School for Marine Science and Technology
706 South Rodney French Blvd.
New Bedford
Massachusetts 02744-1221
Tel 508.999.8193
Fax 508.999.8197
University of Massachusetts Dartmouth

Technical Memorandum

To: George Meservey, Director of Planning & Community Development, Town of Orleans

From: Brian Howes, Director, Coastal Systems Program, SMAST, UMassD
Ed Eichner, Principal, TMDL Solutions

Date: November 30, 2021

RE: 2021 Uncle Harvey's Pond: Water Quality Changes 6 Months Post-Alum Treatment

ABSTRACT
The May 2021 alum treatment of Uncle Harvey's Pond notably improved water quality conditions throughout the pond's water column. Average summer water column total phosphorus mass approximated long-term average spring conditions (a 63% reduction in summer levels) and had secondary benefits of much increased dissolved oxygen concentrations and decreased total nitrogen and chlorophyll a concentrations. The average TP concentrations were at the midpoint of the expected performance after the reduction in the treatment area. The longevity of the water quality benefits of the alum treatment may be limited by the reduction in the treatment area and chlorophyll a concentrations have remained higher than ecoregion thresholds.

I. Introduction and Background

The Town of Orleans Comprehensive Management Plan includes a strategy to coordinate and integrate management of coastal and freshwater systems. During FY18, the Town of Orleans working through the Marine and Fresh Water Quality Committee (OMFWQC) and in coordination with Coastal Systems Program from the School for Marine Science and Technology at UMass-Dartmouth (CSP/SMAST) began to work on freshwater ponds by reviewing available pond water quality data[1] and then prioritizing the development of individual pond and lake management plans. The first pond selected for the development of a plan was Uncle Harvey's Pond (Figure I-1). Each pond management plan included a diagnostic assessment of the pond to determine a reasonable understanding of pond ecosystem functions and water and habitat quality. The diagnostic assessment of Uncle Harvey's Pond (UHP) included synthesis of all available historical water column data and complementary assessment-specific data collected in 2017, such as measurement of sediment nutrient inputs, identification of phytoplankton species, and continuous water column measurements. These in-pond data were combined with watershed information (*e.g.*, septic system and stormwater runoff inputs) to provide a comprehensive understanding of both external and internal nutrient sources and their role in causing the water quality impairments in UHP (*i.e.*, low dissolved oxygen, algal blooms, clarity loss). After these

[1] Eichner, E and B. Howes. 2017. Town of Orleans Freshwater Ponds, Water Quality Monitoring Database: Development and Review. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 217 pp.

ecosystem functions were reasonably established, management options were then developed to address the specific impairments in UHP.

The UHP Management Plan was completed in March 2018 following several OMFWQC discussions and public hearings to answer questions and gather comments.[2] The completed Plan recommended an in-pond alum treatment to immediately address impaired water quality and cyanobacteria algal blooms caused by high phosphorus concentrations and a watershed wastewater management strategy to address the long-term source of in-pond sediment phosphorus loads. The Town Select Board voted unanimously to forward an application for permitting of the alum treatment to the Town Conservation Commission (CC) in September 2020. In March 2021, the CC approved the Town's permit for an alum treatment of the pond and included monitoring requirements and two required reports: a 6 month report and a 1 year report. This Technical Memorandum is the required Uncle Harvey's Pond 6 month report.

The UHP Management Plan recommended an alum treatment area of 4.4 acres of the pond bottom (*i.e.*, all areas with a depth of 3 m or deeper); this bottom area was regularly exposed to anoxic conditions and, thus, would regularly add regenerated sediment phosphorus to the water column. Because UHP is not a Great Pond, town legal review recommended that the pond bottom be divided among adjacent properties based on their shoreline length and a central point in the pond watersheet. It was further recommended that each adjacent property owner would need to sign an affidavit consenting to the alum treatment of their piece of pond bottom. Two adjacent homeowners objected to the treatment and their portion of the pond bottom (~1 acre) was excluded from the alum application through the installation of curtains attached to floats at the pond surface and anchored to the pond bottom and the shoreline (Figure I-2).

II. Uncle Harvey's Pond Alum Treatment and Follow-up Monitoring

The CC had two monitoring components required under their approval of the alum treatment: 1) monitoring of nutrient-related water quality conditions and 2) monitoring of dissolved aluminum levels in the pond. Based on discussions with the Town, Solitude Lake Management LLC (SLM), the firm conducting the alum application, was responsible for the aluminum monitoring, while CSP/SMAST was responsible for the nutrient-related water quality monitoring and providing the required reports.

Water quality samples were collected by both CSP/SMAST and SLM prior to the alum treatment to establish baseline conditions. SLM performed the alum treatment over two days (May 27 and May 28, 2021) and collected dissolved aluminum water quality samples before and after the treatment. CSP/SMAST collected water column readings and samples on May 25 and SLM collected an aluminum sample on May 14. SLM collected post-treatment aluminum samples four times in June and once in August. CSP/SMAST collected post-treatment profiles and water quality samples twice in June and then monthly in July through October.

Water quality conditions measured by CSP/SMAST just prior to the treatment (May 25) generally showed greater impairment than historical May readings. The May 25, 2021 water column was warmer than most past May readings and showed temporary stratification at 3 m

[2] Eichner, E., B. Howes, and D. Schlezinger. 2018. Uncle Harvey's Pond Management Plan and Diagnostic Assessment. Town of Orleans, Massachusetts. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 106 pp.

(Figure II-1); temporary stratification has been noted in historical profiles.[3] As might be expected with stratification, the DO profile showed a pronounced high concentration bulge between 3 and 4 m depth due to phytoplankton photosynthesis and their utilization of high phosphorus concentrations in the deeper waters (see Figure II-1). DO saturations levels within the bulge at 3 m, 3.5 m, and 4 m were 110%, 113%, and 111%, respectively reflecting oxygen inputs from photosynthesis. Deep DO was greater than the MassDEP minimum (5 mg/L). Water column total phosphorus concentrations in the May 2021 sampling were higher than any past May readings (see Figure II-1). Secchi clarity was 3.35 m, which is slightly lower than the average (3.52 m) from available historical spring readings.

The dissolved aluminum concentration measured by SLM on May 14 was less than the laboratory detection limit of 0.1 mg/L (Table II-1). The CC permit conditions included a provision that aluminum levels would be monitored weekly until pre-treatment concentrations were again measured. Water samples collected for aluminum analysis on June 2, June 7, June 22, June 30, and August 10 all had concentrations less than the initial 0.1 mg/L detection limit.

After the May 27/28 alum treatment, most water quality measures collected by CSP/SMAST showed notable improvement. Temperature readings generally showed enough similarity throughout the water column to maintain well-mixed conditions in most profiles; temporary stratification was measured in the June 11 and July 8 profiles (Figure II-2). None of the DO profiles had anoxic conditions and generally showed improvement compared to historical and average readings. The lowest DO concentration was 1.4 mg/L measured at 5 m depth in the August 9 profile, but this profile had DO concentrations at 4 m and 4.5 m that were higher than most of the historical readings at these depths (see Figure II-2). The high concentration DO bulge in the May 25 profile was not observed in the June 4 profile when temperature stratification was not present and the water column was mixed, but returned in the June 11 profile when stratification was re-established. None of the other 2021 profiles had temperature stratification or the high concentration DO bulge. Surface to 4 m depth DO concentrations in all 2021 profiles were above the MassDEP minimum. Improved DO readings are often a secondary benefit of the alum treatment,[4] although the mechanisms can vary from lake to lake (*e.g.*, lower organic matter production from reduced P, better clarity resulting in more photosynthesis, etc.).

The alum treatment significantly reduced water column total phosphorus (TP) concentrations especially in the near-sediment, deep waters. Alum treatments are designed to reduce internal pond phosphorus additions from sediments even if bottom waters are hypoxic or anoxic. In addition, water column phosphorus may be removed from the water column depending on the depth to the alum addition. In the May 25 pre-treatment measurements, water column TP concentrations averaged 28 µg/L with a maximum reading of 37 µg/L at the 4.5 m depth (see Figure II-1). After the treatment took place, water column TP concentrations on the individual dates averaged between 16.6 and 22.6 µg/L. Highest individual TP sample readings (29.6 µg/L) were recorded at shallow depths (*i.e.*, 0.15 m, 1 m) suggesting that they reflected recent watershed inputs rather than sediment inputs (Figure II-3). The deepest TP concentrations decreased throughout the sampling period (see Figure II-3). This decrease would be consistent with the full dose of the available alum settling from the water column.

[3] Eichner, E., B. Howes, and D. Schlezinger. 2018. Uncle Harvey's Pond Management Plan and Diagnostic Assessment.

[4] Smeltzer, E., R.A. Kirn and S.Fiske. 1999. Long-Term Water Quality and Biological Effects of Alum Treatment of Lake Morey, Vermont. Lake and Reservoir Management. 15(3): 173-184. DOI: 10.1080/07438149909354115

Total nitrogen (TN) and chlorophyll concentrations also decreased after the alum treatment. May TN concentrations generally were lower than historical average Spring concentrations (Figure II-4). Average post-alum shallow and deep water column TN concentrations were 0.39 mg/L and 0.43 mg/L, respectively; much lower than the respective long-term (2001-2017) averages of 0.49 mg/L and 0.69 mg/L.[5] These reductions were likely due to improved deep DO conditions; prolonged anoxia will also cause enhanced regeneration of nitrogen from the sediments. N:P ratios continued to remain well above the Redfield ratio indicating that phosphorus continues to be the primary control of water quality even after the alum treatment. As would be expected given the post-treatment reduced TP and TN concentrations, chlorophyll a and total pigment concentrations were reduced throughout the 2021 summer and generally approximated average Spring concentrations (see Figure II-4). Average post-alum shallow and deep water column chlorophyll a concentrations were 7.2 µg/L and 9.2 µg/L, respectively, which are much lower than the respective long-term (2001-2017) averages of 11.0 µg/L and 24.7 µg/L.[6] It should also be noted that all but one of the chlorophyll a concentrations measured in 2021 (n=41) still exceeded the 1.7 µg/L ecoregion threshold.[7]

The lower TP concentrations after the alum treatment resulted in a significantly reduced water column TP mass throughout 2021. UHP water column TP mass throughout the summer was comparable to average UHP mass in the Spring (Figure II-5). In the pre-treatment sampling, the TP in the water column was 2.8 kg, which was slightly higher than the 2012 to 2017 spring average of 2.0 kg.[8] After the alum treatment, the 2021 water column TP averaged 2.0 kg. Summer maximum TP mass in 2012 to 2017 averaged 5.4 kg. Based on these comparisons, the alum treatment prevented 3.4 kg of TP from being released into the UHP water column from the sediments.

Based on the water quality results the alum treatment was successful at significantly reducing 2021 phosphorus release from the UHP sediments, but the anticipated impact was less than was projected based on the treatment area recommended in the UHP Management Plan. The UHP Management Plan recommended treating 4.4 acres or the entire sediment area subject to anoxia (*i.e.*, ≥3 m depth). During the discussion of the potential reductions in the treatment area, Town staff asked CSP/SMAST to predict the potential impact of the projected removal of one acre from the 4.4 acre treatment area (Figure II-6). The reduced alum treatment area resulted in an average water column TP concentration of 19.9 µg/L or approximately the mid-point of the projected treatment range based on a 3.4 acre treatment area. This TP concentration is approximately double the 10 µg/L TP goal listed in the Management Plan. The lower performance of the alum treatment is linked to the reduction in the treatment area and will likely result in a reduction in the longevity of improved water quality conditions.

III. Conclusions/Discussion

The alum treatment of UHP was successful at reducing the sediment additions of TP to the water column and reducing water column TP throughout the 2021 summer. Average TP water column mass during the 2021 summer was 2.0 kg, which is a 3.4 kg reduction from the average summer maximum mass from 2012 to 2017. This 2021 average water column mass is the same as average Spring water column mass from 2012 to 2017. Secondary benefits were also measured

[5] Eichner, E and B. Howes. 2017. Town of Orleans Freshwater Ponds, Water Quality Monitoring Database

[6] Eichner, E and B. Howes. 2017. Town of Orleans Freshwater Ponds, Water Quality Monitoring Database

[7] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[8] Eichner, E., B. Howes, and D. Schlezinger. 2018. Uncle Harvey's Pond Management Plan and Diagnostic Assessment.

in higher dissolved oxygen concentrations: a) all DO concentrations in depths to 4 m were above the MassDEP minimum and b) hypoxia was occasionally measured at 4.5 m and deeper readings, but no anoxia (<1 mg/L DO) was measured. The performance of the alum treatment was at the midpoint of what was expected based on the reductions in the treatment area. The reductions in the treatment area may also restrict the longevity of the alum treatment benefits.

The Management Plan recommended the alum treatment as an initial step toward addressing the water quality impairments in UHP with watershed wastewater management as an important complementary management action. The Town has been discussing this issue as part of additional phases of the Town Comprehensive Management Plan.

Figure I-1. Uncle Harvey's Pond Locus. UHP is a 7.5 acre pond located south of Pochet Road and east of Barley Neck Road. UHP is approximately 0.5 km east of Meetinghouse Pond (see inset).

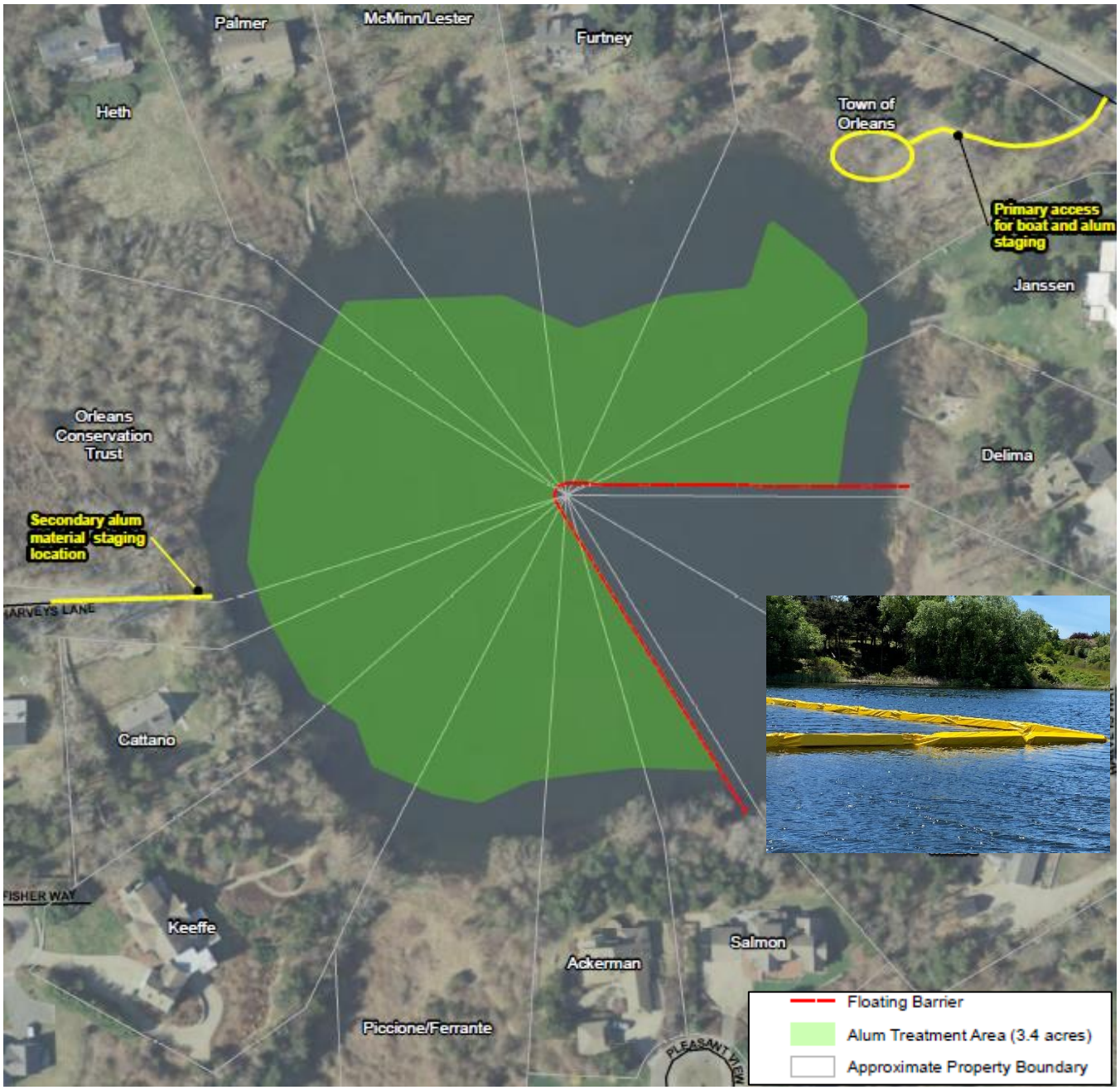


Figure I-2. Uncle Harvey's Pond Alum Treatment Area. Because UHP is not a Great Pond, the Town determined that ownership of the pond bottom was divided among adjacent parcels based on the length of pond shoreline and a central point in the pond. Two of the adjacent homeowners did not agree to the alum treatment and their portions of the pond bottom were separated from the rest of the pond through the installation of anchored curtains that extended from the pond surface to the bottom (shown in the inset picture). The final alum treatment area (green fill) was 3.4 acres or 1 acre less than recommended in the UHP Management Plan. Figure modified from SWCA figure submitted in the Town's Conservation Committee filing for the alum treatment.

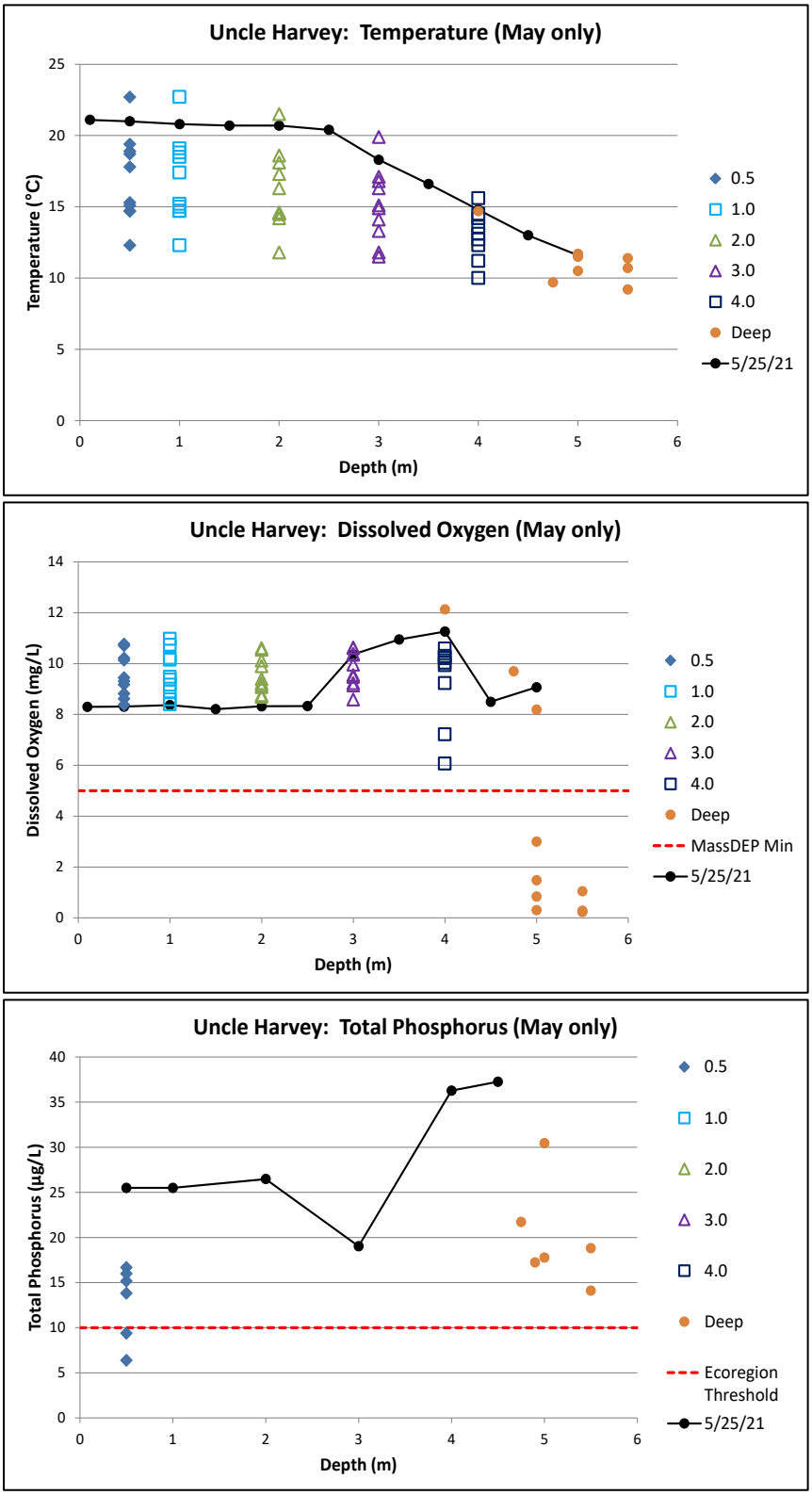


Figure II-1. Pre-Alum Application Dissolved Oxygen, Temperature, and Total Phosphorus in Uncle Harvey's Pond. Water samples and DO and temperature profiles were collected on May 25, 2021 before the alum application. May 2021 temperatures were warmer than most historical readings. May 2021 DO concentrations were lower than usual except for supersaturation concentrations between 3 and 4 m depths. May 2021 TP concentrations were higher than historical readings.

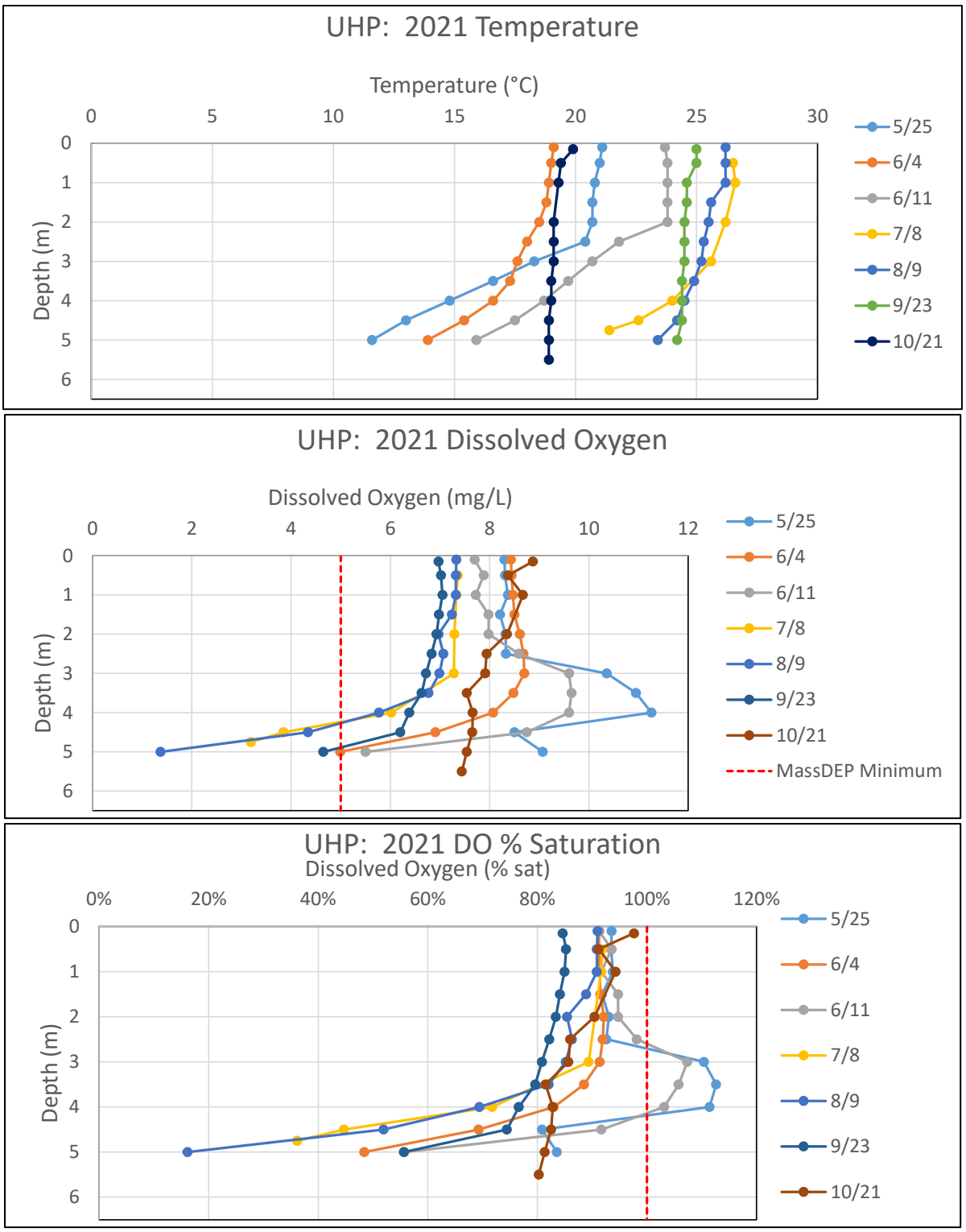


Figure II-2. Uncle Harvey's Pond 2021 Temperature and Dissolved Oxygen Profiles. Pre-alum application profiles were measured on May 25 and post-application profiles were measured on June 4, June 11, and then monthly from July through October. June 11 and July 8 temperature profiles showed temporary stratification conditions, but all other profile had insufficient temperature differences to prevent mixing of the whole water column. DO profiles showed notable improvement from historical readings. May 25 and June 11 profiles, both of which has temperature stratification, had DO concentrations well above atmospheric equilibrium (100% saturation) due to phytoplankton photosynthesis near the stratification layer boundary. All 2021 concentrations from the surface to 4 m were greater than the MassDEP minimum; anoxic concentrations (<1 mg/L) have been measured at depths as shallow as 3 m. Deep DO concentrations did not have anoxia in any of the profiles, but did have occasional hypoxia; 1.4 mg/L was the lowest measured DO concentration among the post-alum profiles.

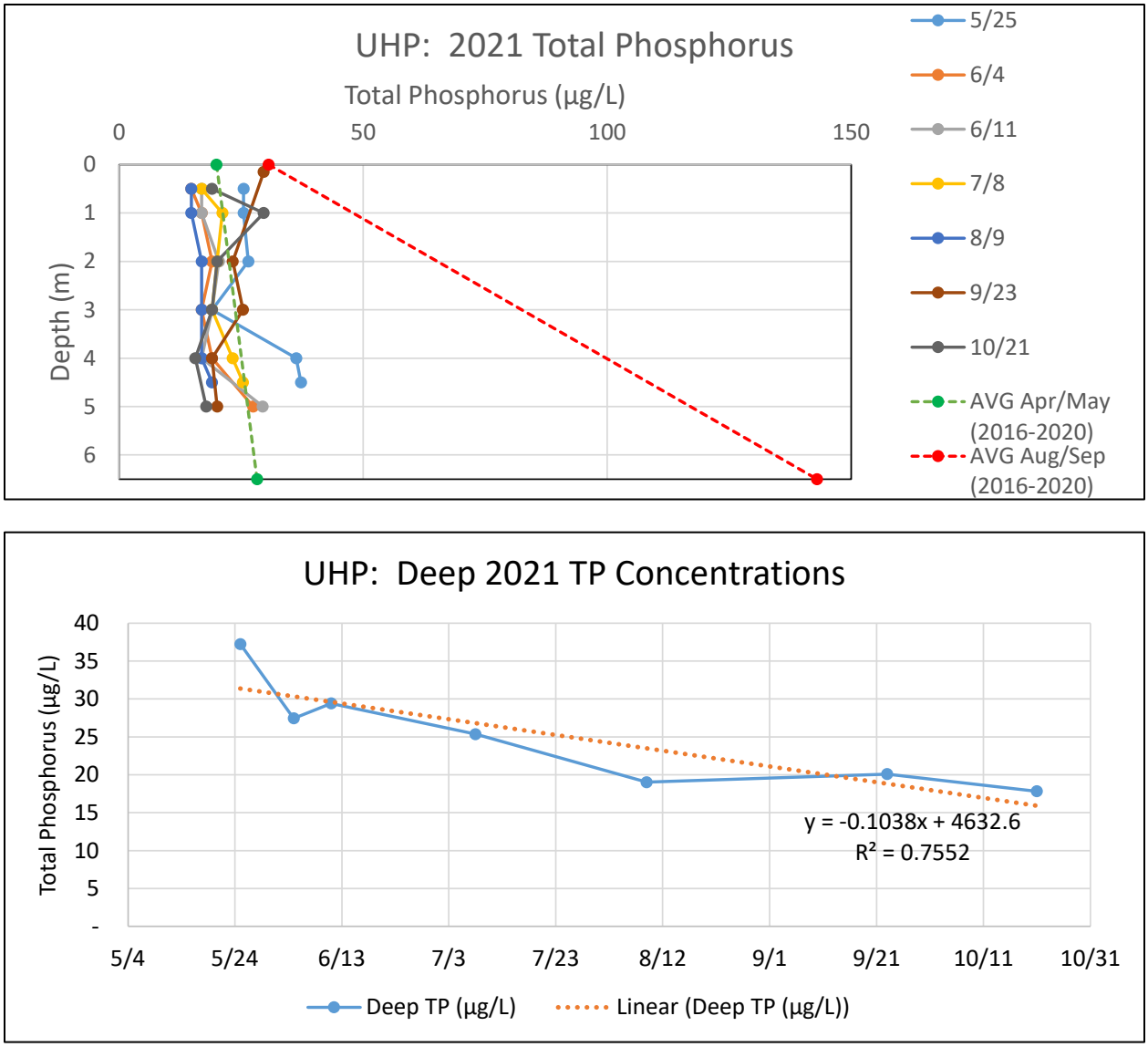
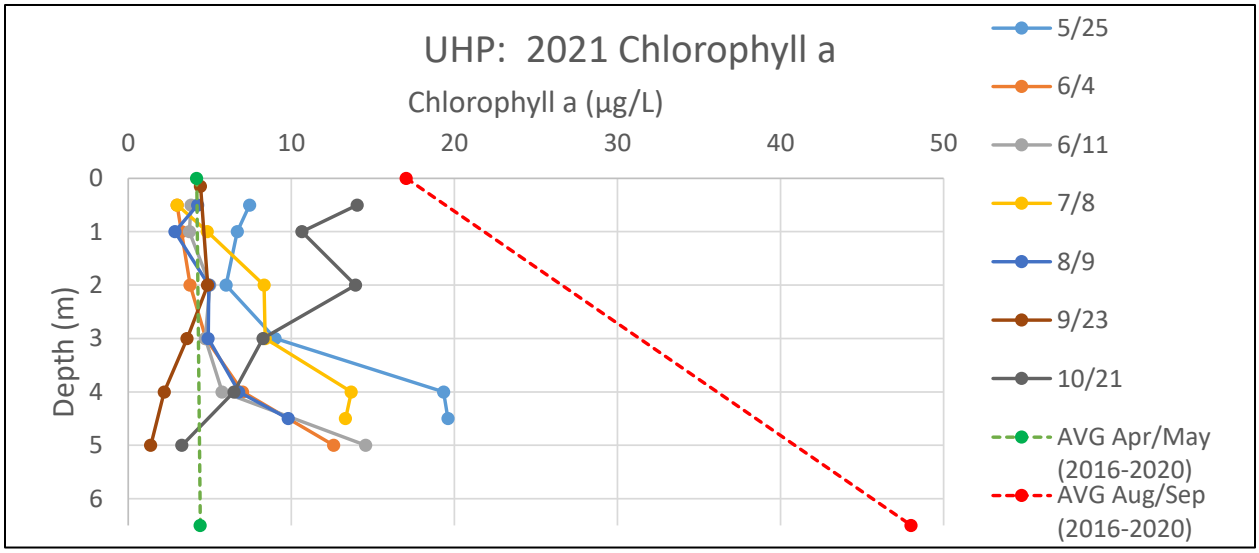


Figure II-3. UHP 2021 Total Phosphorus Concentrations. After the alum treatment, TP concentrations generally fluctuated close to Spring (April/May) averages. Average post-alum water column TP concentration was 19.9 µg/L. Deep TP concentrations decreased throughout the summer, likely due to settling of the alum on the bottom and subjecting the sediments to the full dose.



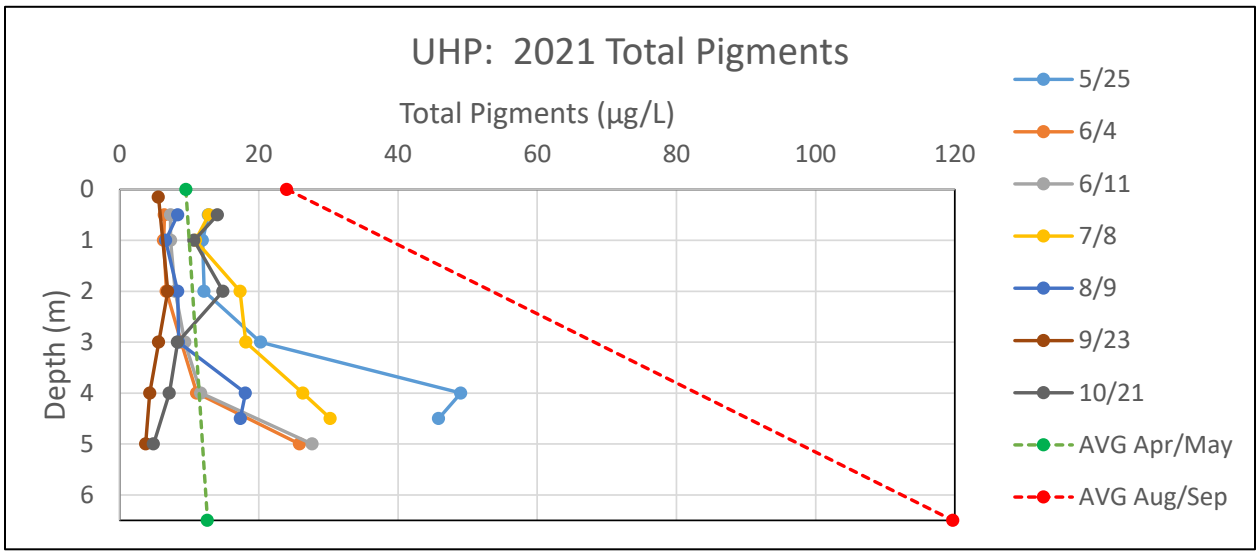


Figure II-4. UHP 2021 Total Nitrogen, Chlorophyll a, and Total Pigment Concentrations. After the May 25 alum treatment, TN, Chla, and total pigment concentrations generally fluctuated close to Spring (April/May) averages. Average post-alum shallow and deep water column TN concentrations were 0.39 mg/L and 0.43 mg/L, respectively, which are much lower than the respective long-term (2001-2017) averages of 0.49 mg/L and 0.69 mg/L. Chlorophyll and total pigment concentrations also notably decreased after the alum treatment compared to long-term averages.

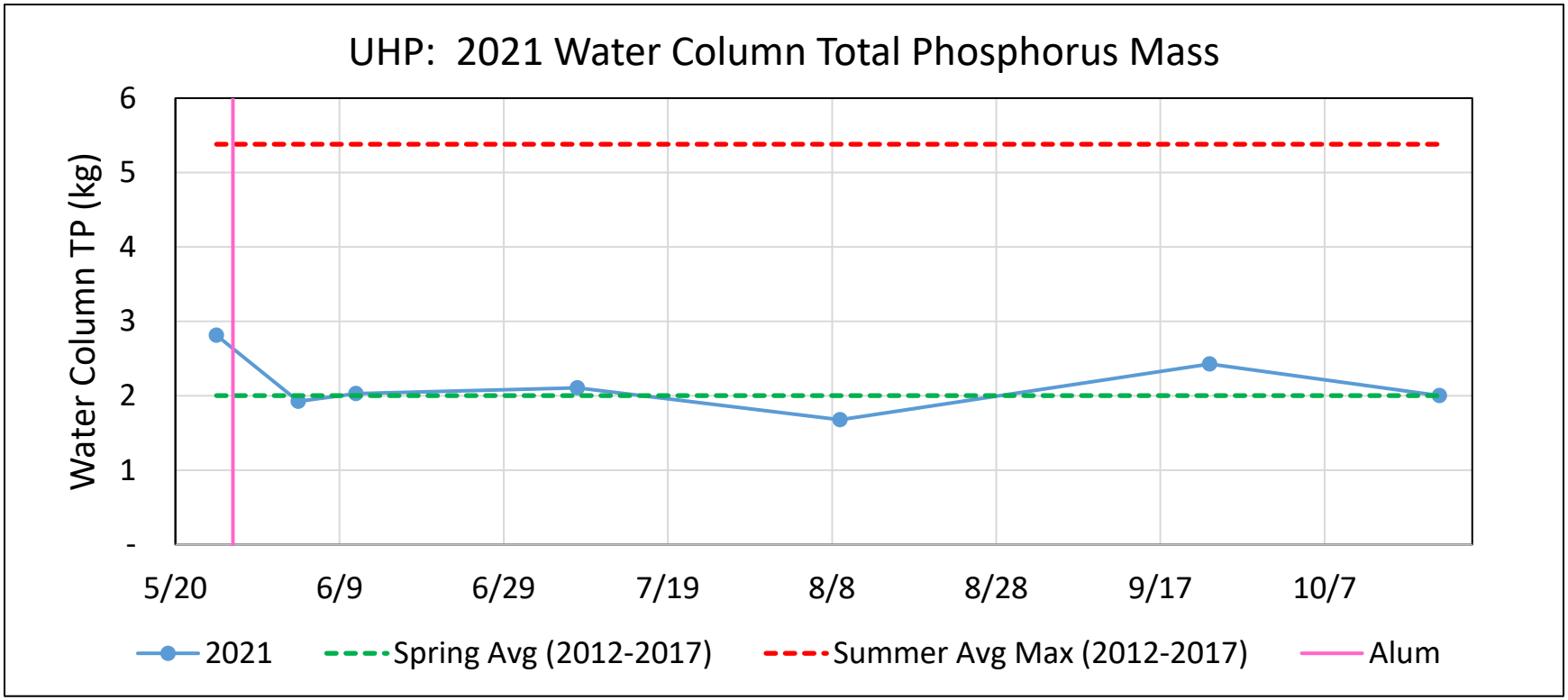


Figure II-5. UHP 2021 Total Phosphorus Mass in the Water Column. Using the volume of the pond and TP concentrations, staff determined the mass of phosphorus in the UHP water column on each of the sampling days. The May 25 mass was 2.8 kg, which was slightly greater than the 2012 to 2017 Spring average mass of 2.0 kg. TP water column mass averaged 2.0 kg during 2021 with a range of 1.7 kg to 2.4 kg. The 2012 to 2017 average of summer maximum water column masses was 5.4 kg. Based on these comparisons, the alum treatment prevented 3.4 kg of phosphorus from being released from the pond sediments into the water column in 2021.

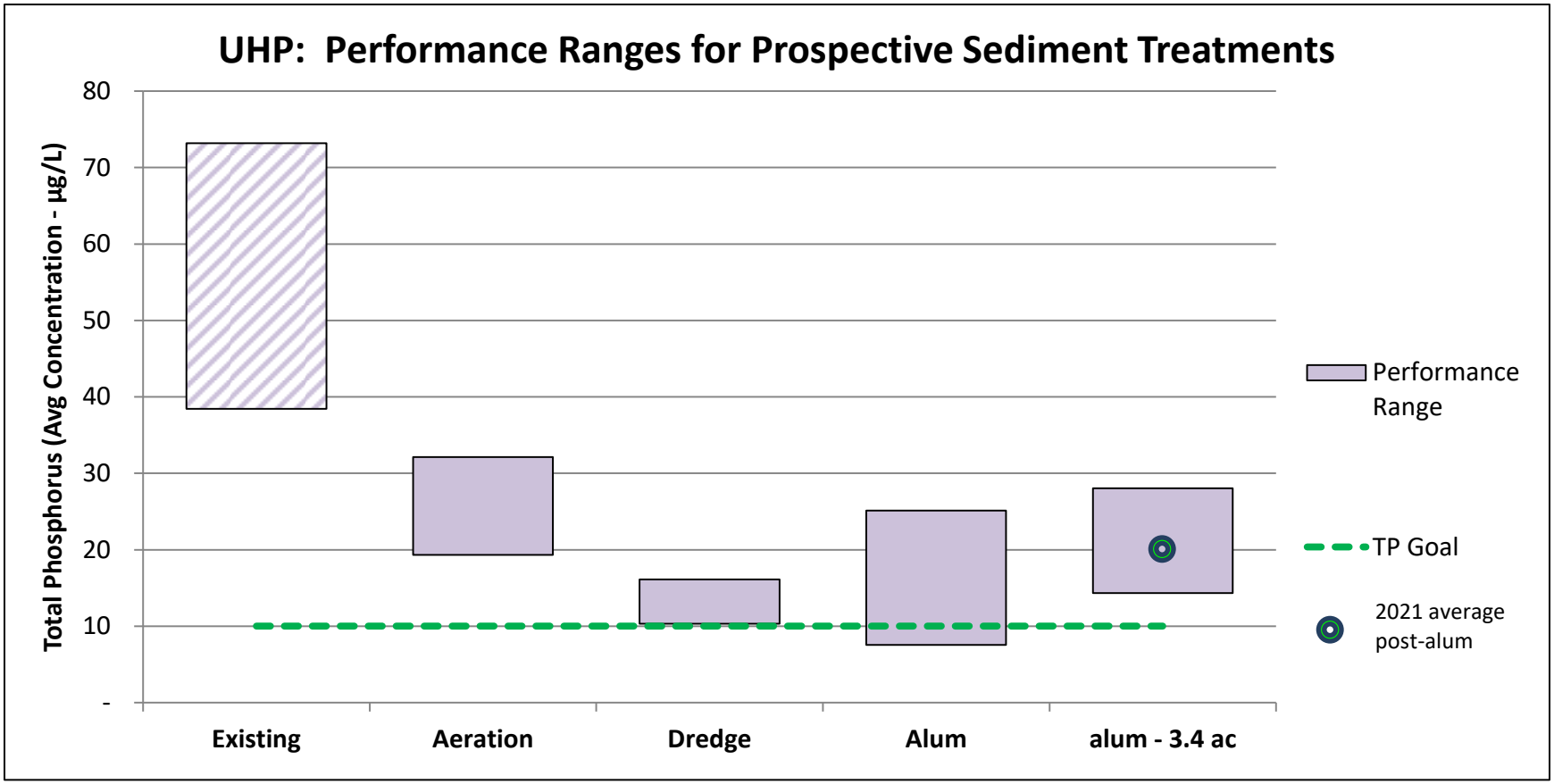


Figure II-6. Prospective Performance Ranges for UHP Sediment Phosphorus Management. The UHP Management Plan recommended treatment of 4.4 acres of the pond bottom with alum (~59% of the pond bottom). Review of the range of potential water column total phosphorus (TP) concentrations for the alum treatment was determined based on past applications. As a result of negotiations with adjacent property owners, the alum treatment area was reduced to 3.4 acres, which caused an increase in the range of expected TP concentrations after the application and increased the lower end of the range above the 10 µg/L TP goal recommended in the Management Plan. The resulting 2021 average water column concentration was 19.9 µg/L or approximately the mid-point of the projected treatment range based on a 3.4 acre treatment area. The decrease in area will likely decrease the longevity of the water quality benefits of the alum treatment.

Table II-1. Uncle Harvey Pond 2021 Water Column Aluminum Concentrations. Water quality samples were collected by SLM prior to the alum treatment on May 14 and after the alum treatment on June 2, June 7, June 22, June 30, and August 10. All post-application dissolved aluminum concentrations were less than the May 14 pre-application detection limit (0.1 mg/L). BDL = below detection limit.

Sample Date	Detection Limit (mg/L)	Result (mg/L)
05/14/2021	0.1	BDL
06/02/2021	0.2	BDL
06/07/2021	0.01	0.0646
06/22/2021	0.026	0.051
06/30/2021	0.026	0.035
08/10/2021	0.01	BDL