
2021 HEA White Pond Data										
July (7/16/21 East Hole)	No A-Pod	No A-Pod	No A-Pod	No A-Pod	2.32			Not measured		Yes
August (8/26/21 East Hole)	No A-Pod	No A-Pod	No A-Pod	No A-Pod	2.39			Not measured		Yes
October (10/7 Center Hole)	40	9.7 (Oct. 7)	221.03		2.14	4.27		Not measured		Yes
October (10/14 Trap)	60	131.6 (Oct. 14)	8689	35.9 Microcystin				Not measured		Yes
Year 2021	100 (estimate)	131.6	8689	35.9 Microcystin	2.28	4.27				Yes
2022 HEA White Pond Data										
May (5/5 East Hole)	None				1.69			31	61.9	No-Pollen
June (6/2 Center Hole)	75	13.46 (Jun. 14)	7.23	Not Detected	1.96	1.92	Not Detected	Not measured		Yes-spotty
July (7/13 East Hole)	110	24.86 (Jul. 5)			2.68			16.5 to 18.3	62.6	Yes-thin
August (8/16 East Hole)	35.5	18.57(Aug. 20)	17.2	0.08 Anatoxin	1.88	2.38	Not Detected	18.3 to 20.1	60.2	Yes-thin-spotty
September(9/8 East Hole)	8	10.32 (Sept.27)			1.55			19.6 to 22.5	58.7	No
October (10/12 East Hole)	40	53 (Oct. 16)	113.24	0.802 Microcystin	1.07	2.61	Not Detected	32.6	61.9	No
November (11/9 East Hole)	20	7.76 (Nov. 2)			1.20			20 to 27.6	60.4	No
December (12/5 East Hole)	A-Pod removed 11/22/22	Not applicable	Not applicable	Not applicable	1.05			Not measured	59.2	No
Year 2022	288.5	53	113.24	0.802 Microcystin	1.64	2.61	Not Detected	Median of 24.2		No - Sept +
2021-22 HEA Reference Data Paired by month and year										
White Pond (7/16/2021)	No A-Pod	No A-Pod	No A-Pod	No A-Pod	2.32			Not measured		Yes
White Pond (7/13/2022)	110	1.05			2.68			16.5 to 18.3	62.6	Yes-thin
White Pond (8/20/22)		18.57			2.00			19.6	61.1	Yes-thin-spotty
Walden (8/20/22)		Not applicable			1.93			20.7	91.9	No
White Pond (10/7/2021)	40	9.7 (Oct. 7)	221.03		2.14	4.27		Not measured		Yes
Walden (10/6/2021)		Not applicable			2.27			Not Measured		No
White Pond (10/12/2022	40	53	113.24	0.802 Microcystin	1.07	2.61	Not Detected	32.6	61.9	No

Note:

1. Year 2022 monthly records represent by month: dry-moist pounds of cyanobacteria removed with the A-Pods; maximum BGA-PC in the A-Pod Trap; lab results when available; water clarity by secchi disc; PC and Cyanotoxin results on dates noted in "()" in column or by Monthly Records Column date.
2. 2021 data is from Higgins Environmental Associates National Science Foundation (NSF) funded field trail with dates noted in "()". Sonde fitted with 30 foot cable for measurements (correction value applied of +1.54893 for 100 foot cable comparison). In 2022, sonde fitted with 100 foot cable.
3. Monthly records maintained by Higgins Environmental Associates field scientist unless noted otherwise; 1987-2014 data from W.Walker 2015 Summary of White Pond Data (http://www.wwwalker.net/whitepond/)
4. Field BGA-PC = field measurements using a multiparameter sonde (Insitu AquaTroll 500) fitted with a blue-green algae (BGA) - phycocyanin (PC) probe with measurements in Relative Flouresence Units (RFUs)
   Most data is from vertical sonde surveys taken monthly and during lab sampling. Sonde snapshots were collected more frequently from A-Pod Trap areas. Other vertical sonde surveys were collected throughout the pond to assess water body quality variance.
5. Lab PC data results provided by the University of New Hamphire. Field BGA-PC at same time/day/location noted in "()". Lab PC is reported in micrograms per liter (ug/L).
6. Average Field Open Water BGA-PC represents the average of vertical sonde survey results from the corresponding date and location noted in the Monthly Records column. Based on multiple vertical surveys, this data also represents the biovolume of PC for the pond as a whole on that day.
7. BGA = blue green algae; PC = phycocyanin; PC is a measure of cyanobacteria biomass at each sample and when correlated to water body volume, serves to represent pond PC biovolume.
8. Water clarity as reported was measured with a secchi disc without the use of a view scope. 1987-2017 secchi disc data utilized a view scope. As such, 2022 results are considered conservative.
   A median secchi disc depth (i.e., water clarity) reading from 1987 to 2017 was calculated at approximately 6 meters (19.7 feet). This has been referred to as the historic baseline secchi disc depth reference.
   Most of the historic mean secchi readings were obtained between June to August of each year when the sunlight angle is higher than earlier or later months of the year for this latitude. Our median values ranged from 22.42 (May-November) to 18.3 (July-August). No measurement was made for June 2022.
9. May 20, 2022 main A-Pod set up in Thoreau's cove. November 22, 2022 main A-Pod removed from Thoreau's Cove. In 2021, main A-Pod set up in Thoreau's cove on August 30th and removed on October 20th, 2021.
10. A total of 288.5 (dry-moist) pounds of cynobacteria were removed in Year 2022 using the A-Pod and were composted on land in a controlled manner. Approximately 100 (moist to wet) pounds were removed in 2021 and composted as part of our NSF-funded trial.
11. On September 28, 2022 water velocity in White Pond calculated using depth specific drogues to be: 8 feet/minute at 2 feet deep; 6 to 7.5 feet/minute at 4 feet deep; negligible at 10 feet deep. Drogue flow patterns in 2022 indicate clockwise flow pattern with eddies near some shore/structure areas.

Table 2 - Surface Water Sample Results - White Pond, Concord, MA

Sample ID:	WP-Trap		WP-Trap		WP-Trap		WP-In		WP-In		WP-In		WP-Out		WP-Out		WP-Out		
Lab Sample Number:	2F03025-01		2H17031-01		2J13028-01		2F03025-02		2H17031-02		2J13028-02		2F03025-03		2H17031-03		2J13028-03		
Date Sampled:	6/2/2022		8/16/2022		10/12/2022		6/2/2022		8/16/2022		10/12/2022		6/2/2022		8/16/2022		10/12/2022		
Parameter	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Units
General Chemistry																			
Nitrate and Nitrite as N	ND	0.03	ND	0.03	ND	0.03	**0.03**	0.03	**0.08**	0.03	**0.04**	0.03	**0.03**	0.03	**0.04**	0.03	ND	0.03	mg/L
Total Nitrogen	**0.6**	0.1	**0.8**	0.1	**1.1**	0.1	**0.23**	0.1	**0.38**	0.1	**0.54**	0.1	**0.13**	0.1	**0.34**	0.1	**0.5**	0.1	mg/L
Kjeldahl Nitrogen	**0.6**	0.1	**0.8**	0.1	**1.1**	0.1	**0.2**	0.1	**0.3**	0.1	**0.5**	0.1	**0.1**	0.1	**0.3**	0.1	**0.5**	0.1	mg/L
Total Phosphorous	**0.05**	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.02	mg/L
Total Organic Carbon	**3.7**	0.5	**3.1**	0.2	**4**	0.2	**2.7**	0.5	**2.7**	0.2	**2.4**	0.2	**2.7**	0.5	**2.7**	0.2	**2.5**	0.2	mg/L
Total Metals																			
Iron	**0.17**	0.05	**0.49**	0.05	**0.4**	0.05	ND	0.05	ND	0.05	**0.08**	0.05	ND	0.05	ND	0.05	**0.05**	0.05	mg/L
Sulfur	**1.5**	0.5	**1.3**	0.5	**1.2**	0.5	**1.4**	0.5	**1.3**	0.5	**1.2**	0.5	**1.3**	0.5	**1.4**	0.5	**1.2**	0.5	mg/L
Field Measured Phycocyanin at Sampling																			
Phycocyanin	**1.87**		**1.95**		**4.02**		**0.251**		**1.91**		**0.87**		**2.09**		**1.74**		**1.1**		RFUs
Phycocyanin and Cyanotoxins by Laboratory Analysis																			
Phycocyanin	**7.23**		**17.2**		**113.24**		**4.46**		**2.51**		**1.69**		**1.92**		**2.38**		**2.61**		ug/L
Cyanotoxin	**ND**		see below		see below		**ND**		see below		**ND**		**ND**		**ND**		**ND**		ug/L
Microcystin					**0.802**														ug/L
Anatoxin			**0.08**						**0.11**										ug/L

Notes for Table 2:

1. All samples collected as discrete (grab) samples.
2. All results reported as total on a wet weight basis. mg/L = milligrams per liter; RFUs = relative fluoresence units; ug/L = micrograms per liter.
3. ND = not detected at or above reporting limit noted.
4. Detected results are highlighted in yellow with bold typeface. Cyanotoxin non-detect data also highlighted in yellow and bold typeface given its importance.
5. Preservatives - laboratory pre-preserved bottles per Standard Methods and Analytes (HNO_3 for Fe, S; H_2SO_4 for N and C; none for P and N; all cooled to less than 4 degrees Celcius from collection to analysis).

Table 3 - Recovered HAB and Sediment Sample Results - White Pond

	Benthic Algae		Cyanobacteria (HAB) Samples						Sediment Samples													
Sample ID:	BPLNT-1		APOD HAB		HAB1-22		HAB-2-22		SED1 WHTS		SED2 WP		SED 3 -WP5	WP-ED-6"		WP-CD-6"		WP-WD-6"		WP-EH-62'		
Lab Sample Number:	1I15020-03		1J15038-04		2H17029-06		2J13027-01		1G21034-01		1H31016-01		1K10047-01	2H17028-03		2H17028-04		2H17028-05		2K10018-03		
Date Sampled:	9/14/2021		10/14/2021		7/5/2022		10/7/22		7/16/2021		8/26/2021		11/9/21	8/10/2022		8/10/2022		8/10/2022		11/7/2022		
Parameter	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Results Top 2"/4-8"/16-24"	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Sample Result	Reporting Limit	Units
General Chemistry									East Hole top 6"		Thoreaus Cove 6"		Vert Profile to 24"	East Hole to 6"		Center Hole to 6"		West Hole to 6"		East Hole Top 2"		
Nitrate and Nitrite as N	Not Tested		Not Tested		492	23	ND	7	Not Tested		Not Tested		East Hole	153	7	224	11	504	24	204	10	mg/kg
Total Nitrogen	3050	10	5860	0.1	12400	10	18200	10	7620	0.1	229	10	1130/1680/1650	10500	10	14500	10	22400	10	8840	10	mg/kg
Kjeldahl Nitrogen	Not Tested		Not Tested		11900	440	18200	1490	Not Tested		Not Tested		Not Tested	10300	154	14300	236	21900	443	8640	985	mg/kg
Total Phosphorous	1570	1.39	3630	2.39	2200	1.62	2040	2.53	580	2.39	899	1.47	2250/2740/2460	2100	0.55	2410	0.91	2390	1.22	1990	1.6	mg/kg
Total Organic Carbon	46	0	40	0	36	0	40	0	3	0	10	0	16/30/29	16	0	23	0	26	0	16	0	Percent (%)
Total Metals																						
Iron	9550	14	12000	24.1	9360	16.3	7320	25.6	8600	24.1	10500	14.8	27300/10100/9280	18100	5.5	10500	9.1	11000	12.3	25700	16.2	mg/kg
Sulfur	3970	140	3680	241	3230	163	2690	256	2370	241	3030	148	9870/4790/4470	6000	55.4	5280	91.4	6180	123	11400	162	mg/kg

Notes for Table 3:

1. HAB = harmful algae bloom; HAB1-22 sample is a composite of 35 pounds of partially-dried HAB removed from main A-Pod Trap "A" on June 29, 2022; HAB2-22 is a composite of 40 pounds of partially-dried HABs removed from A-Pod "A" in Oct 2022.
2. All HAB samples collected as composite samples on date sampled. Sediment samples collected as discrete samples over specified interval (either top 2 inches; top 6 inches; or at 6 inch intervals at SED3-WP5 from a 0 to 24 inch core sample).
3. All results reported as total on a dry weight basis.
4. ND = not detected at or above reporting limit noted.
5. Detected results are highlighted in yellow with bold typeface.
6. Preservatives - samples frozen after collection until laboratory analysis.
7. APOD HAB sample from 10/14/21 was part of our NSF funded work; and serves as a Year 2021 year end "background sample" for Concord's Year 2022 work and results for HAB solids.
8. All sediment samples were collected and analyzed as part of our NSF work; presented results are summarized for informational purposes only.
9. Sample SED3-WP5 was collected using a gravity corer with intact recovery of 24 inches (60 centimeters) of soft sediment. Discrete sediment samples were collected and results reported from the core as follows: top 2 inches/ 4 to 8 inches / 16 to 24 inches.
10. Sample WP-EH-62 was collected in the east hole (deep basin off beach) using a discrete water sampler which is helpful for collecting the very loose, almost smoke-like top 2 inches of sediment. This sample was primarily green-colored detritus with active microbial populations.
11. BPLNT1 = benthic algae (Nitella) sample collected from a grab sample approximately 30 feet deep south of Thoreau's cove.

CHARTS

YEAR 2022 SUMMARY REPORT
RESTORATION OF WHITE POND'S WATER

Chart 1 - **Years 2021-2022 Benefit of CyanoHAB Removal**

Chart 2 - **Years 2021-2022 Monthly White Pond CyanoHAB Population Variance**

Chart 3 - **October Years 2021-2022 Changes in CyanoHAB Biomass and Biovolume in White Pond**

Charts 4-9 - **Year 2022 Monthly Profiles for: CyanoHABs, Temperature, Dissolved Oxygen, Turbidity, pH, Oxidation-Reduction Potential**

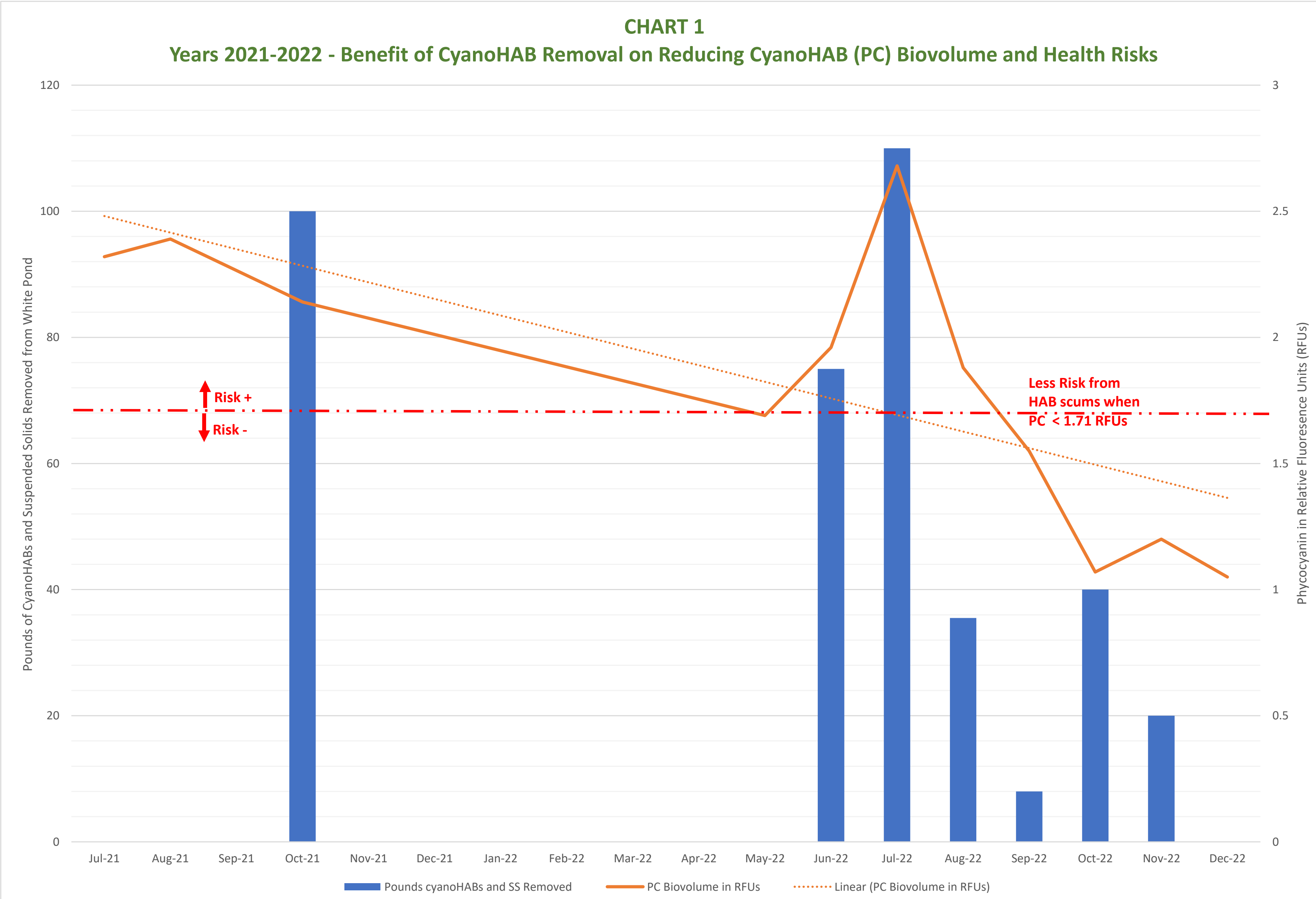


CHART 1
Years 2021-2022 - Benefit of CyanoHAB Removal on Reducing CyanoHAB (PC) Biovolume and Health Risks
Pounds of CyanoHABs and Suspended Solids Removed from White Pond
Phycocyanin in Relative Fluoresence Units (RFUs)
120
100
80
60
40
20
0
3
2.5
2
1.5
1
0.5
0
Risk +
Risk -
Less Risk from
HAB scums when
PC < 1.71 RFUs
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Sep-22
Oct-22
Nov-22
Dec-22
Pounds cyanoHABs and SS Removed
PC Biovolume in RFUs
Linear (PC Biovolume in RFUs)

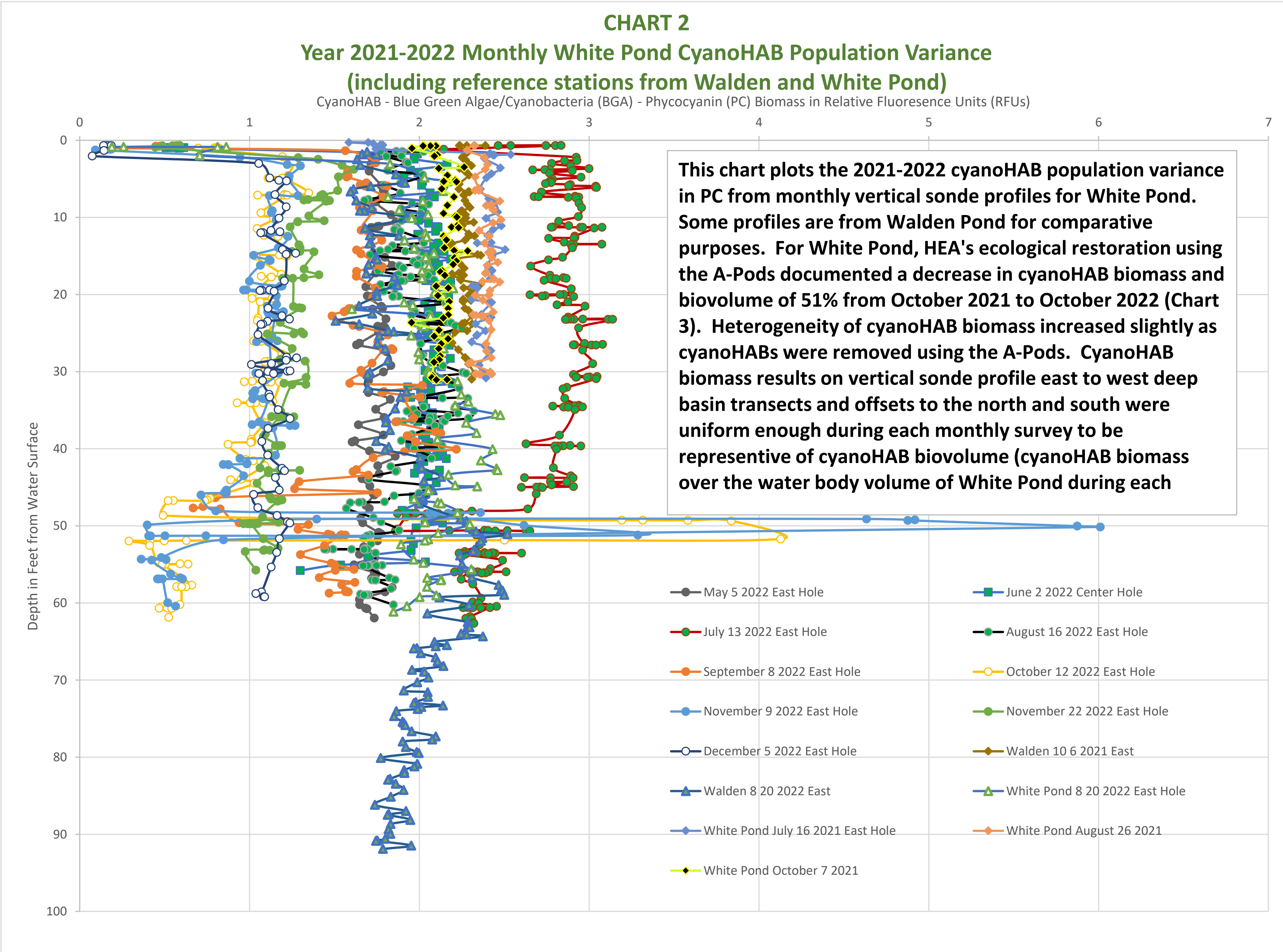


CHART 2
Year 2021-2022 Monthly White Pond CyanoHAB Population Variance
(including reference stations from Walden and White Pond)
CyanoHAB - Blue Green Algae/Cyanobacteria (BGA) - Phycocyanin (PC) Biomass in Relative Fluoresence Units (RFUs)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100
Depth in Feet from Water Surface
This chart plots the 2021-2022 cyanoHAB population variance in PC from monthly vertical sonde profiles for White Pond. Some profiles are from Walden Pond for comparative purposes. For White Pond, HEA's ecological restoration using the A-Pods documented a decrease in cyanoHAB biomass and biovolume of 51% from October 2021 to October 2022 (Chart 3). Heterogeneity of cyanoHAB biomass increased slightly as cyanoHABs were removed using the A-Pods. CyanoHAB biomass results on vertical sonde profile east to west deep basin transects and offsets to the north and south were uniform enough during each monthly survey to be representive of cyanoHAB biovolume (cyanoHAB biomass over the water body volume of White Pond during each
May 5 2022 East Hole
June 2 2022 Center Hole
July 13 2022 East Hole
August 16 2022 East Hole
September 8 2022 East Hole
October 12 2022 East Hole
November 9 2022 East Hole
November 22 2022 East Hole
December 5 2022 East Hole
Walden 10 6 2021 East
Walden 8 20 2022 East
White Pond 8 20 2022 East Hole
White Pond July 16 2021 East Hole
White Pond August 26 2021
White Pond October 7 2021

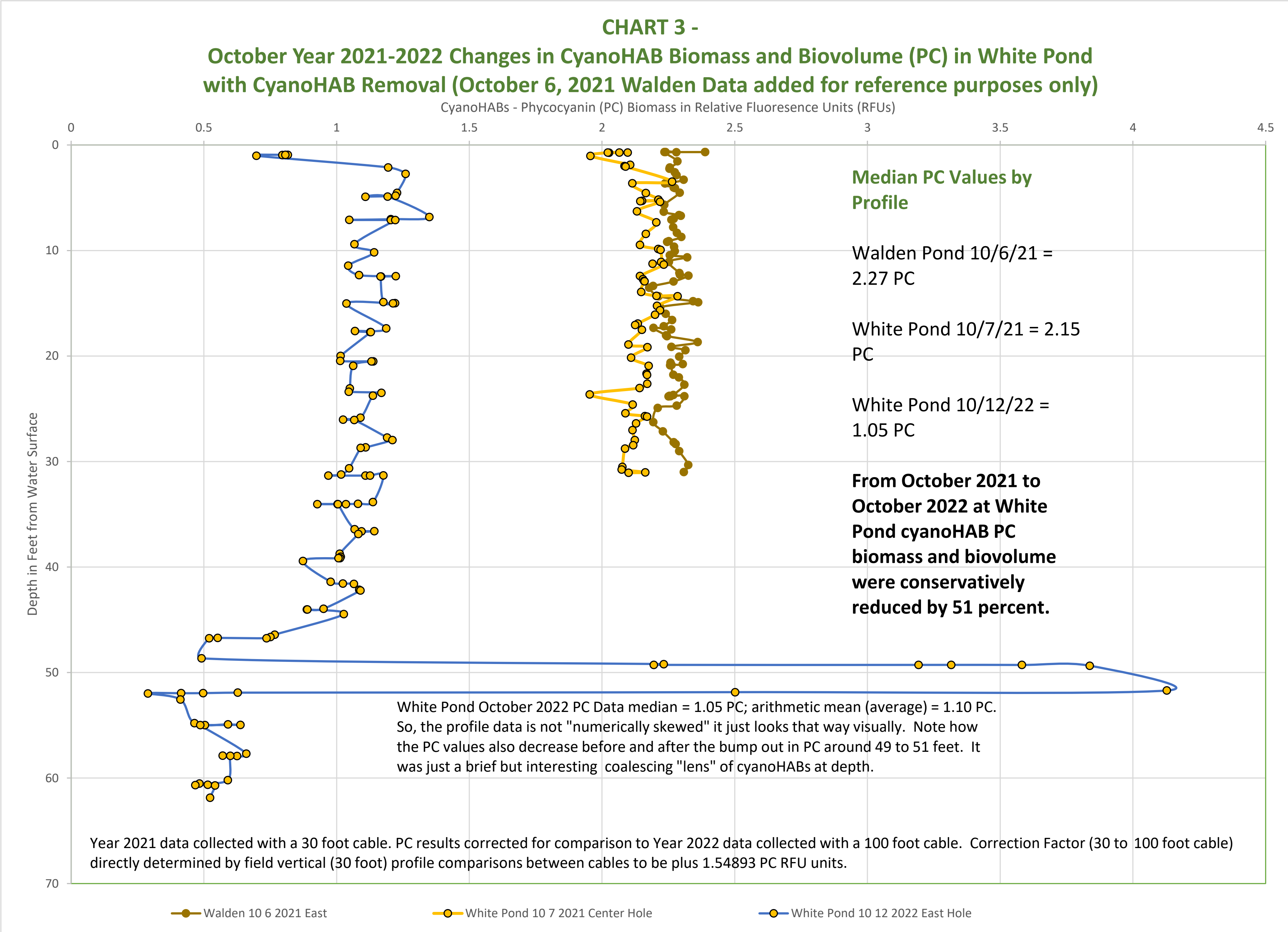
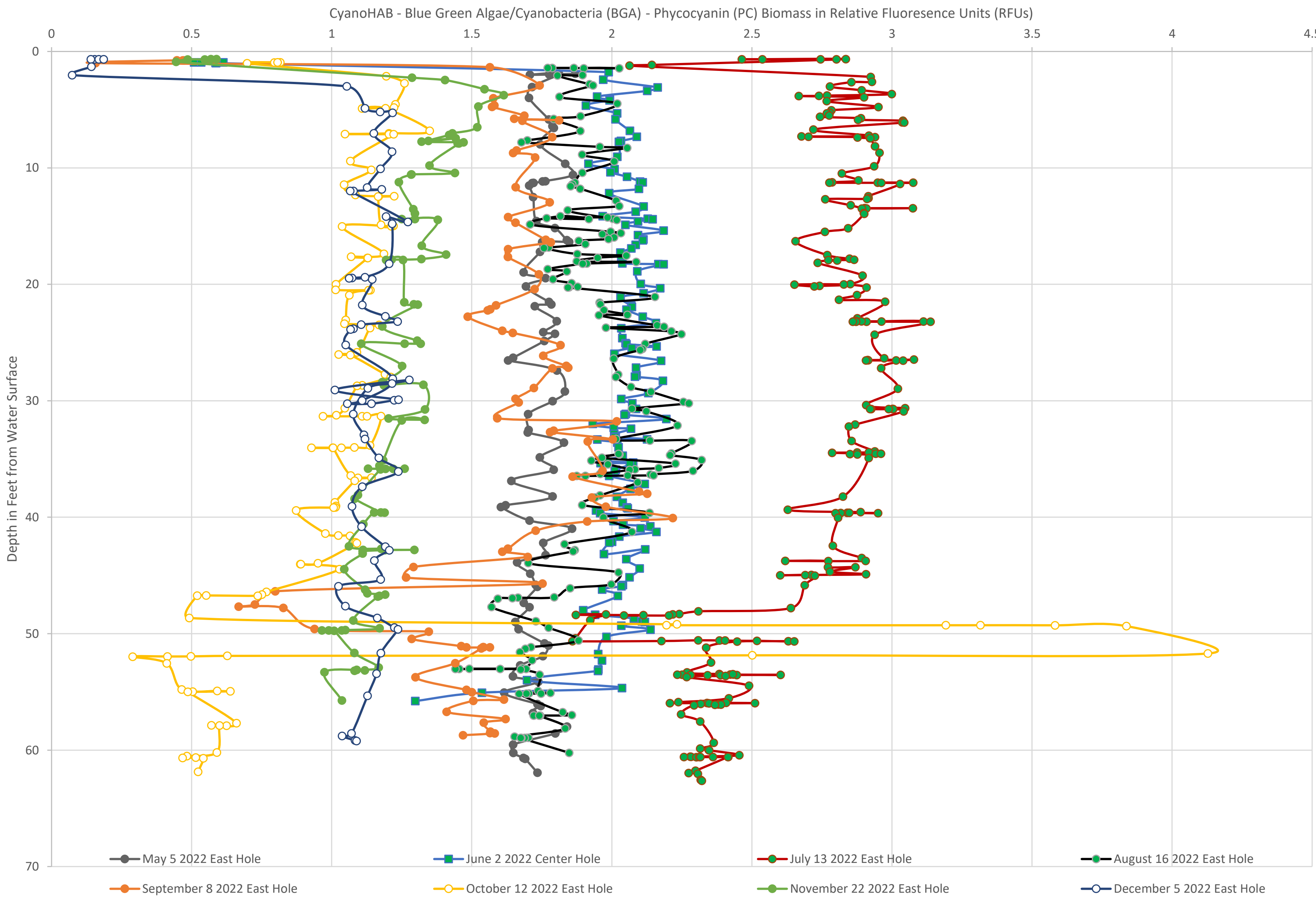


CHART 3 -
October Year 2021-2022 Changes in CyanoHAB Biomass and Biovolume (PC) in White Pond with CyanoHAB Removal (October 6, 2021 Walden Data added for reference purposes only)
CyanoHABs - Phycocyanin (PC) Biomass in Relative Fluoresence Units (RFUs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Depth in Feet from Water Surface
0
10
20
30
40
50
60
70
Median PC Values by Profile
Walden Pond 10/6/21 = 2.27 PC
White Pond 10/7/21 = 2.15 PC
White Pond 10/12/22 = 1.05 PC
From October 2021 to October 2022 at White Pond cyanoHAB PC biomass and biovolume were conservatively reduced by 51 percent.
White Pond October 2022 PC Data median = 1.05 PC; arithmetic mean (average) = 1.10 PC. So, the profile data is not "numerically skewed" it just looks that way visually. Note how the PC values also decrease before and after the bump out in PC around 49 to 51 feet. It was just a brief but interesting coalescing "lens" of cyanoHABs at depth.
Year 2021 data collected with a 30 foot cable. PC results corrected for comparison to Year 2022 data collected with a 100 foot cable. Correction Factor (30 to 100 foot cable) directly determined by field vertical (30 foot) profile comparisons between cables to be plus 1.54893 PC RFU units.
Walden 10 6 2021 East
White Pond 10 7 2021 Center Hole
White Pond 10 12 2022 East Hole

CHART 4
Year 2022 White Pond Monthly CyanoHAB Population Variance



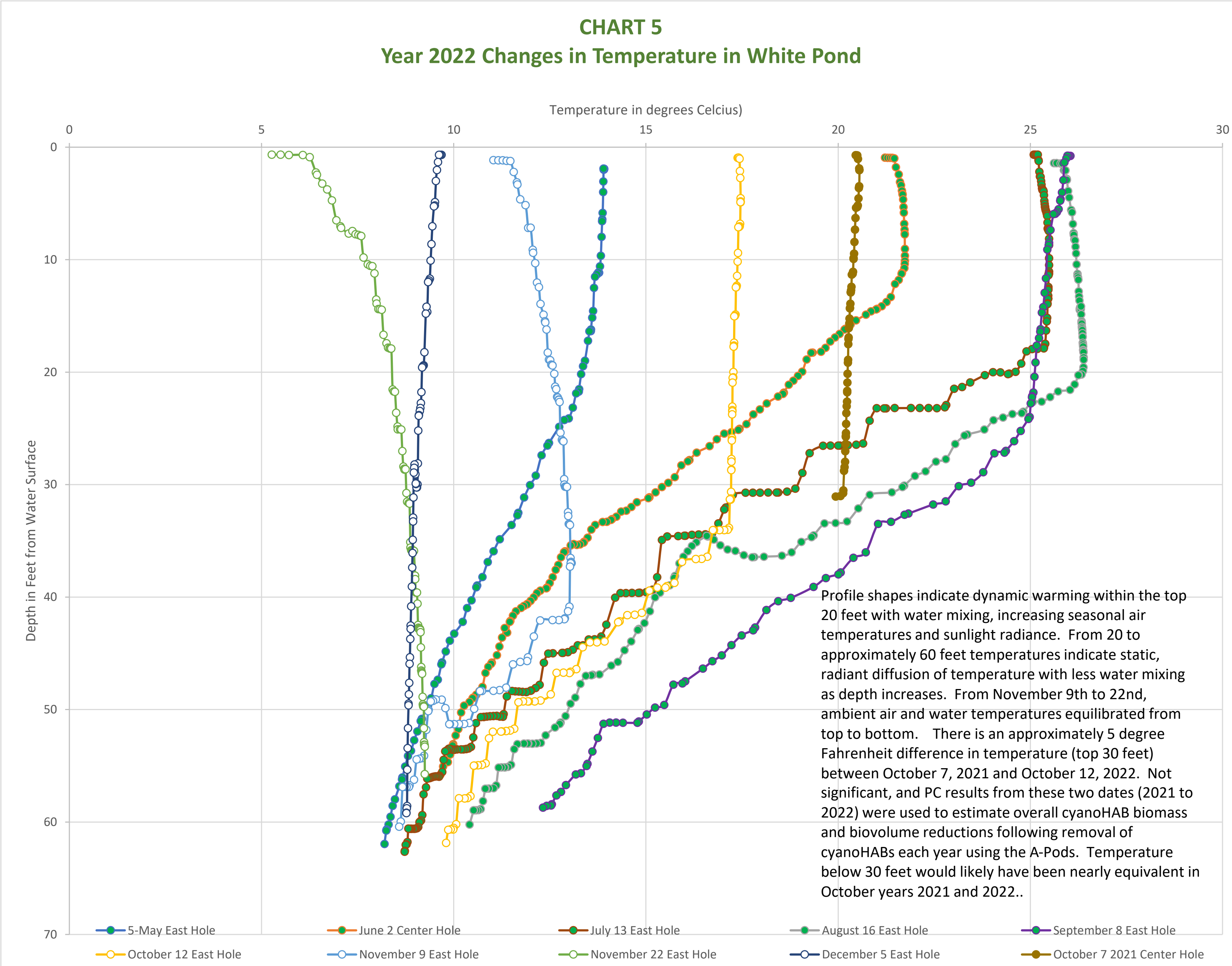


CHART 5
Year 2022 Changes in Temperature in White Pond
Temperature in degrees Celcius)
0
5
10
15
20
25
30
Depth in Feet from Water Surface
0
10
20
30
40
50
60
70
Profile shapes indicate dynamic warming within the top 20 feet with water mixing, increasing seasonal air temperatures and sunlight radiance. From 20 to approximately 60 feet temperatures indicate static, radiant diffusion of temperature with less water mixing as depth increases. From November 9th to 22nd, ambient air and water temperatures equilibrated from top to bottom. There is an approximately 5 degree Fahrenheit difference in temperature (top 30 feet) between October 7, 2021 and October 12, 2022. Not significant, and PC results from these two dates (2021 to 2022) were used to estimate overall cyanoHAB biomass and biovolume reductions following removal of cyanoHABs each year using the A-Pods. Temperature below 30 feet would likely have been nearly equivalent in October years 2021 and 2022..
5-May East Hole
June 2 Center Hole
July 13 East Hole
August 16 East Hole
September 8 East Hole
October 12 East Hole
November 9 East Hole
November 22 East Hole
December 5 East Hole
October 7 2021 Center Hole

CHART 6
Year 2022 Changes in Dissolved Oxygen in White Pond

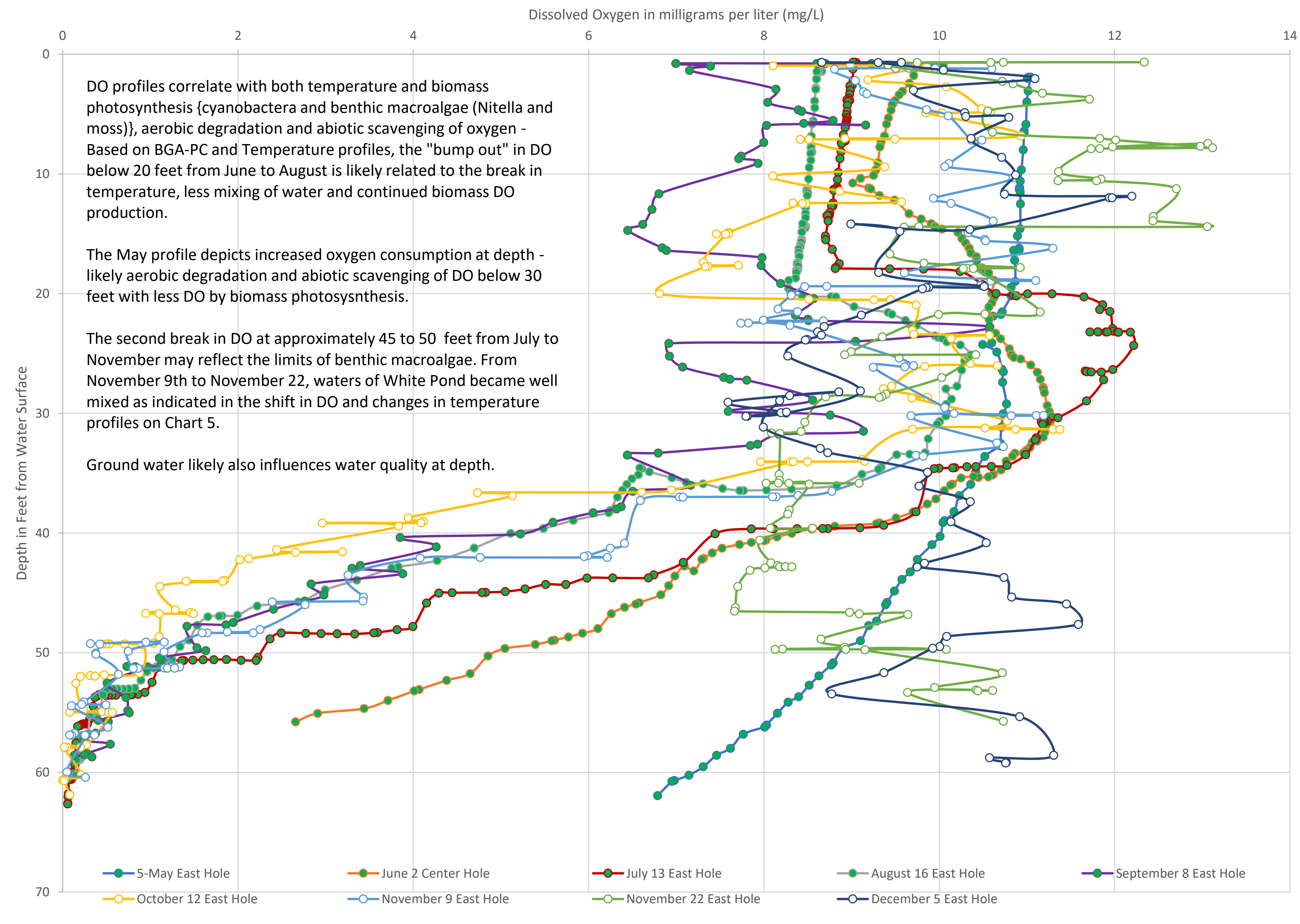


CHART 7
Year 2022 Changes in Turbidity in White Pond

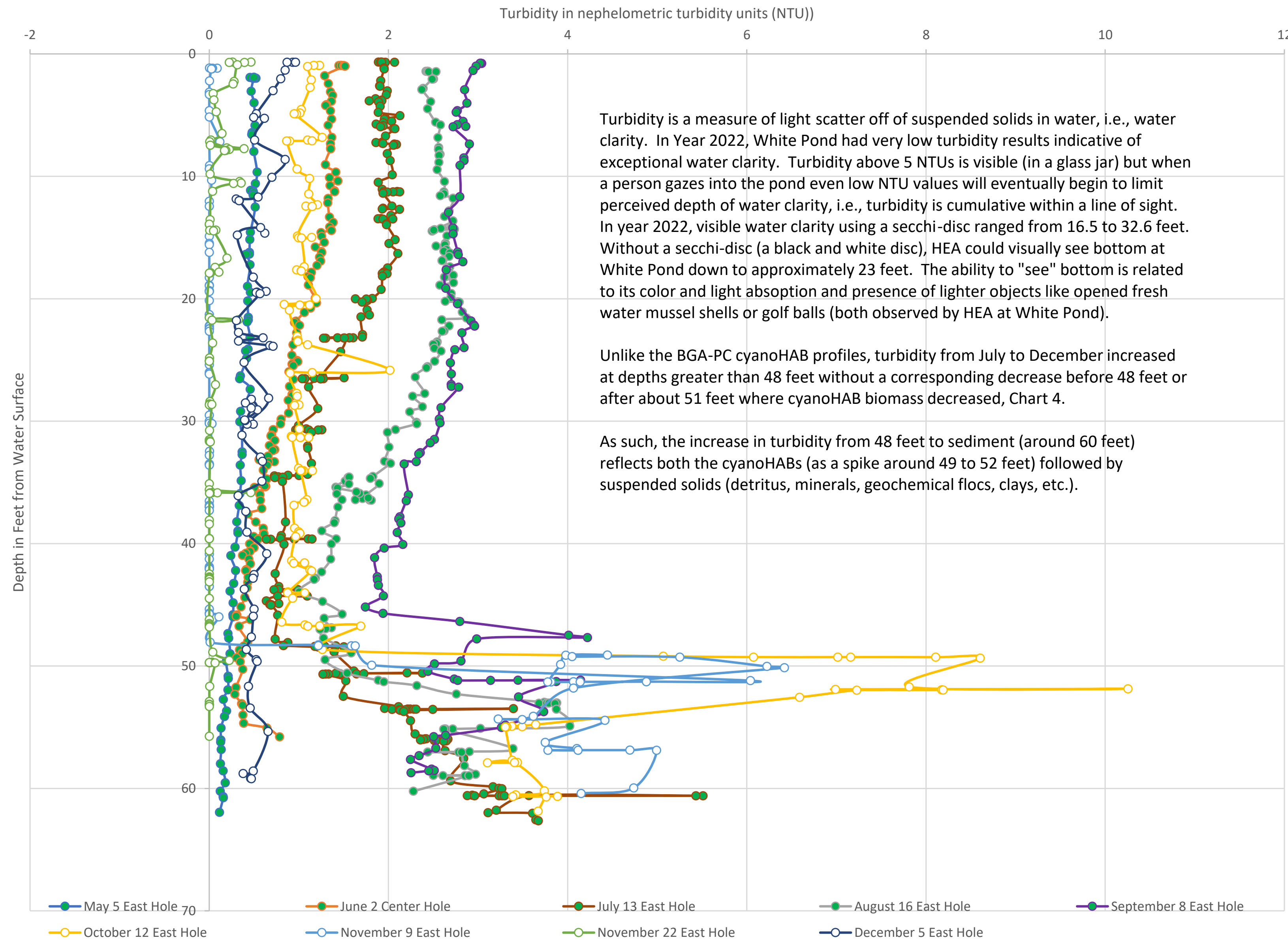
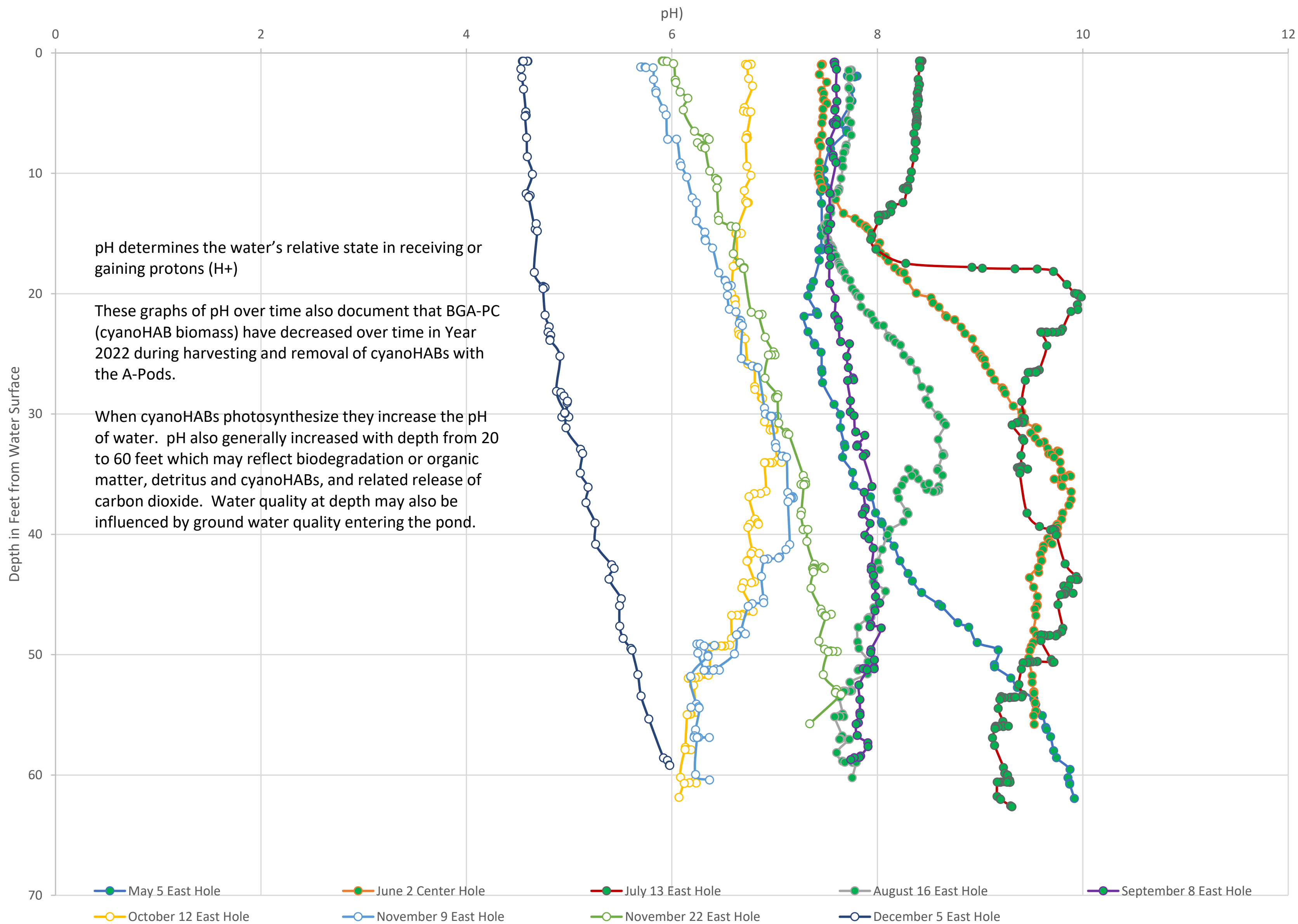


CHART 8
Year 2022 Changes White Pond's pH



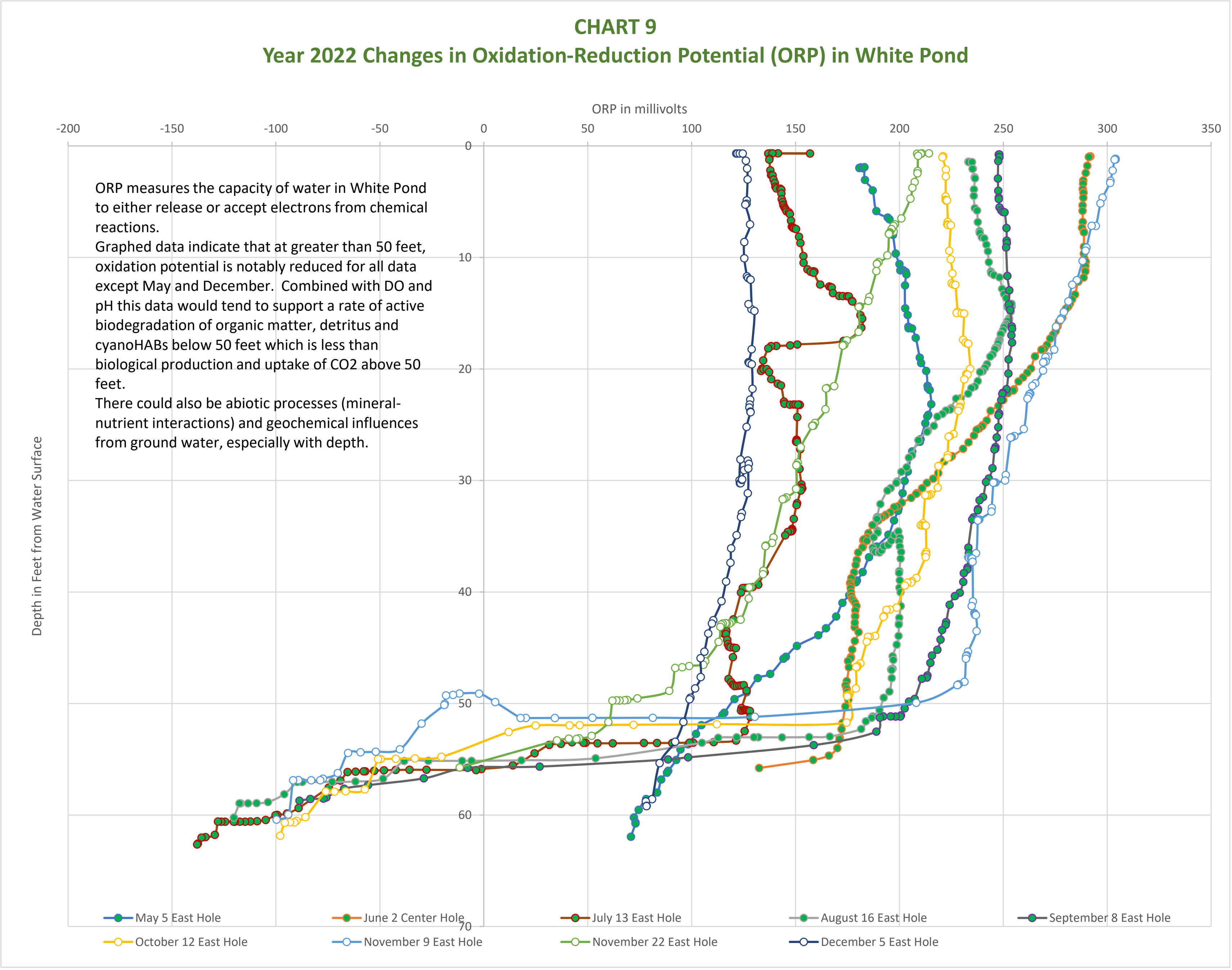


CHART 9
Year 2022 Changes in Oxidation-Reduction Potential (ORP) in White Pond
ORP in millivolts
-200
-150
-100
-50
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
Depth in Feet from Water Surface
ORP measures the capacity of water in White Pond to either release or accept electrons from chemical reactions.
Graphed data indicate that at greater than 50 feet, oxidation potential is notably reduced for all data except May and December. Combined with DO and pH this data would tend to support a rate of active biodegradation of organic matter, detritus and cyanoHABs below 50 feet which is less than biological production and uptake of CO2 above 50 feet.
There could also be abiotic processes (mineral-nutrient interactions) and geochemical influences from ground water, especially with depth.
May 5 East Hole
June 2 Center Hole
July 13 East Hole
August 16 East Hole
September 8 East Hole
October 12 East Hole
November 9 East Hole
November 22 East Hole
December 5 East Hole

LABORATORY DATA SHEETS
(under separate cover due to size)

YEAR 2022 SUMMARY REPORT
RESTORATION OF WHITE POND'S WATER