Cedar Pond
Adaptive Management Monitoring Program:
2025 Annual Technical Report

January 2025 to December 2025

FINAL REPORT

April 2026

for the

Town of Orleans

Prepared by:

Coastal Systems Group
School for Marine Science and Technology
University of Massachusetts Dartmouth
706 South Rodney French Blvd.
New Bedford, MA 02744-1221

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Cover photo: Cedar Pond Outlet and Boards June 17, 2025
(courtesy of Jen Benson, CSP/SMAST)

Acknowledgements:

The authors acknowledge the contributions of the many individuals, groups, and town boards who have worked tirelessly for the restoration and protection of Cedar Pond. Without these pond stewards and their efforts, this project and its associated management actions would not have been possible.

The authors also specifically recognize and applaud the generous commitment of time and effort spent by past and present members of the Orleans Marine and Fresh Water Quality Committee (née Task Force). These individuals collected water quality information, shared their observations, and, on occasion, ferried SMAST staff to monitoring locations on Cedar Pond.

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Executive Summary

Cedar Pond
Adaptive Management Monitoring Program:
2025 Annual Technical Report
January 2025 to December 2025

Cedar Pond is a 15 acre brackish pond on the Cape Cod Bay side of the Town of Orleans. The pond is connected to the Rock Harbor estuary by Cedar Pond Creek. Historical water column data had shown that the pond was extremely impaired,[1] but *ad hoc* management decisions in the recent past caused higher salinity conditions and even worse water quality (*e.g.*, most of the water column with little to no dissolved oxygen). In 2012, the Town contracted with the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) to characterize the Cedar Pond ecosystem and develop strategies to address its ecosystem impairments. After reviewing the available options and strategies for their implementation, the Town approved the 2013 Cedar Pond Management Plan with the goals to: 1) restore water quality, 2) restore the herring run, and 3) protect the adjacent Atlantic White Cedar wetland.[2]

The Management Plan recommended that the Town implement two initial actions to begin to meet the management goals: a) reinstall the boards that historically had been in place at the pond outlet to gradually reduce salinity back to brackish conditions (goal: 1 to 4 parts per thousand) and b) reduce the nutrient inputs by the cormorant population that regularly roosted on the electrical wires over to the pond by relocating the wires. It was also recognized that the sediments were a significant nutrient source, but water quality monitoring was recommended prior to selecting and implementing an appropriate strategy to reduce sediment nutrient regeneration. The Plan further recommended that its implementation should have regular reporting of water quality conditions so that management steps could be adapted/adjusted as the system gradually improved (*i.e.*, adaptive management).

The Management Plan was publicly reviewed by the Marine and Fresh Water Quality Task Force and approved by the Town Select Board and Conservation Commission in 2015, but a group of citizens appealed the approval, and the Town was then required to complete Massachusetts Environmental Policy Act (MEPA) filings and a Development of Regional Impact filing with the Cape Cod Commission. These additional reviews eventually confirmed the initial Town approvals in 2017.[3] CSP/SMAST began water quality monitoring in November 2017, and the outlet boards were reinstalled in January 2018.

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[1] Eichner, E. 2007. Review and Interpretation of Orleans Freshwater Ponds Volunteer Monitoring Data. Final Report. For the Town of Orleans Marine and Fresh Water Quality Task Force and Barnstable County. Cape Cod Commission. Barnstable, MA. 80 pp.

[2] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 54 pp.

[3] Certificate of the Secretary of Energy and Environmental Affairs on the Single Environmental Impact Report: Cedar Pond Water Quality Management Plan. May 26, 2017. EEA#: 15474. 34 pp.

Water quality monitoring initially included: a) the installation of two continuous monitoring devices in the center of the pond in the deep basin, b) regular collection of streamflow and water quality samples in Cedar Pond Creek, and c) water column samples, dissolved oxygen (DO) and temperature profiles, and clarity readings at the same location as the continuous monitoring devices. As specified in the Management Plan, the status of monitoring was reviewed in a mid-year technical memo and all monitoring results throughout the year were summarized in an annual report. Monitoring has continued each subsequent year, and results have been regularly reviewed in Annual Reports (2018-2025).

As part of the Management Plan adaptive management process, CSP/SMAST, Town, and Massachusetts Division of Marine Fisheries (MassDMF) staff typically review monitoring results annually and decide whether adjustments are warranted (*e.g.*, changing the height or configuration of the outlet board elevations). Past reviews led to various actions, including CSP/SMAST adding a continuous water level recorder at the outlet in 2019 to better measure water levels relative to board heights and MassDMF installing fyke nets in the Creek in 2022 to assess whether alewives were entering the pond during the primary spawning period. The Town also began discussions with Eversource to move the power lines over the pond in 2017 and the removal of the key lines was completed in December 2018.

Each annual review of monitoring results has shown water quality improvements in Cedar Pond since the implementation of the Management Plan. These improvements have included:

- **Reduced nitrogen export to Rock Harbor.** Early readings showed that the pond was occasionally adding nitrogen to the Creek discharge from the pond with loads greater than Cedar Pond watershed inputs. In recent years, nitrogen exported to Rock Harbor has fluctuated, but has generally returned to levels measured in 2002/2003 during the MEP Rock Harbor assessment.[4] At the time of the MEP assessment, 58% of the watershed nitrogen inputs were removed (*i.e.*, attenuated) by natural processes in Cedar Pond. As result, the MEP scenario to attain acceptable water quality in Rock Harbor did not include any nitrogen reductions in the Cedar Pond watershed (*i.e.*, no recommended sewering or use of denitrifying septic systems). 2025 nitrogen export was higher than 2023 or 2024, but some of the increase may be due to higher salinities caused by outlet board vandalism during the 2024/2025 winter.
- **Acceptable shallow dissolved oxygen concentrations.** When the boards were removed and salinity was high throughout the water column prior to 2017, DO concentrations were less than the MassDEP regulatory minimum throughout most of water column with occasional anoxia (*i.e.*, no DO) within 6 inches (0.15 m) of the surface. With lower salinity conditions, DO readings in the upper 1 m of the pond have consistently exceeded the MassDEP minimum during recent summers and have often been acceptable in the upper 1.5 m. Vandalism of the boards in the 2024/2025 winter caused higher initial salinity levels in 2025 along with more frequent DO readings less than the MassDEP minimum during the summer.

[4] Howes B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, D.R. Schlezinger, and E.M. Eichner. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, MA. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 132 pp.

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- **Herring in Cedar Pond Creek.** With high salinity and low DO, the habitat for spawning herring was significantly degraded. As a result, reinstalling the outlet boards and the resulting better water quality conditions, herring were caught in the creek by the Town and MassDMF in 2022.
- **Lower salinity in the shallow water column has provided some protection for the adjacent Atlantic White Cedar wetland.** The regular seasonal increase of salinity due to decreased board heights and reduced groundwater levels produces a challenge for sustaining lower salinities, but progress toward this Management Plan goals has been better defined by the regular monitoring. Monitoring has shown that higher board and groundwater elevations during the winter can reduce salinity levels sufficiently to keep salinity levels lower throughout most of the summer and through board adjustments for herring.

In 2025, these improvements were largely sustained except for an apparent vandalism of the outlet boards between September 2024 and May 2025. As part of the Fishway Plan implemented by the Town through agreement with MassDMF and CSP/SMAST, the outlet boards were initially raised during the winter to accentuate groundwater inputs and create lower salinity levels throughout the following year. Initial strategies adjusted the boards once in March to allow spawning herring to enter the pond and again in July to allow juvenile herring to leave the pond. The elevations and configurations of the boards have been adjusted over the years based on water level monitoring at the outlet that showed water levels were generally sufficient to allow herring to enter or leave the pond even at higher board elevations than initially selected. Town staff had adjusted the boards in late August 2024 to an elevation of 1.54 m NAVD88[5] and in May 2025 the elevation was 1.26 m NAVD88, which was the lowest elevation recorded for the boards since they were initially reinstalled in 2017. This low elevation through the 2024/2025 winter exposed the pond to the complete tidal cycles within the Creek. Not surprisingly, salinity levels throughout the water column increased as a result of the increased tidal interaction, but the difference between shallow and deep levels remained sufficiently different to prevent complete mixing of the exceptionally high nutrient levels in the deep waters with the relatively moderately impaired levels in shallow waters The impact of these higher winter/spring salinity conditions resulted in higher salinity levels throughout 2025.

As a result of 2025 monitoring and its review in this Annual Report, CSP/SMAST has the following recommendations for the Town to consider:

- **Complete an assessment of the Cedar Pond sediments** with a goal of evaluating sediment management options. The Management Plan recommended that the sediments be addressed once sufficient monitoring established how much water quality conditions would change from lowering salinity in the pond. The pond sediments were characterized in the 2013 Management Plan and the recommended approach is to duplicate the 2012 sediment core collection and incubation using standard MEP procedures plus an assessment of sediment depth. This information should be sufficient to provide the Town with a strong basis to evaluate sediment management options and their potential costs (*e.g.*, treat in place or excavation).

[5] Elevation measured by CSP/SMAST staff using a GPS RTK.

- **Develop a nutrient TMDL for Cedar Pond** by combining the updated sediment information with regular annual water column sampling. Cedar Pond is listed as a Category 5 water ("Waters requiring a TMDL") in the most recent MassDEP-approved Integrated List.[6] Having a town-developed TMDL would assist the Town in CWMP implementation planning and provide the Town with an additional control over the TMDL process. A TMDL for Cedar Pond would also reduce the uncertainty associated with the TMDL status of Rock Harbor. The 2008 MEP Rock Harbor assessment indicated that the Harbor portion was significantly impaired, but MassDEP did not complete a nitrogen TMDL after the MEP report was finalized.
- **Continue water quality monitoring to implement the Cedar Pond Management Plan**. The Town is in a stable regulatory setting for Cedar Pond with: a) the 2017 MEPA and MassDEP approval of a Superseding Order of Conditions on the Management Plan Environmental Impact Report and b) the 2022 MassDEP Certificate of Compliance (COC) for the conditions. The COC included one on-going condition: that the Management Plan continue to be implemented if there continues to be a positive impact on the Pond's wetland resources. Monitoring allows the Town to document compliance with this condition. As part of the on-going compliance activities, Town Natural Resources staff have secured the outlet boards with a lock to prevent a repeat of the 2025 vandalism.[7] CSP/SMAST staff are available to discuss options with Town and MassDMF staff to reduce the level of data collection while ensuring sufficient information is collected to reliably discuss long-term system status and regulatory compliance.

Overall, 2025 readings showed another year of additional incremental progress toward attaining the Management Plan goals even with the board vandalism, but conditions were a mixed bag of results with the higher salinity readings caused by the board vandalism notably impacting the spring and early summer conditions. Cedar Pond remains impaired and with poorer water and habitat quality than existed in 2002/2003 and pre-2007, but sustained improvements in certain measures (*e.g.*, reduced TN export to Rock Harbor has been sustained and shallow DO readings continued to meet MassDEP standards). Challenges remain about creating stable conditions with the on-going impacts of sustained and significant deep impairments, but there are some signs in the available data that ecosystem changes are still occurring. Recommendations to address the sediments and use planned monitoring for the development of a TMDL should move the Town closer to long-term, lower cost management.

[6] 2024/2026 Cycle: https://www.mass.gov/doc/massachusetts-draft-integrated-list-of-waters-for-the-clean-water-act-20242026-reporting-cycle/download (accessed 3/31/26)

[7] Personal communication from Nate Sears, 4/2/26.

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I. Introduction

Cedar Pond is a 6.4 ha (15 acre) surface water body with a 48.4 ha watershed located within the Town of Orleans (**Figure I-1**). The pond has had a number of historical *ad hoc* management actions, including filling a portion of the pond for the construction of Route 6, siting regional power lines over the pond that were subsequently claimed for roosting by a large summer cormorant population, and 2007 changes to the stream channel connecting the pond to Rock Harbor. The pond had documented water quality problems since at least 2001[8] and was part of the Massachusetts Estuaries Project (MEP) assessment of Rock Harbor.[9]

In 2012, the Town contracted with the Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth (CSP/SMAST) to develop a Cedar Pond Management Plan.[10] The Plan included an assessment of Cedar Pond water quality and the factors causing the conditions in the water column. The assessment included extensive water column, stream, and sediment measurements. The Plan included strategies to address the impairments and was approved by the Town in 2013. It was then subsequently approved by Massachusetts Department of Environmental Protection (MassDEP) and through Massachusetts Environmental Policy Act (MEPA) Office review in 2017.[11]

The Management Plan strategy for addressing the impairments focused on three primary goals: 1) restore water quality in the pond, 2) restore the herring run, and 3) protect the adjacent Atlantic White Cedar wetland. The lowest cost management strategy was to reinstall the boards at the outlet and use natural watershed groundwater inputs to gradually reduce the pond salinity and return the pond to conditions that existed prior to 2007. This strategy was adopted based on an extensive review of historical water quality data documented in the Management Plan that showed lower salinity had impaired, but much improved, water quality conditions compared to the 2012 high salinity conditions. The 2012 data showed that the higher salinity conditions in the pond caused: a) anoxia to be more extensive in the pond water column, b) reduced nitrogen attenuation with more nitrogen was being exported to Rock Harbor, and c) higher salinity was threatening the adjacent Atlantic White Cedar Swamp and was unfavorable for the historical herring run to the pond. The MEPA certificate approving the Management Plan implementation required on-going water quality monitoring of the pond and the development of a fishway plan.

A fishway plan for the connection between the pond and Rock Harbor Creek was developed in coordination among CSP/SMAST, the Town, and the Massachusetts Division of Marine Fisheries (MassDMF). These staff have had regular annual meetings to discuss fish passage, outlet board heights, and water quality results. The fishway plan included a strategy for seasonal raising and lowering of boards at the Pond inlet to facilitate fish passage throughout the summer.

The Management Plan included a series of steps to begin to attain the primary goals. Initial steps were: 1) return the pond to brackish conditions (*i.e.*, reduce salinity from 21-23 ppt to 1-4

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[8] Eichner, E. 2007. Review and Interpretation of Orleans Freshwater Ponds Volunteer Monitoring Data. Cape Cod Commission. 80 pp.

[9] Howes B.L., S.W. Kelley, J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, E.M. Eichner. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, MA. SMAST/DEP Massachusetts Estuaries Project, MassDEP. Boston, MA. 132 pp.

[10] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 54 pp.

[11] Certificate of the Secretary of Energy and Environmental Affairs on the Single Environmental Impact Report: Cedar Pond Water Quality Management Plan. May 26, 2017. EEA#: 15474. 34 pp.

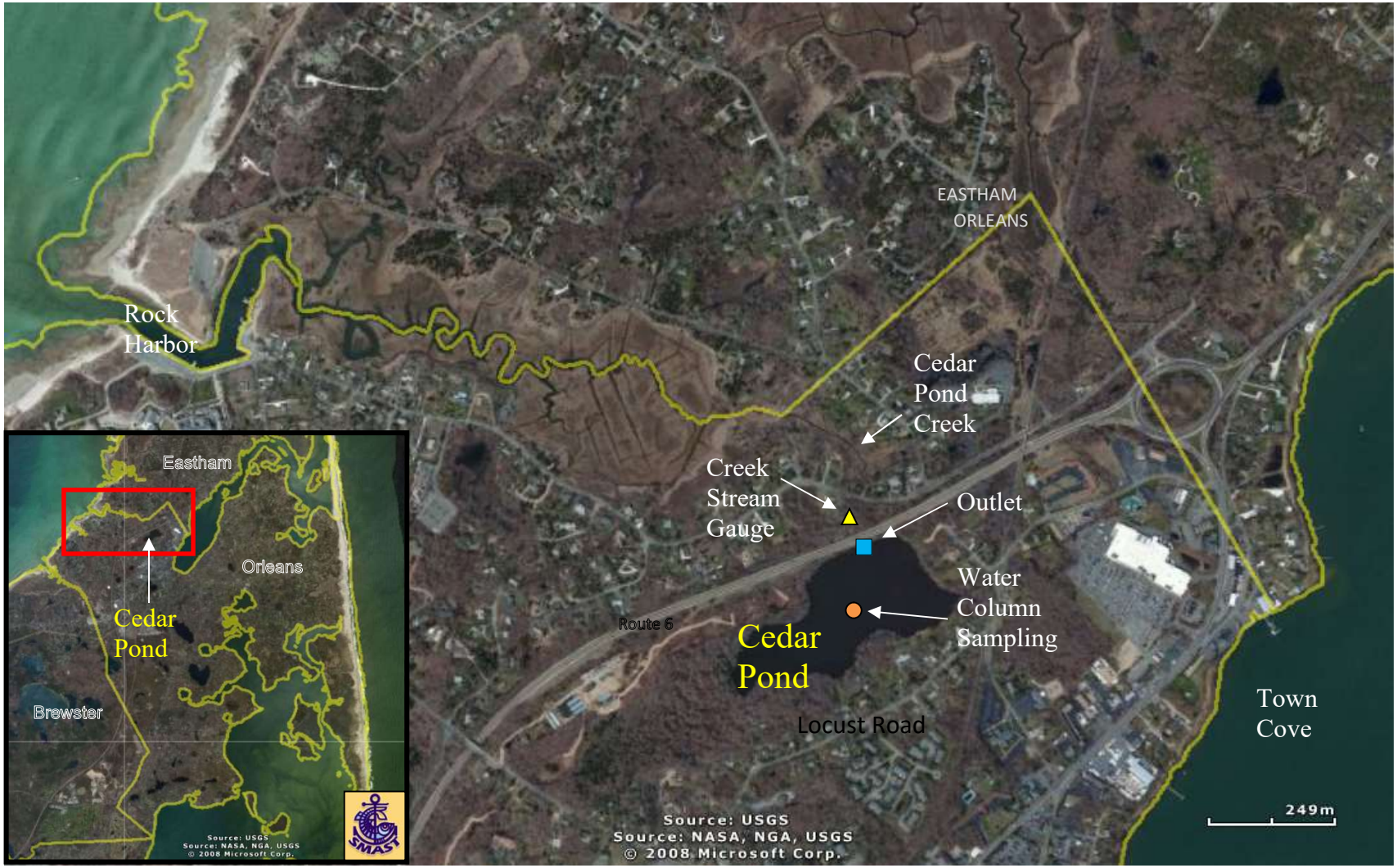

Figure I-1. Cedar Pond Locus and Sampling Stations in the Town of Orleans, MA. Cedar Pond is located in northern Orleans, south of Route 6 and west of Town Cove. The Pond is connected to the Rock Harbor estuary on Cape Cod Bay via Cedar Pond Creek. The creek leaves the pond through a weir at the pond outlet (blue square), flows under Route 6 and Rock Harbor Road, and through a salt marsh to Rock Harbor. Creek flow and water quality have been measured several times at the same location (yellow triangle) and the pond has been sampled regularly since 2000 at the same deep location (orange circle).

ppt salinity) and 2) limit summer nutrient contributions from the large seasonal flock of double-crested cormorants by removing the regional power lines that were strung over the pond. The reduced salinity would improve water quality conditions, provide better habitat for herring, and protect the adjacent Atlantic White Cedar wetland. Moving the regional power lines would reduce a notable nutrient source and improve water quality. Additional discussions about managing sediment nutrients were recommended once initial steps were fully implemented.

In order to facilitate adaptive management and meet the terms of the MassDEP and MEPA regulatory approvals, the Management Plan includes regular reporting and discussion of monitoring results. The required reporting includes an annual report and a semi-annual update on monitoring activities. CSP/SMAST has prepared seven annual reports between 2018 and 2024. This current Annual Report is the eighth Cedar Pond Annual Report. The annual report reviews monitoring completed during 2025, including the data summarized in the 2025 Semi-Annual Report.[12]

In 2022, MassDEP reviewed the Town compliance with the regulatory provisions of the Management Plan approvals, including the Superseding Order of Conditions under the Wetland Protection Act. MassDEP issued a Certificate of Compliance[13] to the Town with one on-going condition: that the Town continue to implement the Cedar Pond Management Plan.

II. Insights from Previous Years Management

One of the strategies in the Management Plan adaptive approach has been to improve water quality by gradually returning Cedar Pond to its historically brackish conditions (*i.e.*, <10 ppt). This management step has been accomplished by reinstalling the tidal boards in the pond outlet and rebalancing the relationship between groundwater and tidal inputs. The initial strategy was that the boards would only allow the highest tides into the pond; this would accentuate the impact of natural watershed groundwater inputs and gradually lower pond salinities. Water column monitoring would accompany the board installation: a) approximately monthly water column samples and DO and temperature profiles at the deepest basin, b) shallow and deep sondes for continuous readings of DO, temperature, water levels and salinity, and c) streamflow readings and water quality samples downstream of the pond. The downstream flow station between Route 6 and Rock Harbor Road is at the same location periodically monitored since 2002 (initially for the Rock Harbor MEP assessment[14]). Initial 2014 board elevations were based on previously collected data.[15] The board elevations were adjusted as additional water column and water level data were collected in following years.

The initial board elevation recommendations were based on a seasonal strategy to first allow spawning herring into the pond and then later to let juveniles leave the pond. The initial elevations were based on allowing at least 6 inches (0.15 m) of water depth to flow over the top from March 15 to June 30. This setting should facilitate entry into the pond by river herring migrating upstream from Cape Cod Bay/Rock Harbor for spawning within the pond. On July 1, the board elevation

[12] CSP/SMAST Technical Memorandum. October 14, 2025. Cedar Pond Adaptive Management Monitoring Program: 2025 Semi-Annual Report (Status of field activities between January 2025 and August 2025). From: E. Eichner, D. Schlezinger, and M. Labrie. To: G. Meservey and N. Sears, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 9 pp.

[13] MassDEP Certificate of Compliance to Town of Orleans. February 2, 2022. DEP files number: SE 54-2286.

[14] Howes B.L., S.W. Kelley, J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, E.M. Eichner. 2008. Rock Harbor MEP report.

[15] CSP/SMAST Technical Memorandum: Board Height Recommendation for Cedar Pond Outlet. October 10, 2014. From: Howes, B., E. Eichner, R. Samimy, J. Ramsey, and S. Kelley. To: G. Meservey, Town of Orleans and C. Kennedy, Chair, Marine and Fresh Water Quality Task Force. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 13 pp.

would be adjusted to allow at least 2 inches (0.05 m) of outflowing water over the top board. This adjustment would last until November 15 and would be designed to allow juvenile herring (spawn of the year) to leave the pond as seasonal levels naturally decrease during the summer. Boards were to be adjusted by Town staff to attain the specified amount of water over the boards throughout the management period.

The 2018 data review noted that water quality improved compared to 2017, but was not sustained as water column salinity increased after the boards were lowered at beginning of July. As a result, Town, DMF, and CSP/SMAST staff discussed options to better attain the Management Plan goal of reduced salinity while also addressing fishway access goals. As a result, it was agreed that the specified board elevations would be maintained in 2019, but the opening in the boards would be reduced to a 6 inch notch (**Figure II-1**). The goal of this board configuration was to continue to allow prospective fish passage, but reduce the cross-sectional area exposed to high tide water inputs. It was hoped that this change in the board configuration would sustain the lower salinity levels measured in the winter and early spring. CSP/SMAST also added another water level recorder at the pond outlet to provide additional data about water levels at the outlet and better guidance for board elevations. This recorder was in addition to the shallow and deep water level recorders on sondes in the center of the pond.

The 2019 annual data review, which included the addition of the board notch, showed that winter and early-spring salinity in the pond was significantly reduced and water quality was improved compared to 2018. The pond began March 2019 (the beginning of board lowering) at a low salinity (~6 ppt) just above the Management Plan targeted range of 1 to 4 ppt.[16] Because 2019 sampling season began at a lower salinity level, salinity levels throughout 2019 were lower than 2018. However, once the notch board was added in March, 2019 water column salinity levels increased at the same rate that had been measured in 2018 after the outlet boards were lowered. With the 2019 lower salinity setting, pond water quality improvements were measured for a number of ecological metrics including higher DO levels, lower nitrogen and phosphorus levels, and less nitrogen and phosphorus transferred from the pond to Rock Harbor. Subsequent review of the 2019 outlet water level data showed that board elevation could be raised another 4 inches higher while still attaining the water level goals for herring entrance and exit.[17]

As a result, the elevation of the bottom of the notch was raised in 2020 and water quality incrementally improved again, but summer salinity rates increased at the same rate measured in 2018 and 2019 once the boards were lower even though it was to a higher elevation. Water quality conditions in 2020 showed a greater proportion of the water column achieving the MassDEP minimum DO concentration (*i.e.*, 5 mg/L[18]), lower TN and TP water column concentrations, and lower export of TN and TP out of the pond to Rock Harbor. Even though the water quality conditions were improved, the pond continued to have impaired conditions.[19]

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[16] Eichner, E., B. Howes, and D. Schlezinger. 2020. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2019 to December 2019. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 38 pp.

[17] CSP/SMAST Technical Memorandum: Cedar Pond Board Adjustment. October 21, 2020. From: E. Eichner, Howes, B., and D. Schlezinger. To: G. Meservey, Director of Planning & Community Development and N. Sears, Natural Resources Manager, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 6 pp.

[18] 314 CMR 4.05

[19] Eichner, E., B. Howes, and D. Schlezinger. 2021. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2020 to December 2020. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 44 pp.

Figure II-1. Notched Board at Cedar Pond Outlet. After reviewing 2018 water levels at the outlet, Town, MassDMF, and CSP/SMAST staff agreed that the boards at the outlet could have a notch in the upper board to facilitate fish passage while also trying to limit the volume of high tides reaching Cedar Pond. Subsequent water level monitoring in 2019 showed that once a notch was added, salinity levels increased at the same rate as in 2018 when the boards were lowered. 2020 monitoring suggested that the elevation of the bottom of the notch could be increased while also attaining similar frequency of acceptable water levels meeting the Fishway Plan goals. Notch elevations are adjusted according to Fishway Plan goals for 6 inches of water over the notch bottom in the spring for spawning herring immigration (March 15 to June 30) and 2 inches of water over the notch bottom in mid/late summer to allow young of the year emigration (July 1 to November 15). No herring had been observed during more than 81 visits from 2018 through 2021, but use of fyke nets by Town and MassDMF in March/April 2022 trapped and released 30 alewife herring. Herring in the Cedar Pond Creek is one indication of improving water quality conditions in Cedar Pond.

In 2021, the COVID pandemic disrupted much of Cedar Pond reporting, but monitoring continued without disruption. Water quality conditions were incrementally better than in 2020 with:

1) all DO profile concentrations from the surface to 1 m were above the MassDEP minimum (5 mg/L[20]) for the first time,
2) shallow salinity concentrations were generally lower, but increased at same rate as 2018-2020 once the notch was added for fish passage,
3) shallow TN concentrations were approximately the same as 2020, but shallow TP concentrations were the lowest measured 2018-2021, and
4) deep water column conditions continued to be impaired, but stronger salinity stratification (*i.e.*, shallow lower salinity and deep higher salinity) generally kept the impaired conditions from mixing into the shallower portions of the water column.

Monitoring in 2022 showed that water column DO concentrations were incrementally better than in 2021 with acceptable DO concentrations throughout a greater portion of the water column than in any of the previous 2018-2021 monitoring years. Deep conditions continued to be impaired, but stronger salinity stratification has generally reduced their impact on shallower waters. The rate of salinity increase after the addition of the notch at the outlet was lower in 2022, largely because spring salinity concentrations were higher. The late summer peak salinity was similar to 2019-2022 levels. The improved 2022 water quality conditions reduced the TN exported to Rock Harbor. Annual average nitrogen export to Rock Harbor had decreased from 8.3 kg/d in 2018 to 1.5 kg/d in 2022. The 2022 nitrogen export closely approximated the rate measured in 2002/2003 (1.1 kg/d) measured for the Rock Harbor MEP assessment.[21]

The 2022 monitoring also included proof that Cedar Pond water quality had improved enough to encourage herring to return to the pond. Prior to 2022, no fish were observed entering or leaving Cedar Pond during more than four years of Management Plan monitoring, including over 80 visits to the pond outlet and Cedar Pond Creek by Town, CSP/SMAST, and MassDMF staff. During discussions of 2021 monitoring results, MassDMF offered to assist the Town in installing fyke nets in Cedar Pond Creek during the primary alewife/herring spawning period (March/April 2022) to see if any herring were swimming toward Cedar Pond. During this deployment, 30 alewife herring were trapped and released. This was an additional encouraging sign about improved water quality conditions in Cedar Pond and provides some hope that future alewife visits will increase due to fish returning to the pond where they were born.

In 2023 and 2024, water quality was generally incrementally better each year, but still impaired. Nitrogen export to Rock Harbor in 2023 was lower than any previous years (2018-2022) with a daily export of 0.8 kg/d or less than the 2002/2003 MEP measurement of 1.1 kg/d.[22] In 2024, TN export was slightly higher than 2023, but consistent with the 2002/2003 levels.[23] Shallow DO readings in both 2023 and 2024 continued to be greater than the MassDEP minimum, something that had been sustained since 2021. Salinity levels were lower than 2022 levels in both 2023 and 2024, but 2024 levels were higher than 2023. Temperature stratification kept deep anoxia separated from shallow portions of the water column and 2023 deep TN and TP average concentrations were the highest recorded in five years of monitoring, while 2024

[20] 314 Code of Massachusetts Regulations 4.05(4)1.

[21] Howes B.L., S.W. Kelley, J. S. Ramsey, R.I. Samimy, D.R. Schlezinger, E.M. Eichner. 2008.

[22] Eichner, E., D. Schlezinger, and R. Samimy. 2024. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2023 to December 2023. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 52 pp.

[23] Eichner, E., D. Schlezinger, and R. Samimy. 2025. Cedar Pond Adaptive Management Monitoring Program: Annual Technical Report, January 2024 to December 2024. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 47 pp.

averages were slightly lower. In both the 2023 and 2024 annual reports, it was recommended that the Town consider more active management of the pond, including development of strategies to address the sediments, which are the cause of the deep anoxia and the high deep nutrient levels.

III. Cedar Pond Adaptive Management Program 2025 Results

This section discusses the 2025 data, including data previous presented in the semi-annual report, and its interpretation for compliance with MassDEP, MEPA, and the Town Conservation Commission requirements. Monitoring during the 2025 calendar year followed the same protocols as previous years, including:

a) monthly water column samples and readings between March and November,
b) twice a month samples and measurement of streamflow out of the pond,
c) continuous measurement of pond water level fluctuations, DO, temperature, salinity, and chlorophyll at shallow and deep depths, and
d) tracking of fishway factors, including outlet board heights, water levels over the boards, fish observations,

III.A. Water Column Monitoring

CSP/SMAST staff collected 2025 water column samples and profiles on 11 dates between March and November: March 5, March 20, March 24, April 16, May 20, June 17, July 17, August 14, September 15, October 15, and November 13. On each date, temperature, dissolved oxygen (DO), and salinity profiles were collected and water quality samples were collected at a minimum of three depths in the water column: 0.5 m, 1.5 m, and deep (typically 3 m to 3.5 m). Water column samples were collected at the same location as the continuous water column monitoring devices. All collected water quality samples were assayed at the Coastal Systems Analytical Laboratory at SMAST/UMASS Dartmouth using the same assay procedures used for Town water quality samples collected from estuaries and freshwater ponds.

III.A.1. Cedar Pond Water Column: 2025 Salinity, Temperature, Dissolved Oxygen Profiles

Between 2001 and 2006, prior to the 2007 changes to Cedar Pond Creek, average surface and deep salinity in Cedar Pond was 8.6 ppt and 16.4 ppt.[24] After the 2007 changes, average surface and deep salinity increased to 18.4 ppt and 21.1 ppt, respectively. The persistence of the higher deep salinity is due to Cedar Pond being deeper than the Creek, so higher salinity tidal water flows into the Pond and settles into the deep basin. The greater congruence of shallow and deep salinity allowed the water column to more easily mix. The smaller difference in shallow and deep salinity also reduced the temperature difference between shallow and deep water so that temperature and salinity would both reinforce easier water column mixing. Easier water column mixing would bring deep anoxia and higher nutrient concentration closer to the surface and create greater impairments throughout a higher percentage of the water column, conditions that were measured in the early years of the Management Plan implementation.

Once the outlet boards were reinstalled in November 2017, groundwater inputs to the Pond began to have a greater impact on temperature and salinity levels. By 2022, shallow and deep temperatures were sufficiently different to sustain temperature stratification during the summer. In 2022 through 2024, temperature stratification generally began in May or June and lasted to August or September. This temperature stratification isolated waters deeper than 1.5 to 2 m and prevented anoxia and high nutrients from mixing into the shallower portions of the water column (**Figure III-1**). Salinity levels also developed relatively stable stratification, which tended to reinforce the temperature stratification, and kept waters deeper than 2 m from mixing with shallower waters even after temperature stratification regularly began to break down in the later summer (**Figure III-2**).

[24] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan.

In 2025, water column temperature profiles tended to be consistent with recent monitoring. Temperature profiles in March and April had sufficiently similar readings that there was no notable stratification (**see Figure III-1**). In May, stratification was measured between 2 and 2.5 m depth and was sustained at slightly shallower depths in June and July. In August and on each subsequent monitoring date, water column temperatures were not sufficient to sustain temperature stratification. Temperatures increased from April through July before decreasing in each subsequent monthly profile. In the October and November profiles, deep temperatures were higher than shallow temperatures due to tidal inputs sinking to the bottom.

Salinity readings in 2025 began the year much higher than previous recent years and decreased throughout the rest of the year (**see Figure III-2**). Readings at 0.5 m and 1.5 m tended to be the same in the summer and mostly varied between 11 and 13 ppt. Deep salinity levels tended to range between 17 and 18 ppt and higher than shallow salinity in all monthly profiles. The relatively higher 2025 salinity levels corresponded to lower groundwater levels and likely lower inputs of zero salinity groundwater. Monthly groundwater levels from January through September were below average with February and April setting new record lows for data collected between 1976 and 2024 (**Figure III-3**). Lower groundwater levels would tend to reduce groundwater inputs because the overall regional lens would have a lower elevation and lower force toward the discharge margins (*i.e.*, where Cedar Pond is located). Lower groundwater input would also be consistent with the lower than average precipitation during the 2024/2025 winter (**Figure III-4**). Aquifer recharge tends to be higher during colder periods when plant transpiration is limited. Orleans precipitation in December 2024 and January and February 2025 was below average.

DO profiles in 2025 generally showed deep anoxia, usually reinforced by stratification (**Figure III-5**). In the March 5 profile, DO throughout the water column was greater than the MassDEP minimum of 5 mg/L.[25] This is the first time this has been measured in any of the DO profiles collected in Cedar Pond over the last 25 years, although part of this may be due to extremely cold temperatures near the bottom (~4°C) impacting bacterial activities. Subsequent 2025 profiles had deep anoxia with or without temperature stratification. When temperature stratification occurred (May, June, and July profiles), anoxia was usually present throughout the entire deep layer. When temperature stratification was not present (*i.e.*, in profiles after July), anoxia occurred at depths of 2.5 to 3 m and deeper. Comparison of historical and recent DO levels showed that 2025 levels were relatively consistent with recent levels (2022-2024) albeit with 1.5 m levels that were higher on average.

Review of 2025 DO saturation levels showed that while deep levels were generally less than 5%, as would be expected by the persistent deep anoxia, most of the profile shallow levels also showed occasional impacts of sediment oxygen demand (**Figure III-6**). Shallow 2025 DO saturation levels varied from 90% to 113%. Levels near 110% typically occur due to excessive phytoplankton photosynthesis, while levels near 90% show that atmospheric mixing of the water column is insufficient to address sediment oxygen demand. Of the ten DO profiles collected in 2025, five of the profiles had shallow DO saturation levels of 94% or less and three had levels of 109% or greater. Impaired systems often fluctuate rapidly changing between conditions. Saturation levels in 2025 were similar to previous recent profile readings (2022-2024) although readings at 1.5 m tended to be more consistent if still depressed (**see Figure III-6**).

[25] 314 Code of Massachusetts Regulations 4.05(4)1.

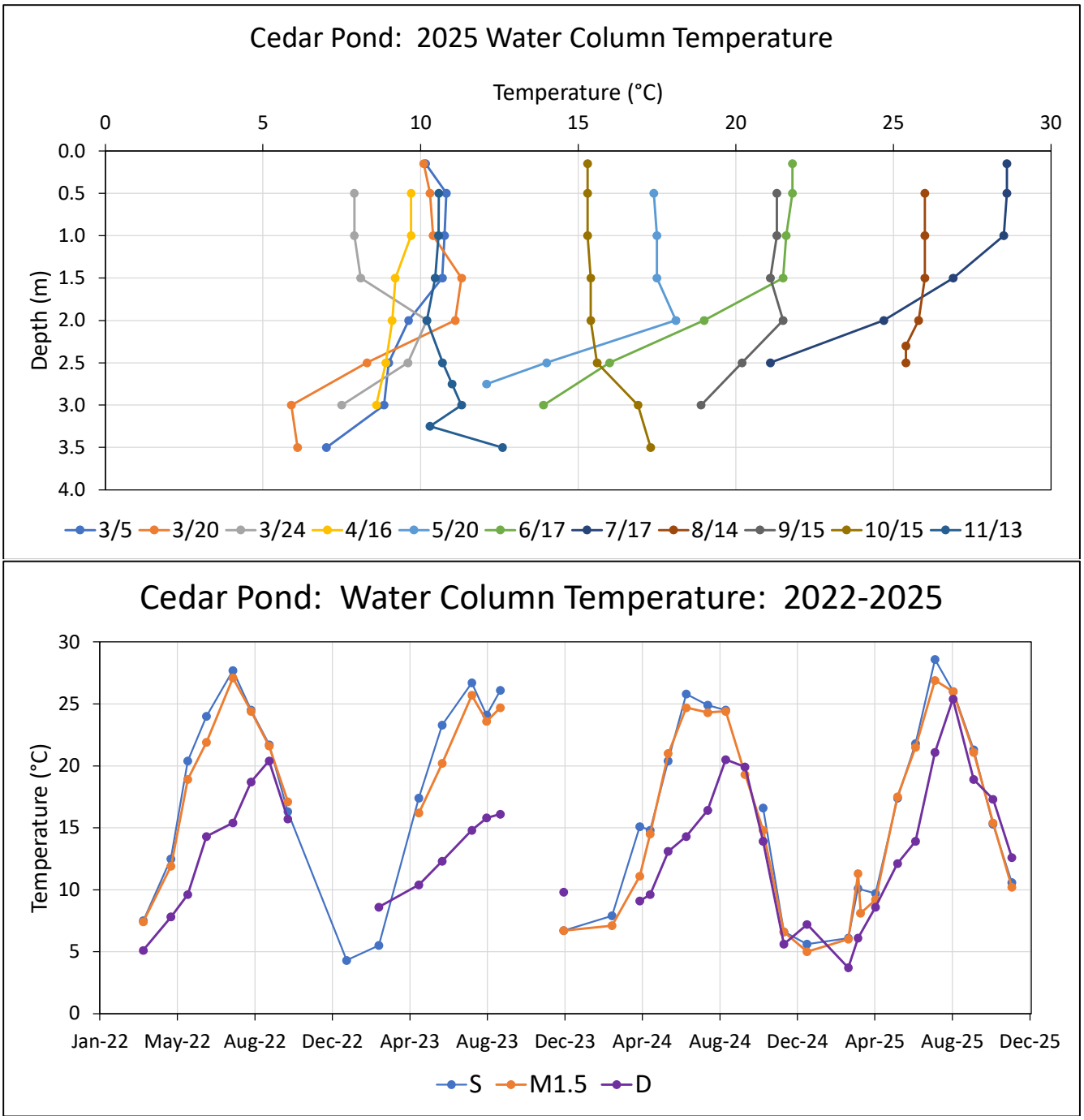
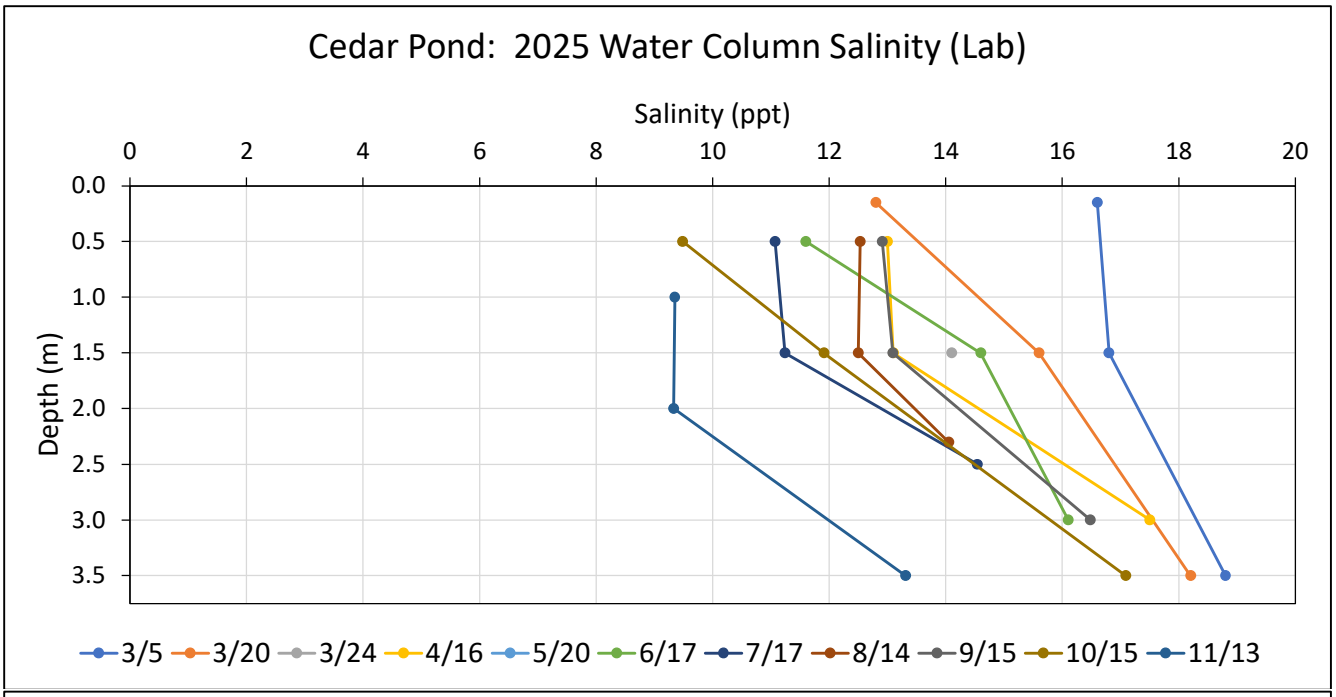


Figure III-1. Cedar Pond Water Column Temperature: 2025 and Recent Historical (2022-2025). 2025 profile temperatures were similar with no stratification until the May readings. Stratification persisted through the July profile, but did not occur in any of the subsequent profiles. Temperatures increased from May through July and then decreased, returning to March/April conditions in November. Deep temperatures in October and November were higher than shallow temperatures, consistent with warmer tidal inputs sinking to the pond bottom due to higher salinity content. 2025 readings were similar to those in previous years except deep temperatures tended to be higher.



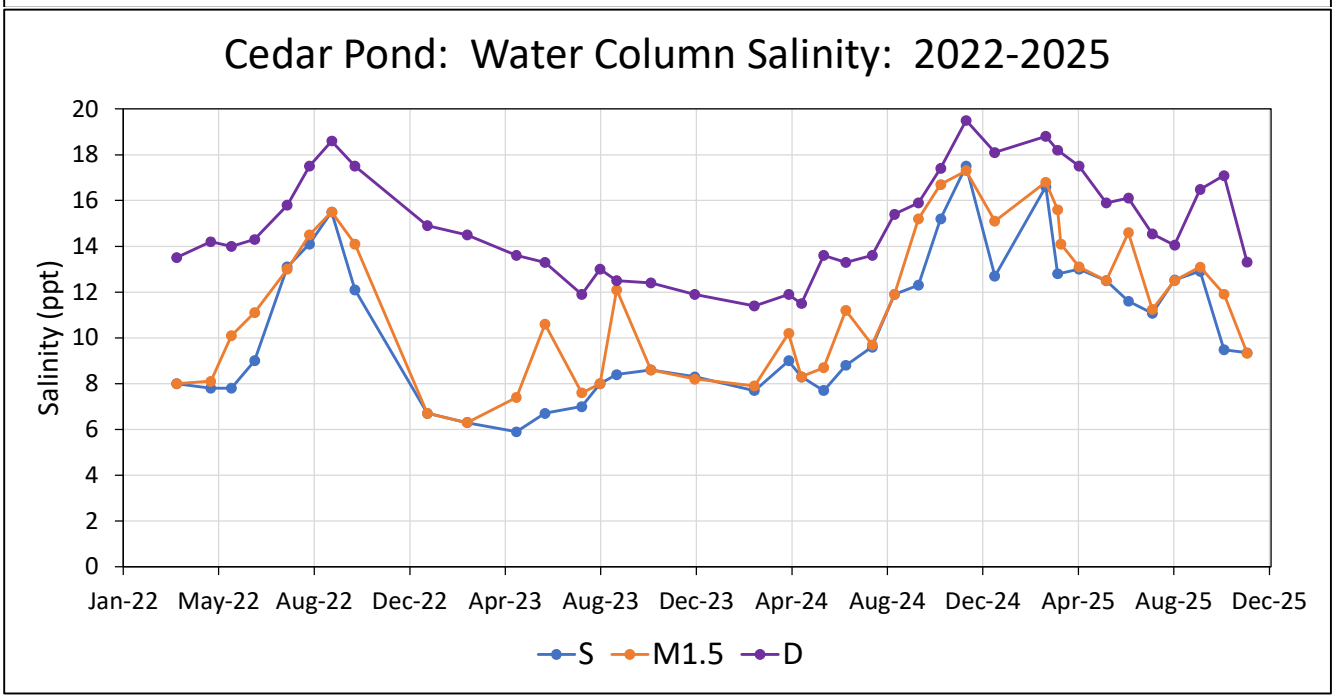


Figure III-2. Cedar Pond Water Column Salinity: 2025 and Recent Historical (2022-2025). 2025 profile salinity readings began the year at a much higher level than previous recent years likely due to historically low groundwater levels. Salinity levels at all depths decreased in each subsequent profile after early March, returning to levels measured in August 2024 in the October 2025 profile. Even with 2025 higher levels, salinity stratification was relatively stable, keeping waters deeper than 2 m from mixing with shallower waters. Readings at 0.5 m and 1.5 m tended to be the same in the summer and mostly varied between 11 and 13 ppt, while deep salinity levels tended to range between 17 and 18 ppt. Deep salinity levels were higher than shallow salinity levels in all monthly profiles.

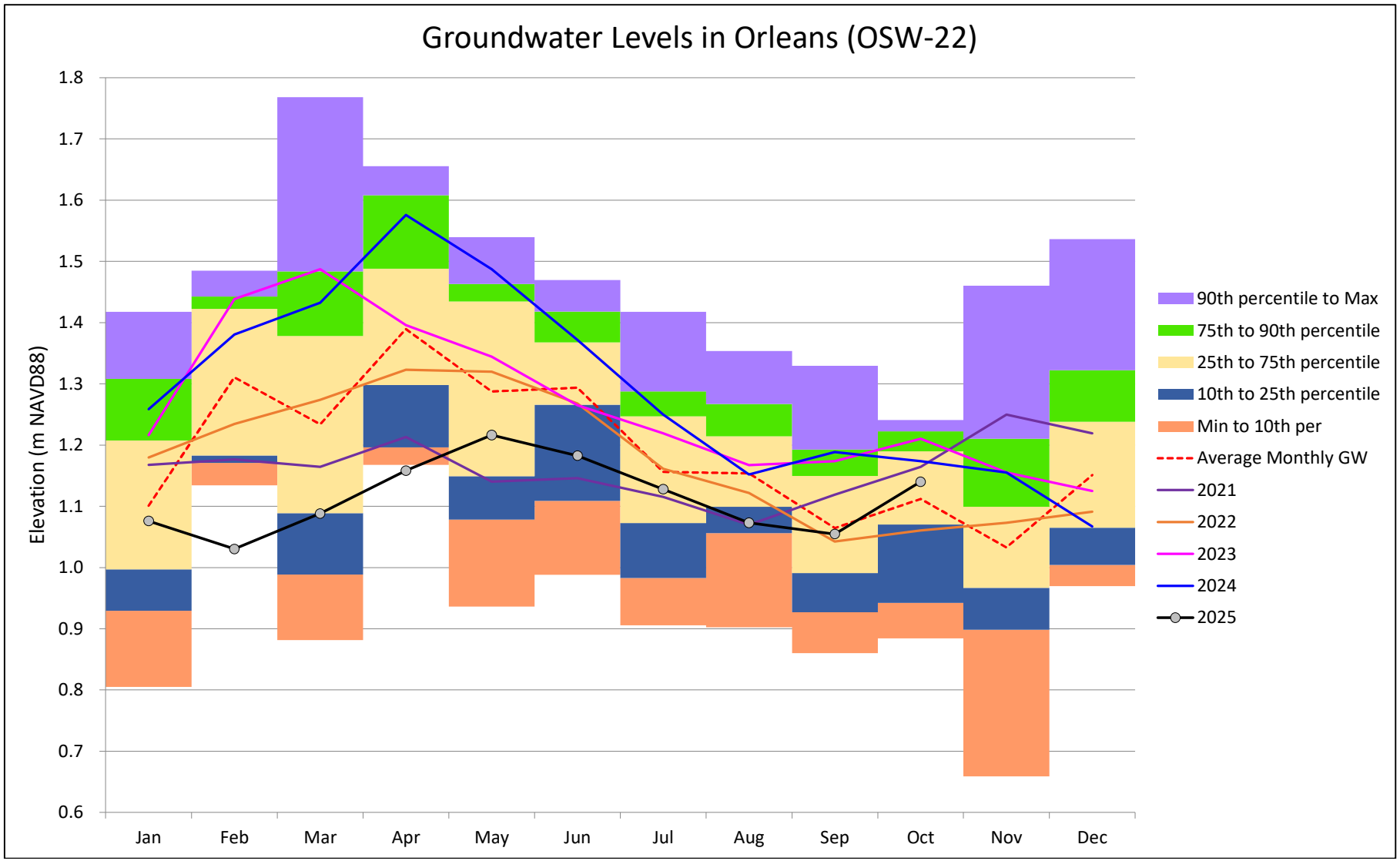


Figure III-3. Orleans Groundwater Elevations. Monthly groundwater levels from January through September 2025 (black line with gray markers) were less than the long-term monthly averages (orange dashed line) with February and April levels setting new record lows for a 1976 to 2025 dataset (https://waterdata.usgs.gov/blog/wdfn-field-measurements/; accessed 2/20/26). Lower groundwater levels would tend to reduce groundwater inputs to Cedar Pond. Note: the October 2025 readings are the last water level readings for this well in the USGS database; monitoring of groundwater levels at this well, the longest historical record within Orleans, appears to have ended.

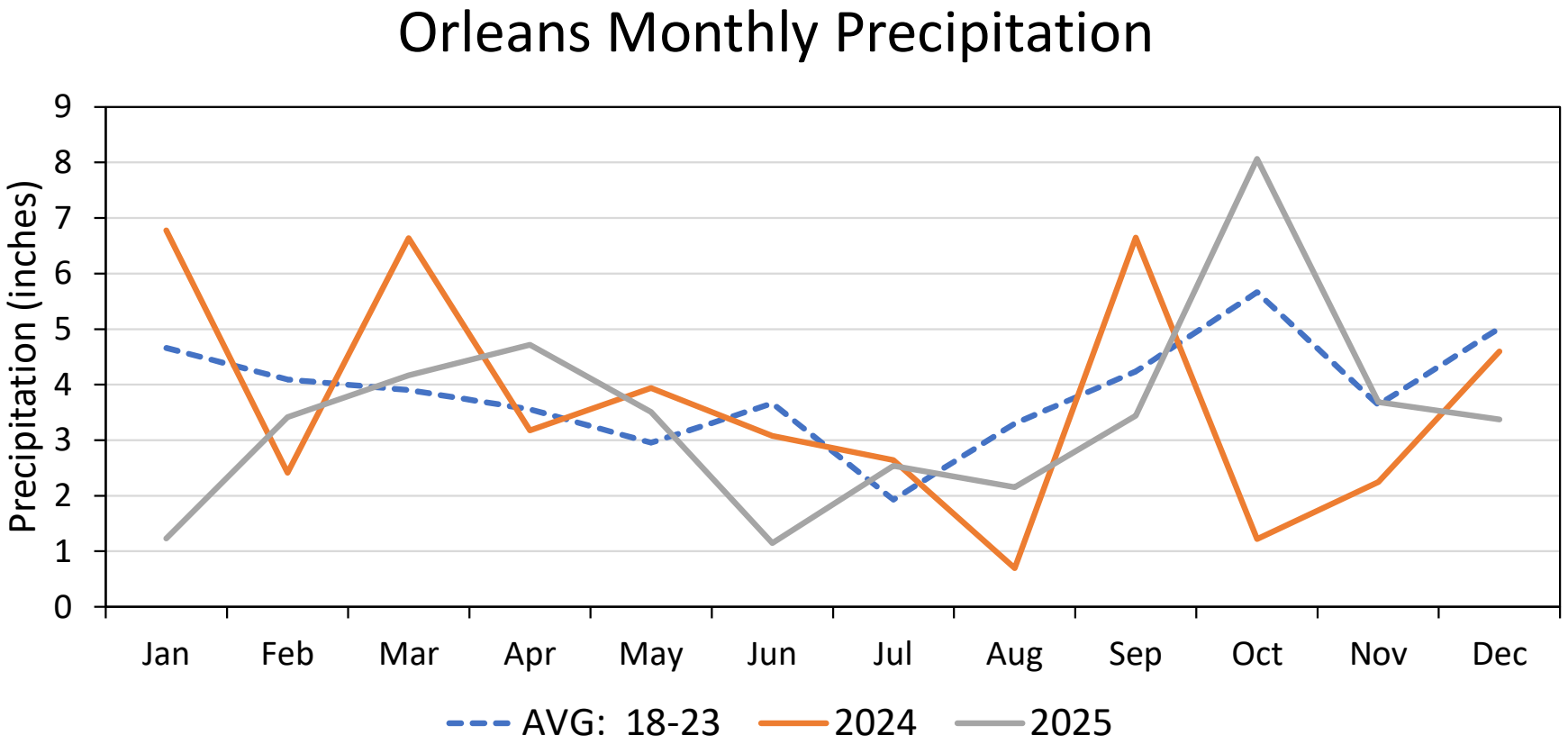


Figure III-4. Orleans Precipitation. Recharge to groundwater from precipitation generally is maximized during the winter when transpiration from plants is minimal. During the winter of 2024/2025, precipitation amounts in Orleans in October, November, and December 2024 and January and February 2025 were less than average with January 2025 more than three inches less than average. Lower precipitation during the primary recharge period would tend to reduce groundwater levels.

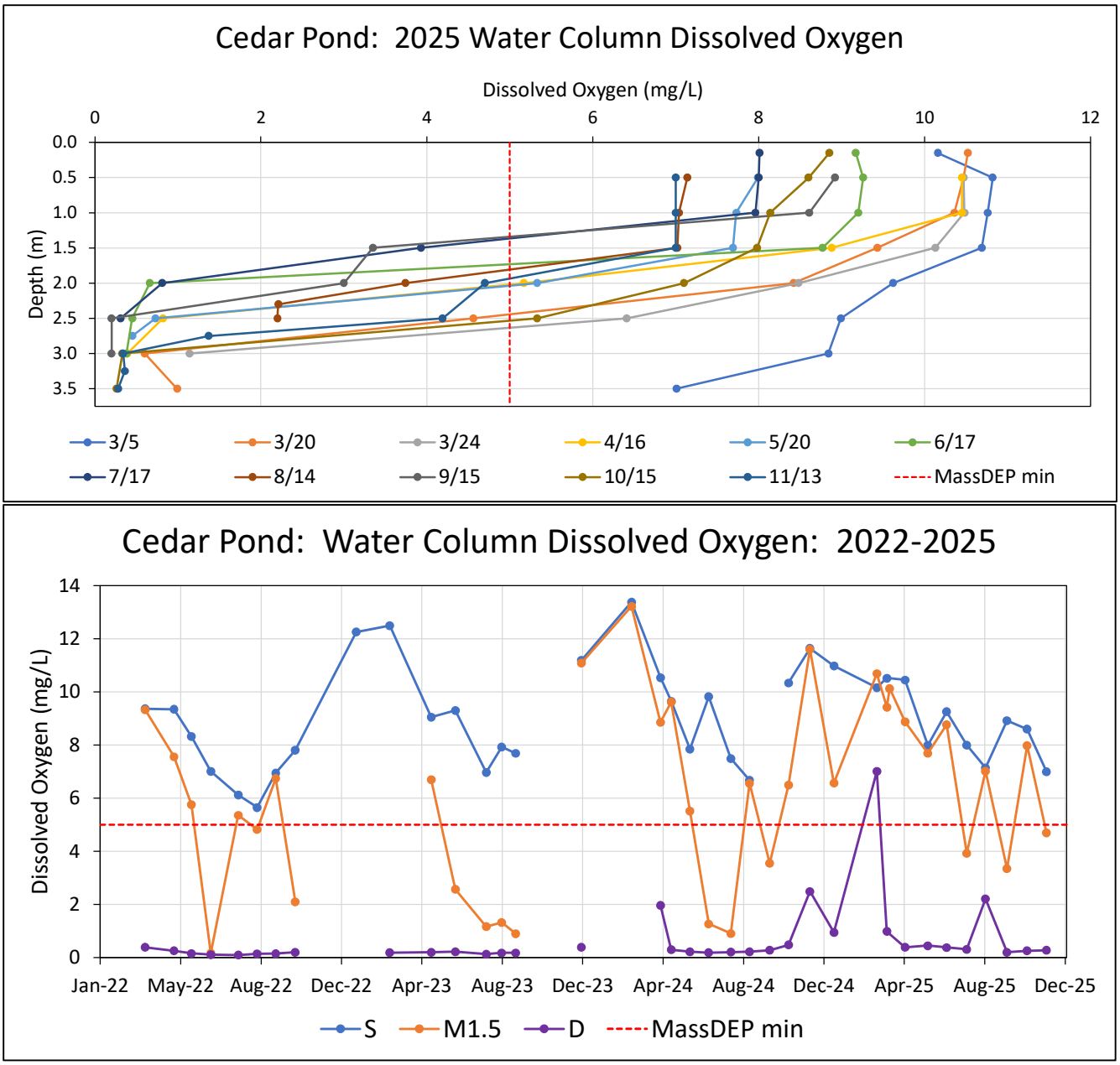


Figure III-5. Cedar Pond Water Column Dissolved Oxygen: 2025 and Recent Historical (2022-2025). 2025 profile DO readings generally showed deep anoxia, usually reinforced by stratification except for the March 5 profile. The March 5 DO profile had concentrations greater than the MassDEP minimum of 5 mg/L throughout the water column; this is the first time DO greater than 5 mg/L has been measured throughout the Cedar Pond water column in over the last 25 years of monitoring. The higher than expected deep DO may have been due to extremely cold deep temperatures (~4°C) reducing bacterial activities. Subsequent 2025 DO profiles had deep anoxia with or without temperature stratification; temperature stratification in May, June, and July profiles had anoxia/hypoxia throughout the entire deep layer. In profiles after July 2025, when temperature stratification was not present, anoxia occurred at depths of 2.5 to 3 m and deeper. Historical review of recent DO levels (2022-2024) showed that 2025 levels were relatively consistent with recent levels; 2025 levels at 1.5 m tended to be slightly higher.

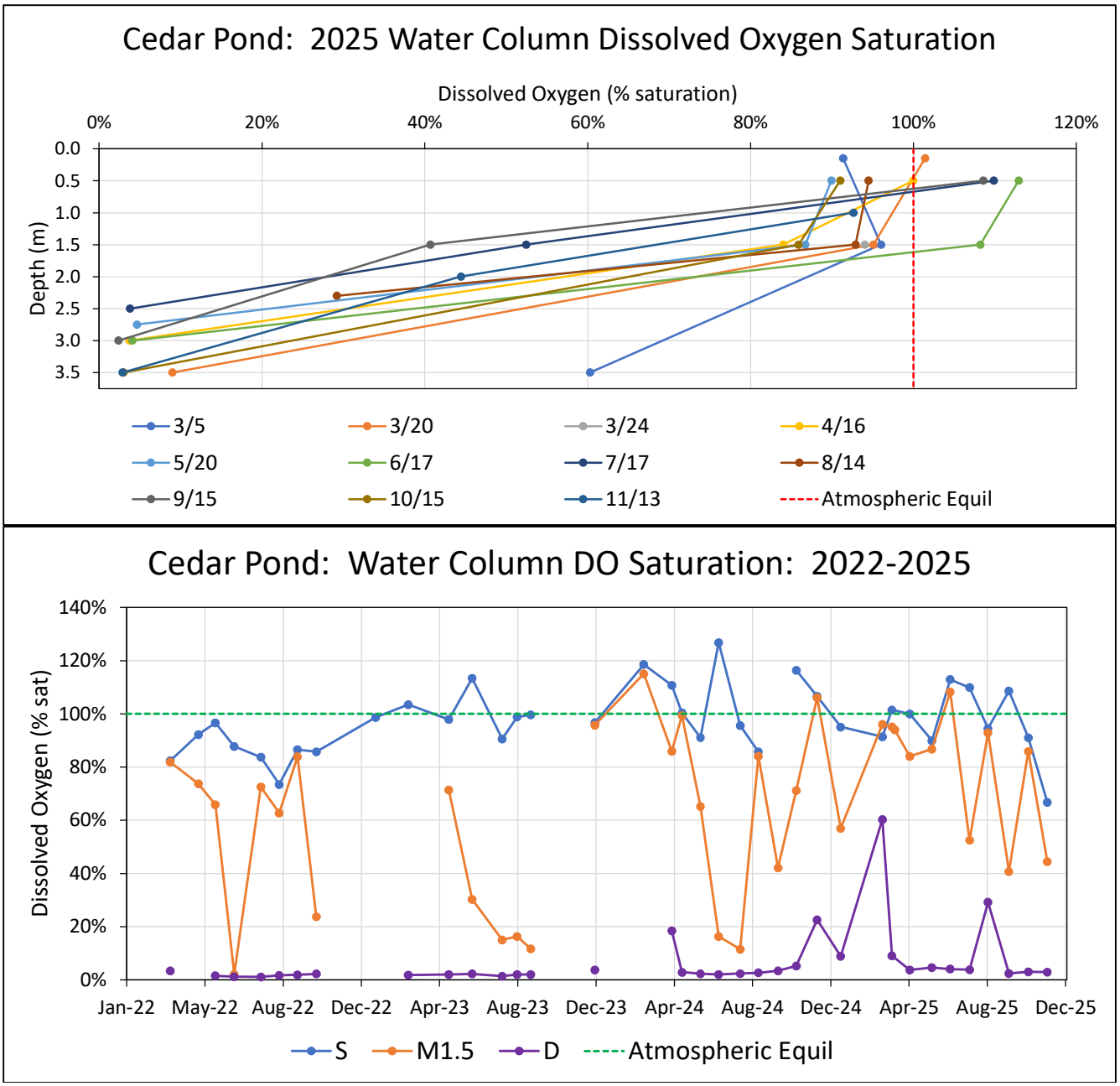


Figure III-6. Cedar Pond Water Column Dissolved Oxygen Saturation: 2025 and Recent Historical (2022-2025). Review of 2025 DO saturation levels showed changeable impact of sediment oxygen demand on the whole water column. Deep levels were generally less than 5%, as would be expected by the persistent deep anoxia, but shallow levels were regularly less than 94% and occasionally greater than 109%. Levels near 110% suggest active phytoplankton photosynthesis producing more DO than can be vented to the atmosphere by regular mixing. In contrast, levels near 90% show that regular mixing was insufficient to balance DO consumption by sediment oxygen demand. Of the ten DO profiles collected in 2025, five of the profiles had shallow DO saturation levels of 94% or less and three had levels of 109% or greater. Impaired systems often fluctuate rapidly changing between conditions. Saturation levels in 2025 were similar to previous recent profile readings (2022-2024) although readings at 1.5 m tended to be consistently higher, if still depressed.

III.A.2 Cedar Pond Water Column: 2025 Continuous Water Quality Recordings

Continuous water column monitoring devices have been in place in Cedar Pond since 2018. These autonomous recording devices (shallow and deep) were installed over the deepest spot in the pond and have been deployed at this location in Cedar Pond since the initial 2018 monitoring after the Management Plan approval, as well as in 2009, 2012, and 2015 as part of prior pond assessments.[26] The devices record DO, salinity, chlorophyll-*a* and water depth every 15 minutes.

The shallow device has been historically deployed at a depth of 1.2 to 1.3 m, while the deep device has been installed at depths between 3.4 and 3.7 m. In 2025, the shallow device was initially installed at an average depth of 1.3 m and then was adjusted to an average depth of 1.6 m after March (**Figure III-7**). The deep device was installed at an average depth of 2.8 m until August 14 and then was adjusted to an average depth of 3.2 m.

Continuous 2025 temperature readings showed a higher rate of warming of the shallow waters that eventually caused temperature stratification between the two depths (**Figure III-8**). In the monthly water column profile readings, stratification was first measured in the May 20 profile (**see Figure III-1**), but the continuous readings show that stratification initially occurred in early May and persisted until early August. The August 14 monthly temperature profile readings did not indicate temperature stratification. Maximum shallow temperature was 28.3°C (July 8, 4:30 PM), while the maximum deep temperature was 22.2°C (August 11, 1:45 AM).

As noted in the monthly profiles, both shallow and deep continuous salinity generally decreased throughout the sonde deployment period (**Figure III-9**) as groundwater levels and associated inputs to the pond increased to more average conditions. Average shallow salinity in January and February were 16.8 ppt and 17.6 ppt, respectively, while average shallow salinity in July and August were 12.3 ppt and 12.4 ppt, respectively. As would be expected because of how tidal inputs sink to the bottom, deep salinities were generally higher than shallow levels, but also decreased as groundwater inputs increased. Average deep salinity in March and April were 18.3 ppt and 17.5 ppt, respectively, while average deep salinity in July and August were 15.0 ppt and 14.6 ppt, respectively.

Continuous 2025 DO readings showed that shallow levels through mid-May were mostly greater than the MassDEP minimum, but much more variable with regular low levels from mid-June through early November when the devices were removed (**Figure III-10**). Deep DO levels were mostly anoxic except for early March, which also matched the monthly water column DO profile on March 5 (**see Figure III-5**). Deep DO levels decreased from 7 mg/L on March 5 when the temperature was 4°C to anoxia levels (<1 mg/L DO) on March 12, when the temperature was 5.2°C. Freshwater begins to freeze at a temperature of 4°C, so it is likely that the increase in temperature increased sediment bacterial activity and led to the rapid lowering of the DO levels. The increased variability in shallow DO levels would be consistent with more active phytoplankton population during the summer. Review of daily summer DO patterns show

[26] CSP/SMAST Technical Memorandum: Cedar Pond Continuous Monitoring. January 14, 2016. From: B. Howes, E. Eichner, and D. Schlezinger. To: G. Meservey, Director of Planning & Community Development and C. Kennedy, Chair, Marine and Fresh Water Quality Task Force, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 6 pp.

complex variability with some indication of diurnal patterns (*i.e.*, lower DO at night compared to higher levels during the day).

Continuous 2025 chlorophyll-a readings were very high throughout the year with a high baseline and occasionally higher levels indicating blooms (**Figure III-11**). Monthly shallow chlorophyll-a averages ranged from 7.8 µg/L (March) to 49.3 µg/L (June) with an overall average of 15.8 µg/L. June readings were somewhat truncated because of battery failure; readings began again on June 17 and appear to have caught the peak of a bloom. Deep readings began to increase in mid-April and peaked on June 24 at 483 µg/L; this pattern suggests phytoplankton growth was likely occurring at depths greater than Secchi clarity. Research has suggested that sufficient light for plant growth can occur at 2.4X Secchi readings in clear water.[27] Given that 2025 Secchi clarity averaged 0.8 m (range 0.5 m-1.1 m) between April and September (**Figure III-12**), the multiplier would suggest that sufficient light was present at a deeper depth than the shallow sensor for phytoplankton growth. Phytoplankton with motility or buoyancy control would have a competitive growth advantage in deeper water where higher nutrient levels were present.

[27] *e.g.*, Lee, Z., Shang, S., Du, K., & Wei, J. 2018. Resolving the long-standing puzzles about the observed Secchi depth relationships. *Limnology and Oceanography*, *63*(6), 2321–2336. https://www.jstor.org/stable/26629412.

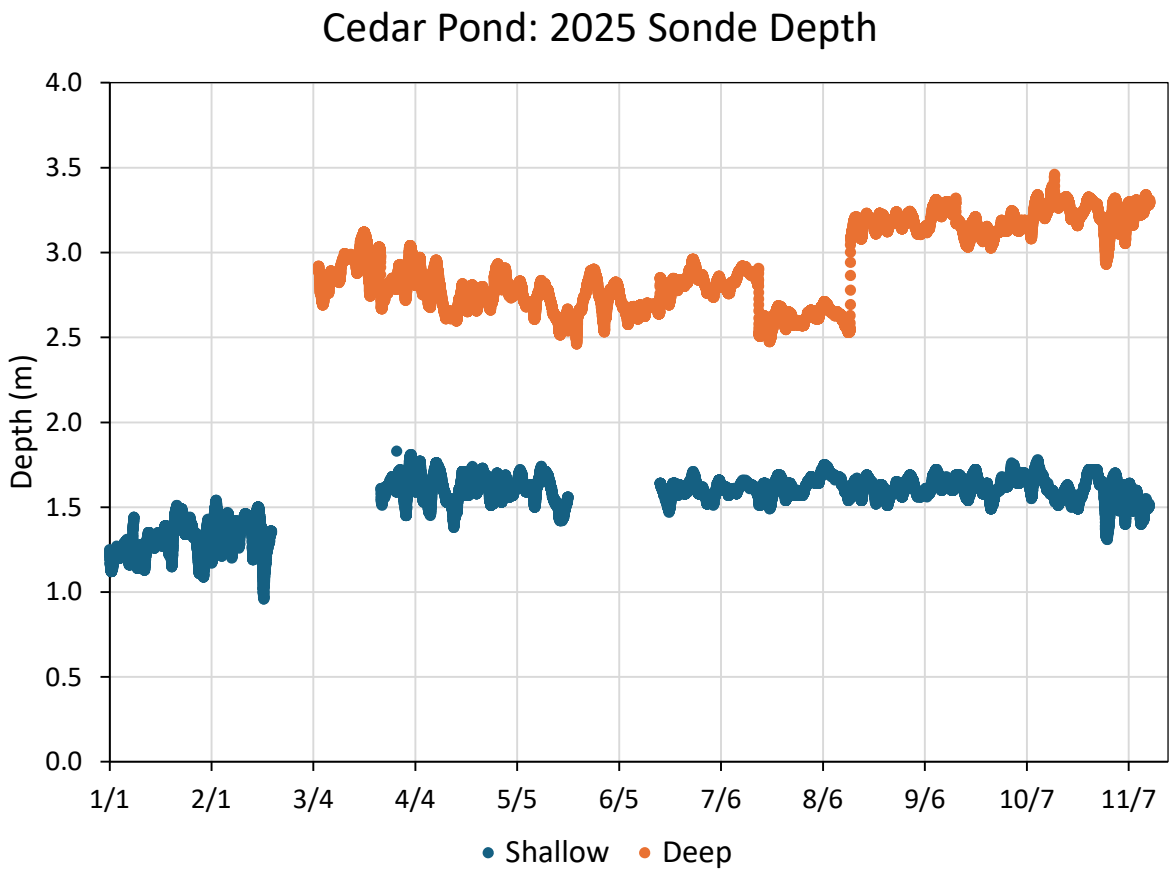


Figure III-7. Cedar Pond 2025: Continuous Sensor Depth. Two sonde platforms with multiple sensors were deployed over the deepest portion of Cedar Pond from January through early November, in much the same way they have been installed since 2018. Platforms contained sensors for depth, temperature, salinity, DO, and chlorophyll-a. All sensors recorded readings every 15 minutes, but had periods where devices did not record properly. The shallow device was initially installed at an average depth of 1.3 m and then was adjusted to an average depth of 1.6 m after March. The deep device was installed at an average depth of 2.8 m until August 14 and then was adjusted to an average depth of 3.2 m.

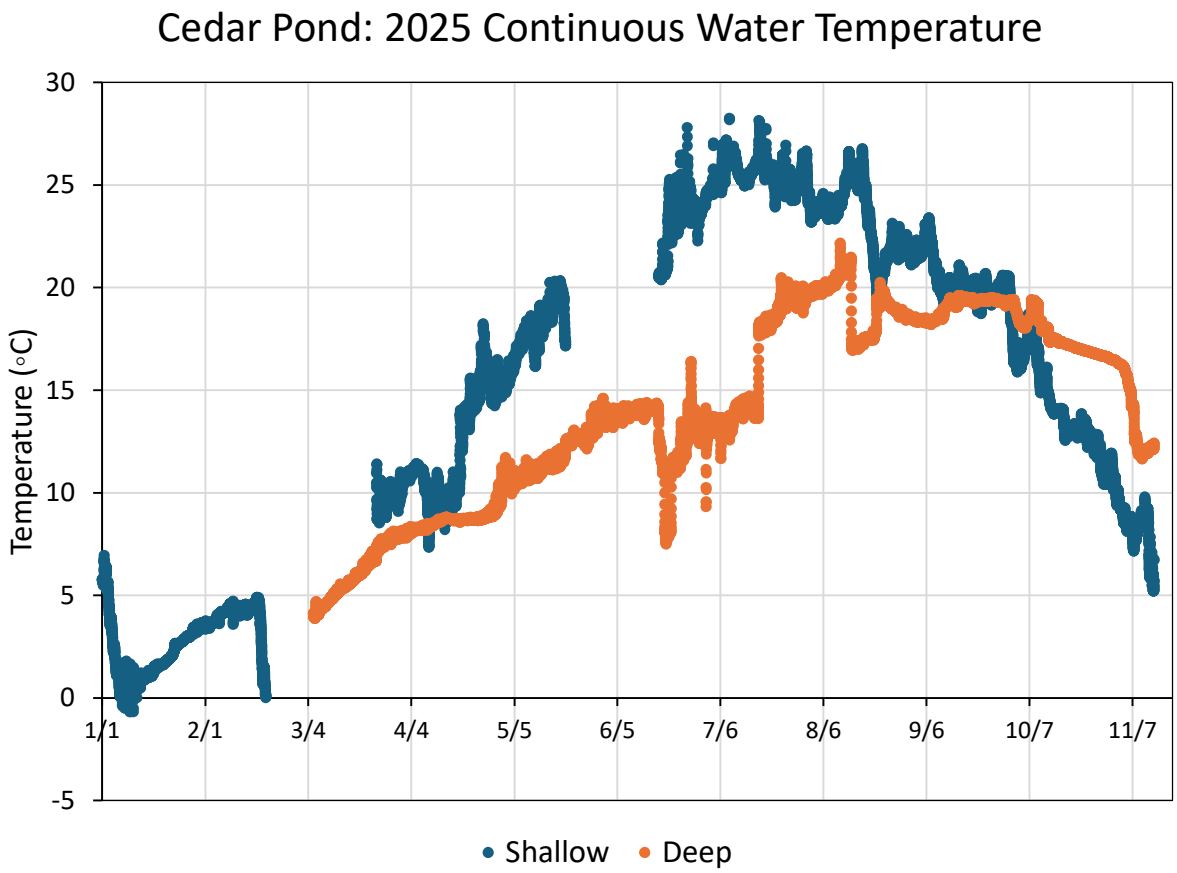


Figure III-8. Cedar Pond 2025: Continuous Sensor Temperature. Continuous 2025 temperature readings showed a higher rate of warming of the shallow waters that eventually caused temperature stratification between the shallow and deep readings in late April/early May. The first measured stratification in the monthly profile readings was in the May 20 profile. Continuous readings showed that stratification persisted until early August, while the monthly profile readings on August 14 did not indicate temperature stratification. Maximum shallow temperature was 28.3°C (July 8, 4:30 PM), while the maximum deep temperature was 22.2°C (August 11, 1:45 AM). Shallow temperatures in early January were slightly below (-0.6°C) freshwater freezing temperature (*i.e.*, 0 °C).

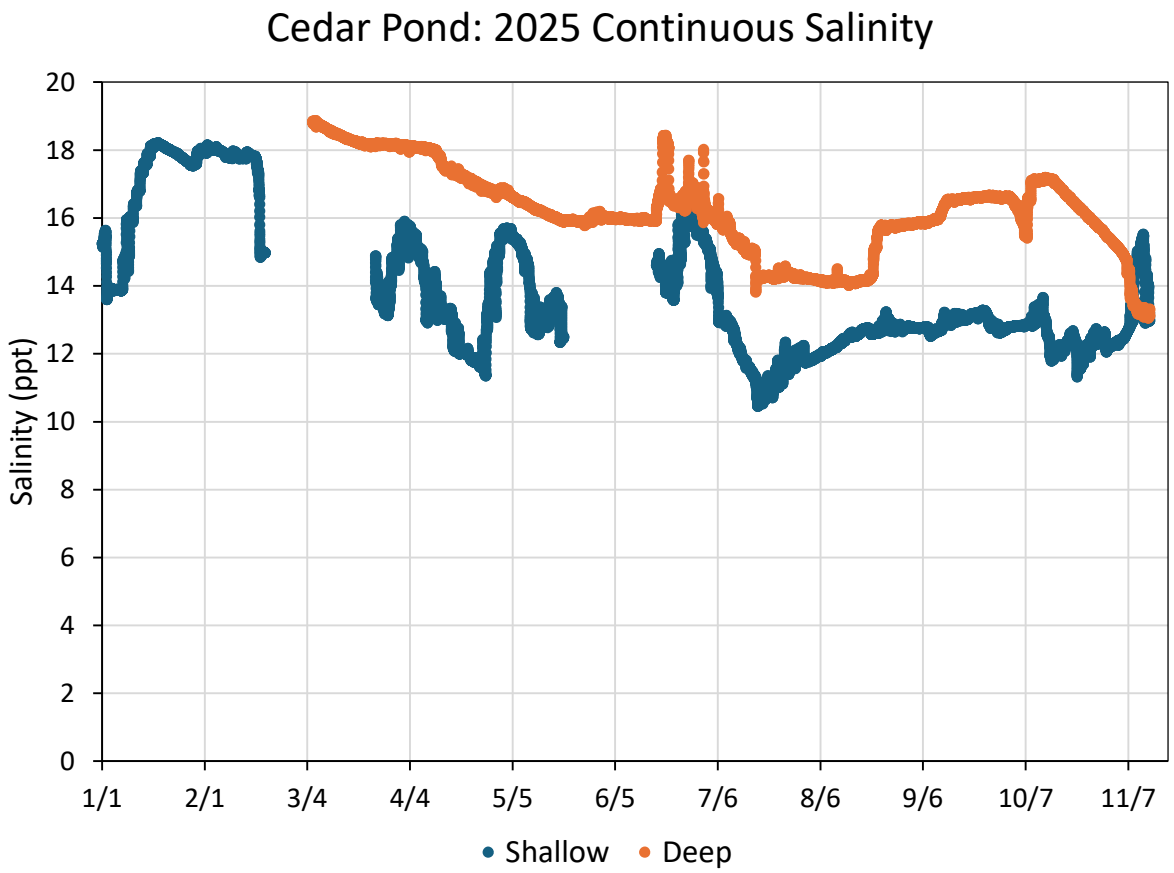


Figure III-9. Cedar Pond 2025: Continuous Sensor Salinity. Continuous 2025 salinity readings generally decreased throughout the deployment period (January-early November). The high salinity levels January-March were likely due to low groundwater inputs driven by exceptionally low groundwater levels. As the deployment period progressed, groundwater levels moved closer to seasonal average conditions and corresponding salinity levels decreased. Average shallow salinity in January and February were 16.8 ppt and 17.6 ppt, respectively, while average shallow salinity in July and August were 12.3 ppt and 12.4 ppt, respectively. As would be expected because of how tidal inputs sink to the bottom, deep salinities were generally higher than shallow levels, but also decreased as groundwater inputs increased. Average deep salinity in March and April were 18.3 ppt and 17.5 ppt, respectively, while average deep salinity in July and August were 15.0 ppt and 14.6 ppt, respectively. The shallow and deep salinity readings were generally sufficiently different to prevent mixing between the two depths.

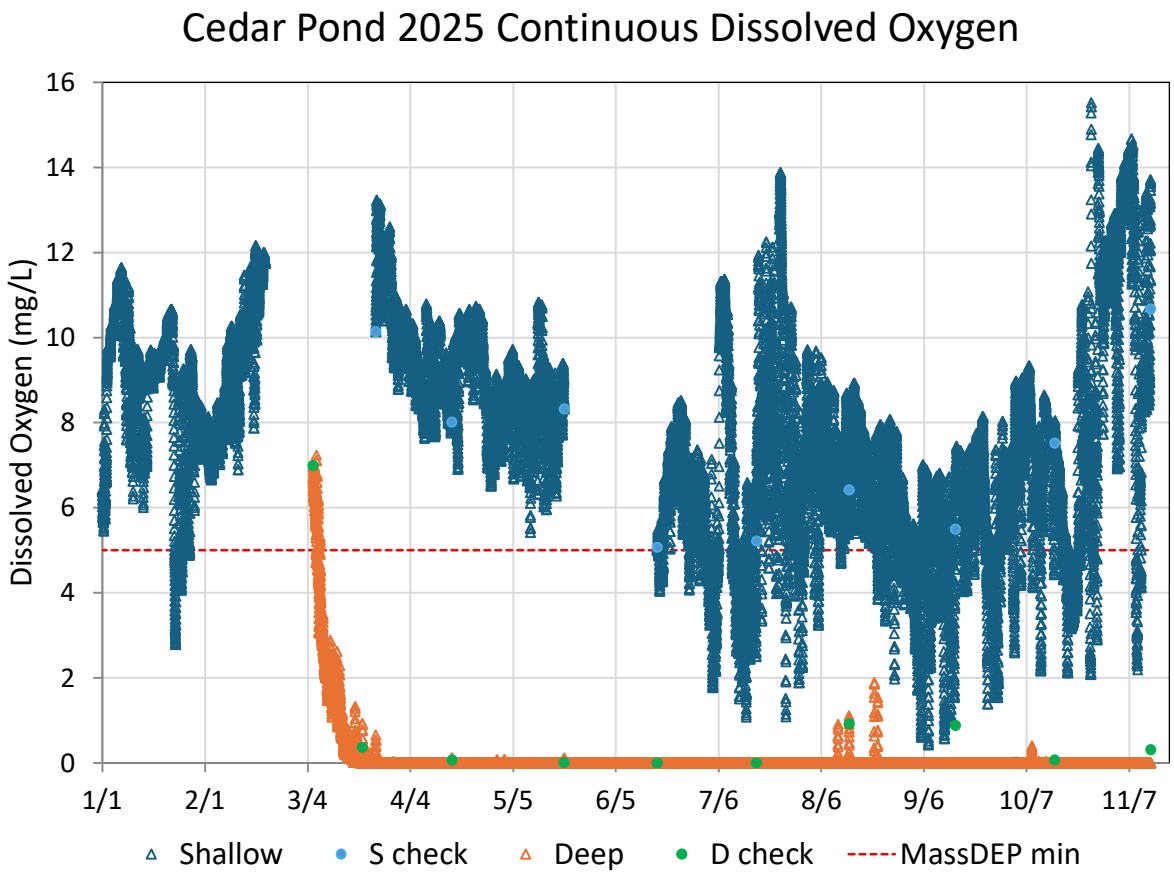


Figure III-10. Cedar Pond 2025: Continuous Sensor Dissolved Oxygen. Continuous 2025 DO readings showed that shallow levels through mid-May were mostly greater than the MassDEP minimum, but much more variable with regular occurrences of levels less than the MassDEP minimum (red dashed line) from mid-June through early November when the devices were removed. Deep DO levels were mostly anoxic except for early March, which also matched the monthly water column DO profile on March 5, which had DO readings at all depths that were greater than the MassDEP minimum. Deep DO levels decreased from 7 mg/L on March 5 when the temperature was 4°C to <1 mg/L DO on March 12 (*i.e.*, anoxic levels), when the temperature was 5.2°C. The increased variability in shallow DO levels in the latter half of the year would be consistent with more active phytoplankton population during the summer. Review of daily summer DO patterns show complex variability with some indication of diurnal patterns (*i.e.*, lower DO at night compared to higher levels during the day), but variability likely related to daily tidal changes.

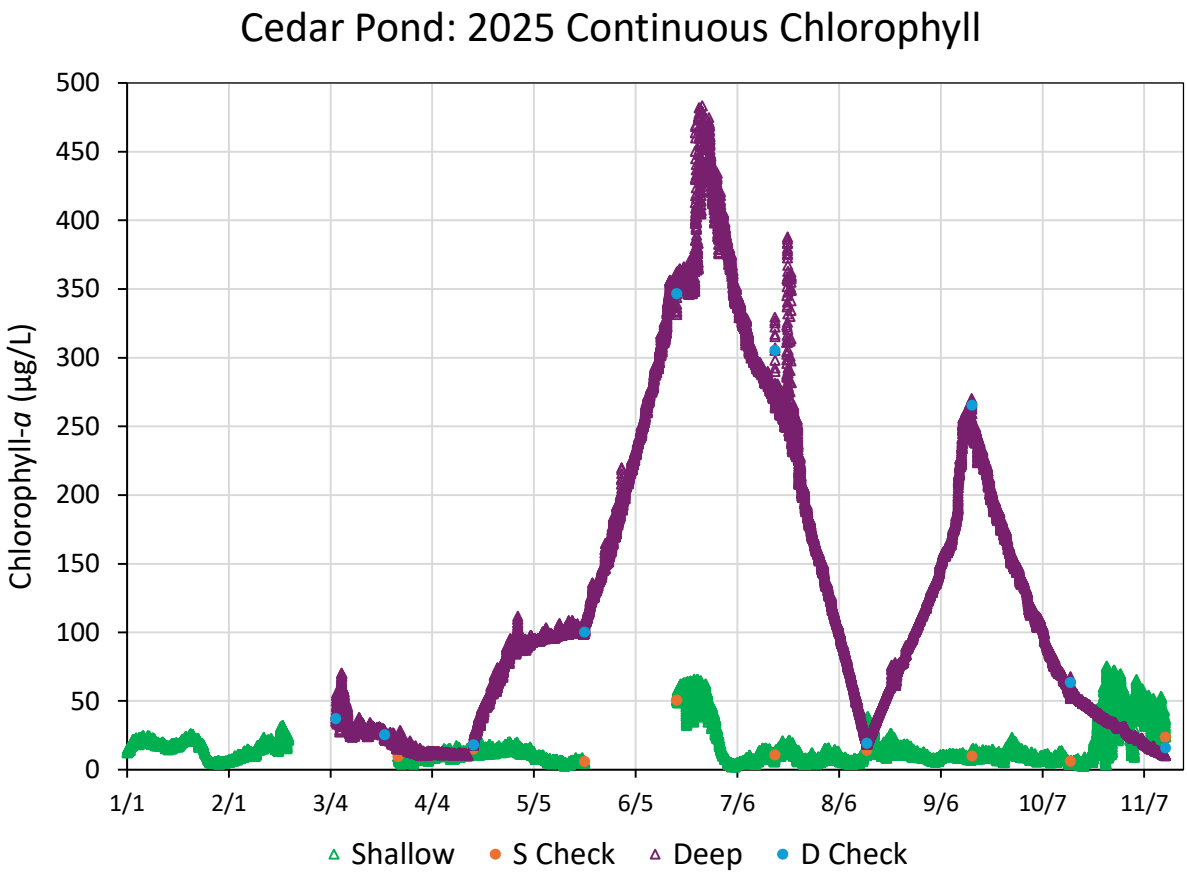


Figure III-11. Cedar Pond 2025: Continuous Sensor Chlorophyll-a. Continuous 2025 chlorophyll-a readings were very high throughout the year with a high baseline (approximately 7 to 15 µg/L) and occasionally much higher levels indicating blooms. Monthly shallow chlorophyll-a averages ranged from 7.8 µg/L (March) to 49.3 µg/L (June) with an overall average of 15.8 µg/L over the entire deployment period. June shallow readings were somewhat truncated because battery failure, but the high shallow levels were reinforced by exceptionally high deep levels. Deep readings began to increase in mid-April and peaked on June 24 at 483 µg/L; this pattern suggests phytoplankton growth was likely occurring at depths greater than Secchi clarity. PAR (Photosynthetically Active Radiation) light readings have shown that sufficient light for plant growth can occur at 2.4X Secchi readings in clear water, which would mean there was sufficient light for phytoplankton growth deeper than the shallow sensor.

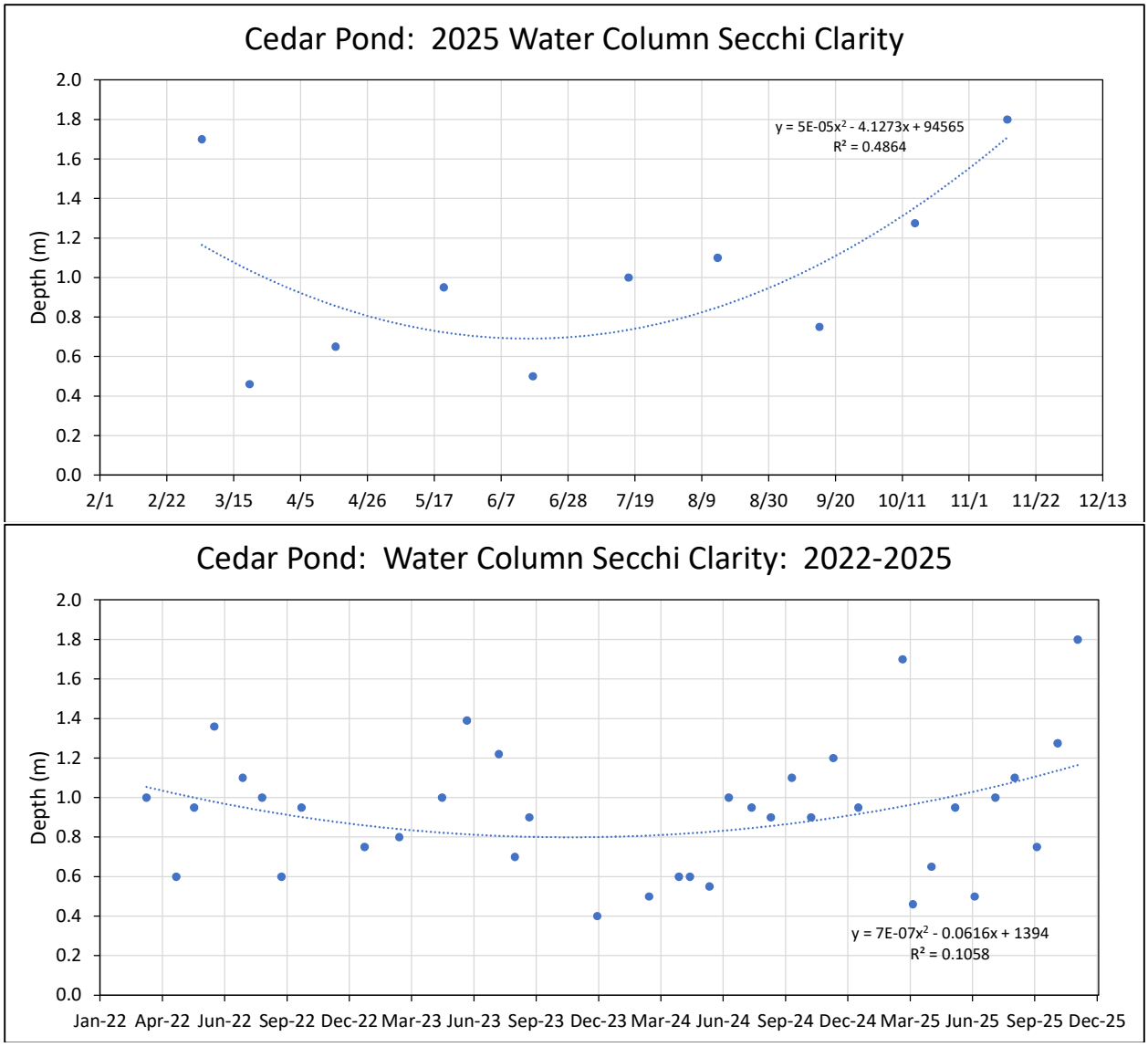


Figure III-12. Cedar Pond Water Column Secchi Clarity: 2025 and Recent Historical (2022-2025). Secchi clarity was at its 2025 maxima in early March and mid-November. Between April and September 2025 clarity averaged 0.8 m with a range 0.5 m to 1.1 m. Secchi clarity has been relatively stable over the past four years: the overall 2022-2025 average was 0.92 m, while the overall April-September 2022-2025 average was 0.89 m.

III.A.3. Cedar Pond Water Column: 2025 Laboratory Assay Water Quality Results

Water quality samples were collected in tandem with the 2025 water column profile readings. Water samples were generally collected at shallow, middle, and deep depths; average depths of these samples in 2025 was 0.4 m, 1.5 m, and 3.1 m, respectively. The middle and deep depths approximate the average depths of the continuous recorders. All collected samples were assayed at the Coastal Systems Analytical Facility at SMAST using the same assays that have been utilized for all historical Cedar Pond samplings, MEP assessments, and Town estuary monitoring. Sampling procedures and chemical assay methods were the same as presented in the Town's QAPPs for freshwater[28] and estuarine[29] water quality monitoring. Samples were analyzed at the laboratory for the following constituents: salinity, ortho-phosphorus, total phosphorus (TP), ammonia-nitrogen, nitrate+nitrite-nitrogen (NOx), dissolved organic nitrogen (DON), particulate organic nitrogen (PON), particulate organic carbon (POC), chlorophyll-*a*, pheophytin-*a*, and specific conductivity.

Water quality samples in 2025 generally showed that average concentrations for all parameters had no significant statistical difference ($\rho<0.05$, T test) between shallow and middle depths, but most of the deep averages were statistically different from shallow and middle depths. This finding was consistent with the notable impact of sediments on dissolved oxygen levels noted previously, as well as the regular temperature and salinity stratification between shallow and deep portions of the water column. This condition was also similar to conditions measured in 2023 and 2024.

All 2025 TN and TP concentrations showed that Cedar Pond continued to have excessive nutrients (**Figure III-13**), as it also was in all seven previous annual assessments (2018-2024). However, April to October 2025 TP averages at all depths were lower than 2023 and 2024 levels and approximated levels in 2022, which were the lowest levels of the previous years (**Figure III-14**). April to October middle TN average approximated most of the corresponding averages from previous years, but the shallow (0.8 mg/L) and deep averages (1.9 mg/L) were the lowest of any of the years since the start of the Management Plan implementation. While these lower average levels are encouraging, they were not outside of a reasonable range for the variability of the readings from the previous years.

Review of 2025 N:P ratios showed that Cedar Pond was phosphorus-sensitive in the spring (March), but slowly transitioned to nitrogen-sensitive conditions, often with large sensitivity differences between various water column depths (**Figure III-15**). In the March 5 profile, N:P ratios at all depths were 27 or greater, above the Redfield ratio (16) threshold. In the March 20 profile, the shallow N:P ratio increased to 39 and the middle depth ratio was approximately the same as March 5 (36), but the deep ratio decreased to 20. In April, ratios decreased at all depths, but maintained the pattern of a higher ratio in shallow waters. After June, all ratios throughout the water column were nitrogen-sensitive (*i.e.*, ratios less than 16). These shifts also occurred in 2023 and 2024 and continue to suggest that sediment phosphorus inputs increase relative to

[28] Town of Orleans Ponds and Lakes Monitoring Program, Quality Assurance Project Plan, 2024-2027. June 2024. Prepared by Town of Orleans Marine and Fresh Water Quality Committee and Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. 51 pp.

[29] Town of Orleans Estuary Monitoring Quality Assurance Project Plan: Namskaket, Little Namskaket, Rock Harbor, Nauset, and Upper Pleasant Bay. 2006. Howes, B. and R. Samimy, School for Marine Science and Technology, University of Massachusetts Dartmouth and Town of Orleans. 50 pp.

nitrogen inputs during the summer. Review of ortho-P and DIN levels (not shown) showed that shallow ortho-P concentrations more than doubled after June, but DIN levels were relatively stable, indicating comparatively greater sediment P inputs. The N:P ratio shifts also suggest that management of water quality conditions should continue to have an adaptive water quality monitoring component to ensure that steps to reduce nutrient loads achieve sustainable and acceptable water quality conditions. It is unclear what sort of impact these relatively rapid changes in nutrient control might have on which species are favored in the phytoplankton population.

As would be expected given the higher nutrient concentrations, water column pigment concentrations were also elevated in 2025, but shallower readings were less than in 2024 (**Figure III-16**). Average shallow and middle 2025 chlorophyll-a concentrations were similar (9.3 µg/L and 12.6 µg/L, respectively), while the deep readings were approximately 10X higher (average = 109 µg/L). This pattern was consistent with the continuous recording which suggested that a large portion of water column phytoplankton growth was occurring between 1.2 m and 2.8 m (**see Figure III-11**). In 2024, the average 0.5 m, 1.5 m, and deep chlorophyll-a concentrations were similar throughout the water column: 19.4 µg/L, 23.9 µg/L, and 23.7 µg/L, respectively. Review 2025 chlorophyll to pheophytin ratios generally support the idea of growth throughout most of the water column with deep ratios were between 0.75 and 1 between May and October, indicating active growth rather than senescence.

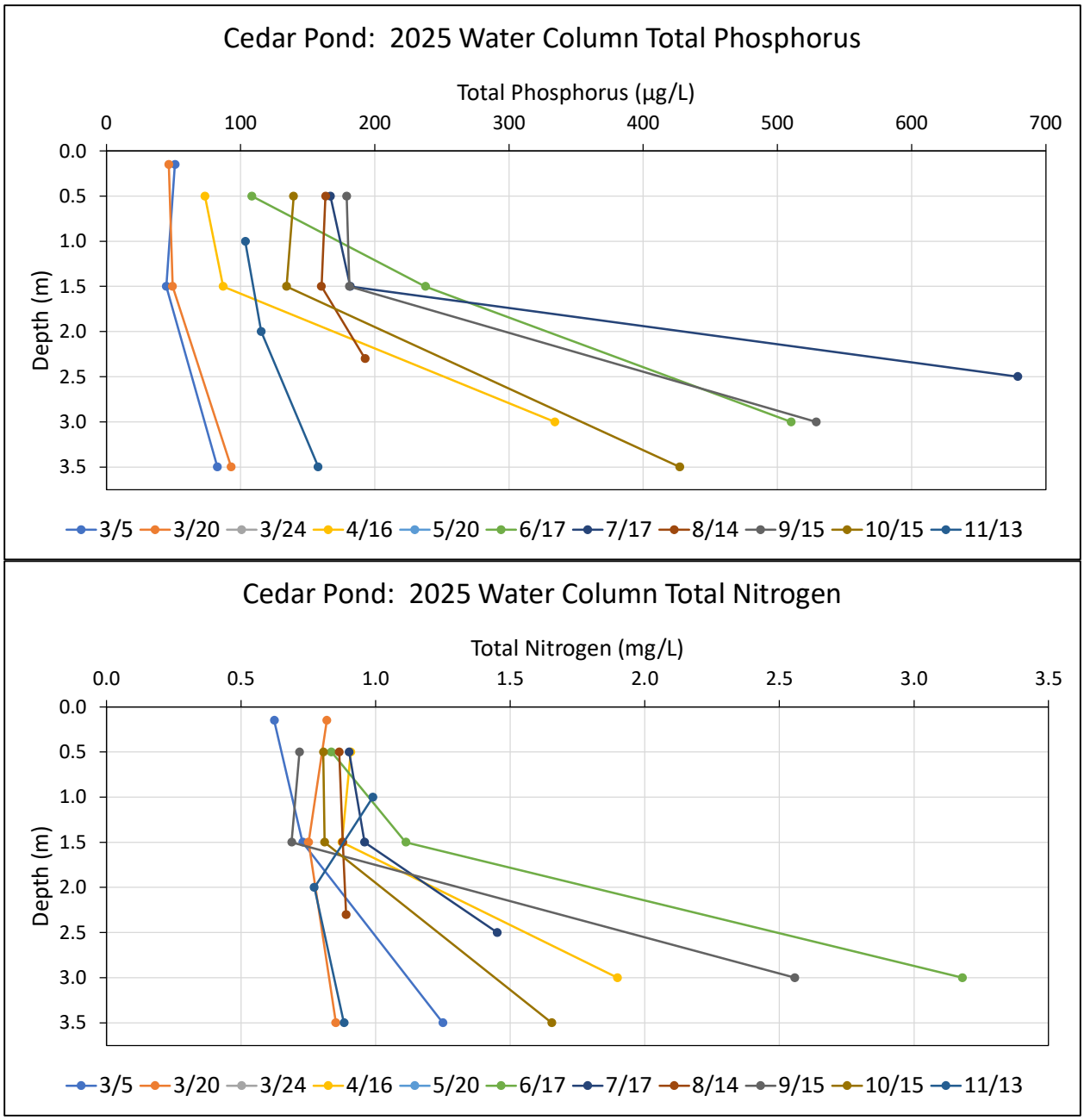
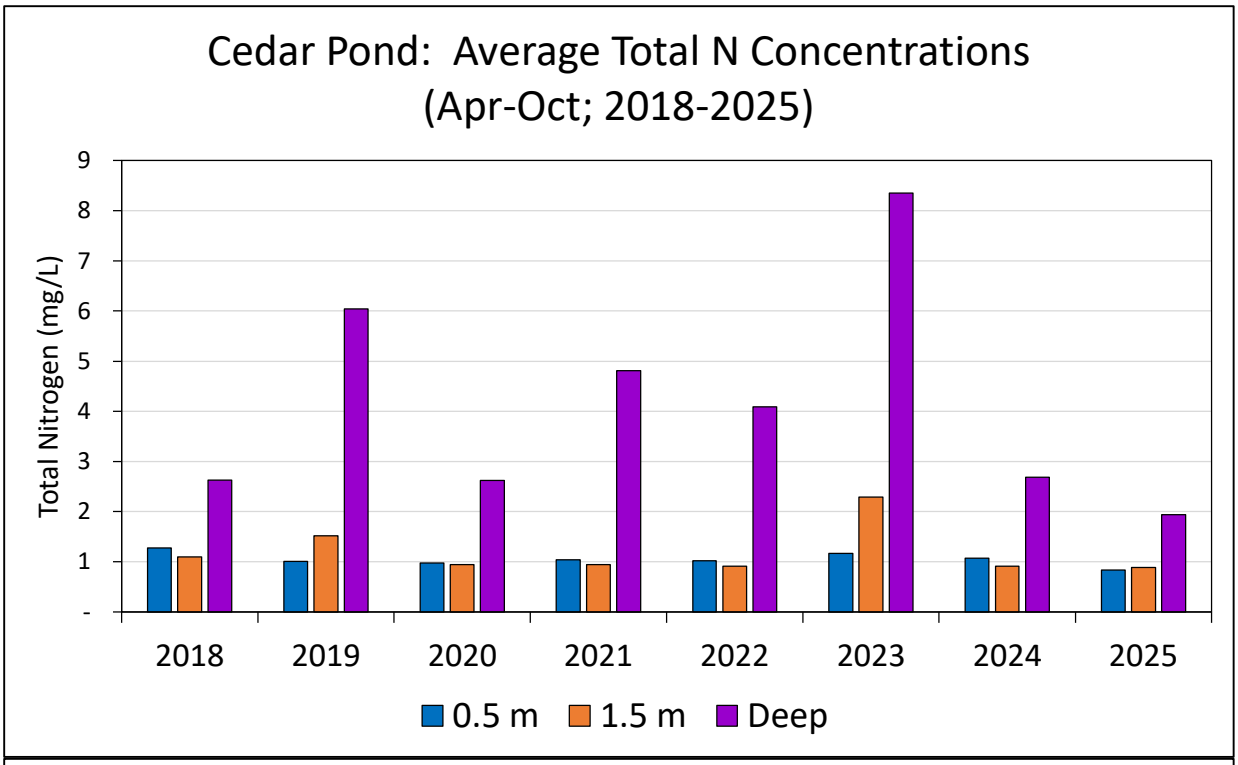


Figure III-13. Cedar Pond 2025 Water Column Total Phosphorus and Total Nitrogen Concentrations. TP and TN concentrations were elevated at all depths throughout 2025, just as they have been for all seven previous annual assessments (2018-2024), but TP concentrations were lower than 2023 and 2024 levels. Shallow and middle depth TP concentration began 2025 near 50 µg/L and then gradually increased throughout the summer, reaching a peak of approximately 180 µg/L in September. Deep TP readings began to increase in April, rising from approximately 90 µg/L in March to more than 300 µg/L. Shallow TN concentrations were relatively stable, in a range from 0.72 mg/L to 0.91 mg/L between April and October. Deep TN concentrations ≥3 m were generally greater than 1.6 mg/L and peaked at 3.2 mg/L. The summer increases in deep TN and TP concentrations continue to reinforce that attaining acceptable water quality throughout the Cedar Pond water column will require management of sediment nutrient additions.



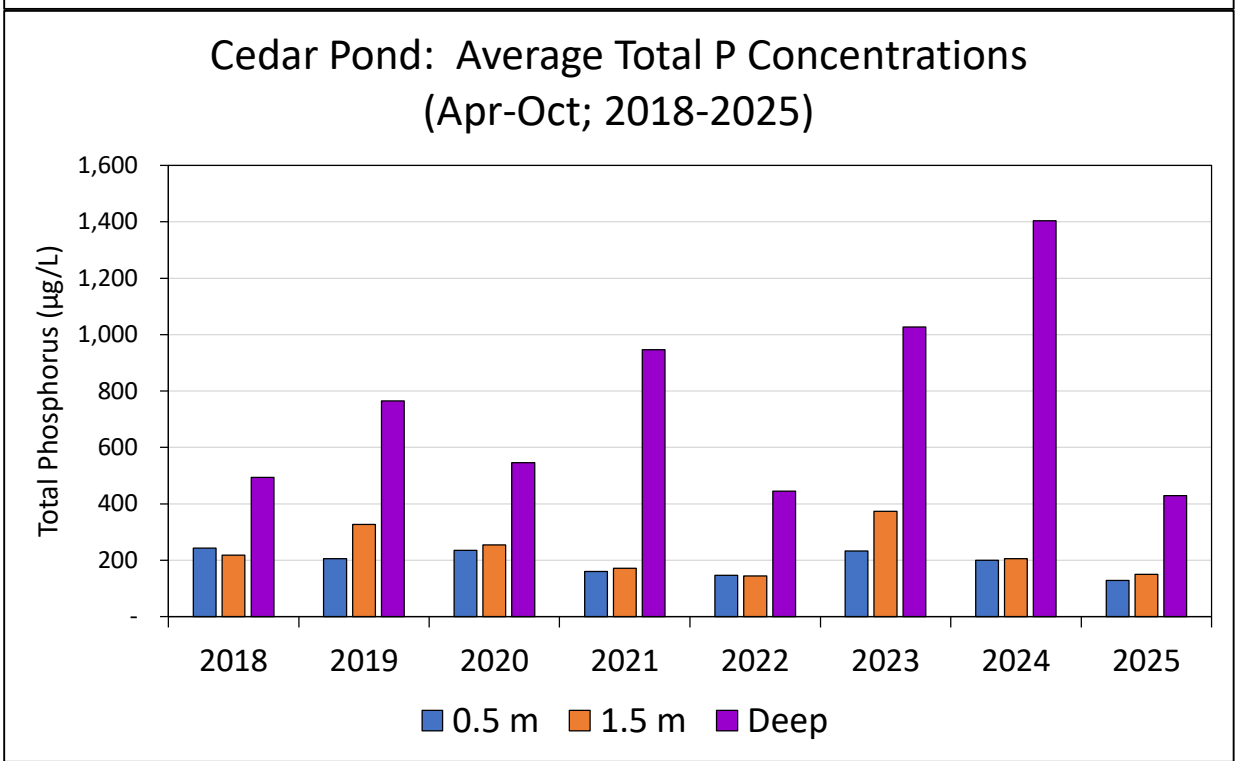


Figure III-14. Comparison of Average Water Column Total Phosphorus and Total Nitrogen in Cedar Pond (2018-2025). April to October 2025 TP averages at all depths were lower than 2023 and 2024 levels and approximated levels in 2022, which were the lowest levels of the previous years. April to October middle TN average approximated most of the corresponding averages from previous years, but the shallow (0.8 mg/L) and deep averages (1.9 mg/L) were the lowest of any of the years since the start of the Management Plan implementation. While these lower average levels are encouraging, they were not outside of a reasonable range for the variability of the readings from the previous years.

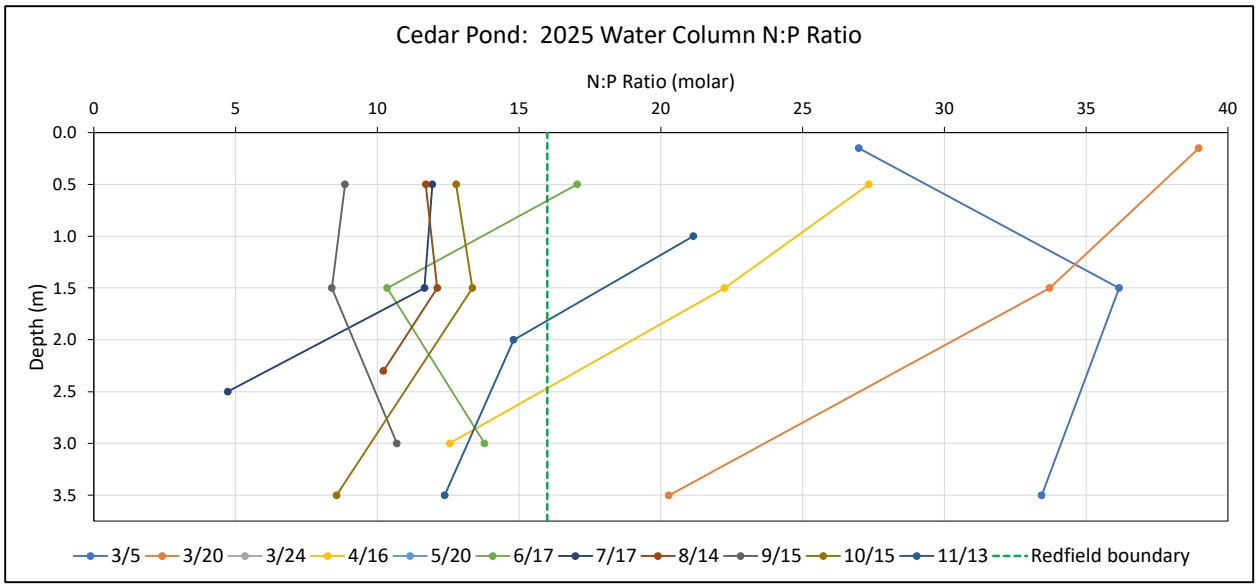


Figure III-15. Cedar Pond 2025 Water Column N to P ratio. Review of 2025 N:P ratios showed that Cedar Pond was phosphorus-sensitive in the spring (March), but slowly transitioned to nitrogen-sensitive conditions, often with large sensitivity differences between various water column depths. In the March 5 profile, N:P ratios at all depths were 27 or greater, above the Redfield ratio (16) threshold. In the March 20 profile, the shallow N:P ratio increased to 39 and the middle depth ratio was approximately the same as March 5 (36), but the deep ratio decreased to 20. In April, all ratios decreased, but maintained the pattern of a higher ratio in shallow waters. After June, all ratios throughout the water column were nitrogen-sensitive (*i.e.*, ratios less than 16). These shifts also occurred in 2023 and 2024 and continue to suggest that sediment phosphorus inputs increase at a greater rate than nitrogen inputs during the summer.

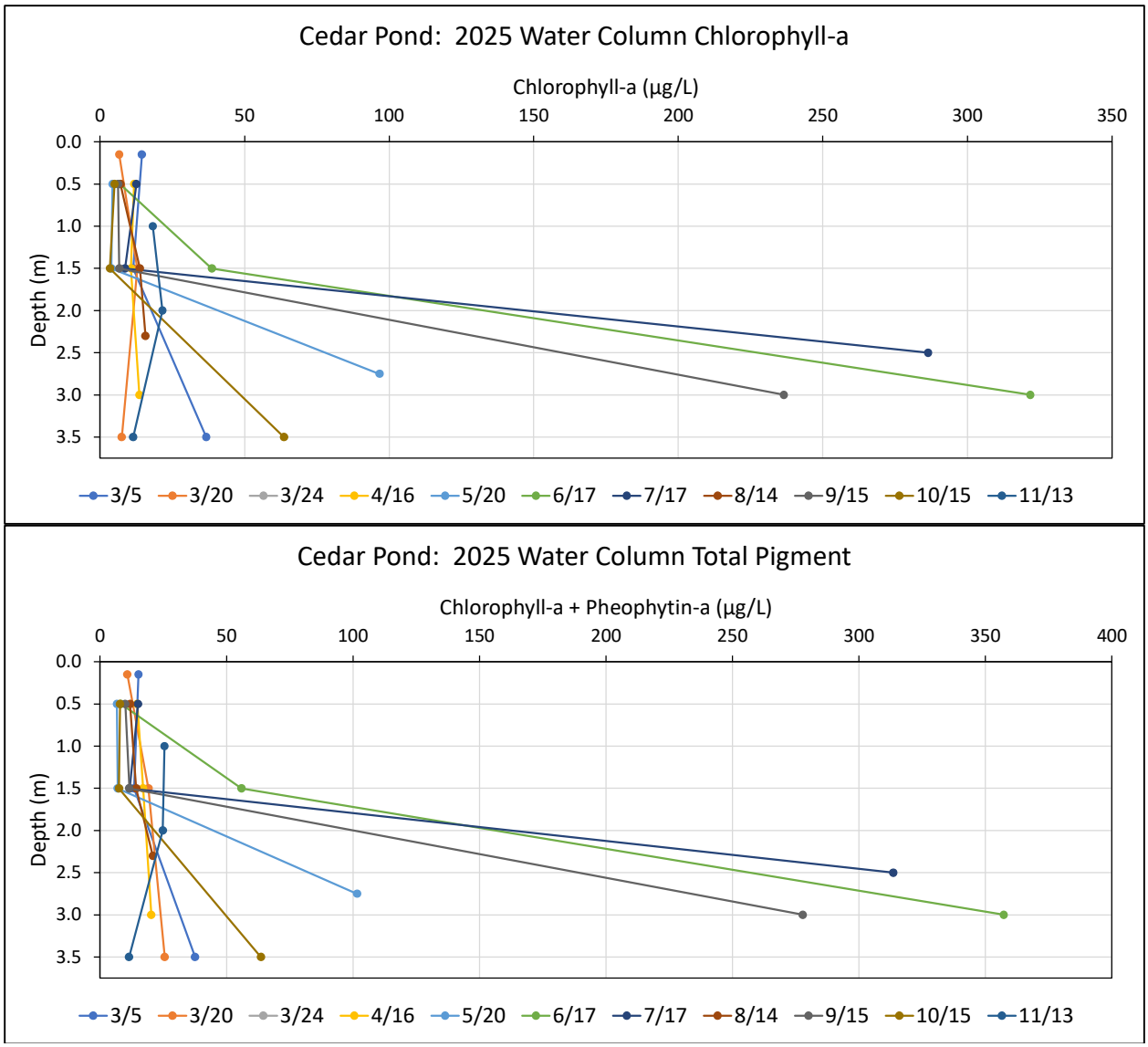


Figure III-16. Cedar Pond 2025 Water Column Chlorophyll-a and Total Pigments. Average shallow and middle 2025 chlorophyll-a concentrations were similar (9.3 µg/L and 12.6 µg/L, respectively), while the deep readings were approximately 10X higher (average = 109 µg/L). This pattern was consistent with the continuous recordings, which suggested that a large portion of water column phytoplankton growth was occurring between 1.2 m and 2.8 m. Review 2025 chlorophyll to pheophytin ratios generally support the idea of growth throughout most of the water column with deep ratios were between 0.75 and 1 between May and October, indicating active growth rather than senescence.

III.A.4. Cedar Pond Creek: 2025 Flow, Water Levels and Water Quality Monitoring

Streamflow has been measured in Cedar Pond Creek at the same location continuously since November 2017 (*i.e.*, just north of Route 6; see **Figure I-1**). This is the same location used during the: a) 2003-2004 streamflow measurements for the MEP assessment of Rock Harbor,[30] b) 2012 streamflow measurements for the development of the Cedar Pond Management Plan,[31] and c) throughout annual implementation of the Management Plan in 2018-2025. In addition to continuous stage readings and low tide instantaneous outflow readings at this location, water quality samples have also been regularly collected. Collecting stream data at the same location both continuously and at regular intervals and using the same measurement methods has allowed data from the various time periods to be directly comparable and provide a good basis for measuring any changes that are occurring in Cedar Pond.

During 2025, low tide instantaneous flow readings and water quality samples were collected 17 times: once a month during January, October, November, and December and mostly twice a month during the remaining months (**Figure III-17**). Flow readings in 2025 averaged 0.021 m^3/s with the highest flows of 0.052 m^3/s recorded on both May 2 and May 20. July through September 2025 flows averaged 0.007 m^3/s, which was similar to averages during this portion of the year in all previous 2020-2025 years flows except for 2021, which had the highest recorded flow over the whole period of record on September 10. Continuous stage readings at the same location where instantaneous flow readings were collected showed that outflow at low stage was relatively stable except for a period during July and August when flow was minimal (**Figure III-18**).

Average monthly total nitrogen (TN) exported from Cedar Pond in 2025 was 1.46 kg/d (**Figure III-19**). Review of each 2025 month showed that six of the 12 months with three during the summer (May-September) had TN exports lower than the 1.1 kg/d measured in 2002/2003 for during the Rock Harbor MEP assessment.[32] Review of historical TN export showed that 2018 had no monthly TN export rates less than the MEP rate and 2023 had the maximum number of months (10) less than the MEP rate (**Figure III-20**). The 2023 average monthly rate of 0.82 kg/d was the lowest measured in the 2018-2025 monitoring period. During the May-September summer, the maximum number of months less than the MEP rate was four months (out of 5) in 2020, 2022, and 2023. These counts were an improvement of the 2018 and 2019, when none of the summer months were less than the MEP rate. Average monthly total phosphorus (TP) export in 2025 was 0.22 kg/d compared to a minimum of 0.09 kg/d in 2022 and a maximum of 1.55 kg/d in 2018.

Review of the TN export rates showed that Cedar Pond has generally met the goal of returning TN export to 2002/2023 levels. TN export have varied, but average monthly levels have been less than 1.5 kg/d since 2022 with 5 to 10 months each year less than the 2002/2003 MEP level. Three to four summer months have also been less than the MEP levels since 2020. Cedar Pond was still impaired during these years, but the Management Plan goal of reducing TN exports to those matching the MEP levels has largely been met.

[30] Recording from June 28, 2002 to May 23, 2004, 23 month deployment

[31] Recording from June 5 and September 20, 2012, 3 month deployment, documented in Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan.

[32] Howes B., S. Kelley, J. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2008.

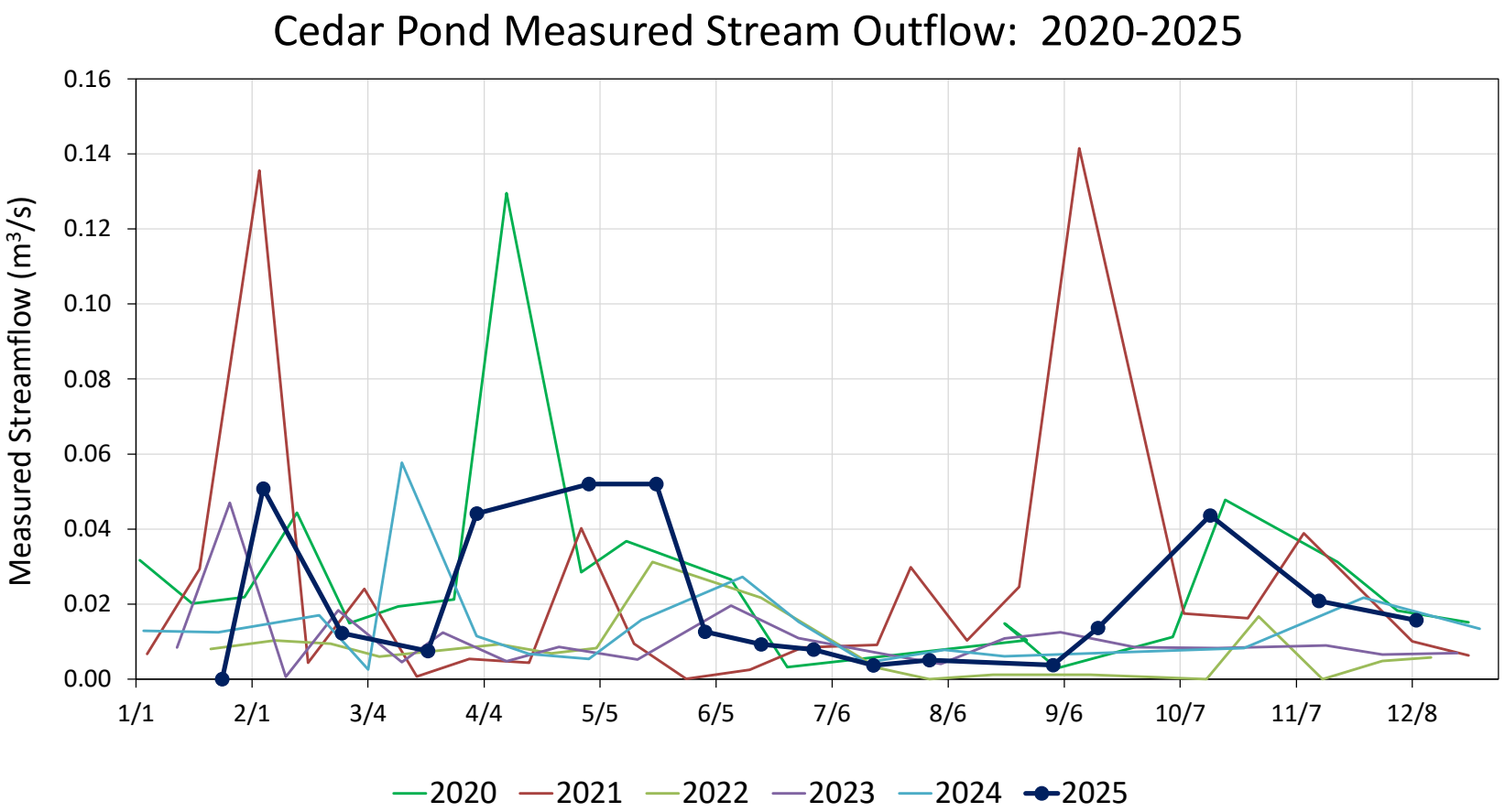


Figure III-17. Cedar Pond Creek 2025 Instantaneous Streamflow (2020-2025). Low tide instantaneous flow readings and water quality samples were collected 17 times during 2025: once a month during January, October, November, and December and mostly twice a month during the remaining months. Average 2025 flow was 0.021 m^3/s with the highest flows of 0.052 m^3/s recorded on both May 2 and May 20. July through September 2025 flows averaged 0.007 m^3/s, which was similar to all previous flows during the 2020-2025 period except for 2021, which had the highest recorded flow over the whole period of record on September 10.

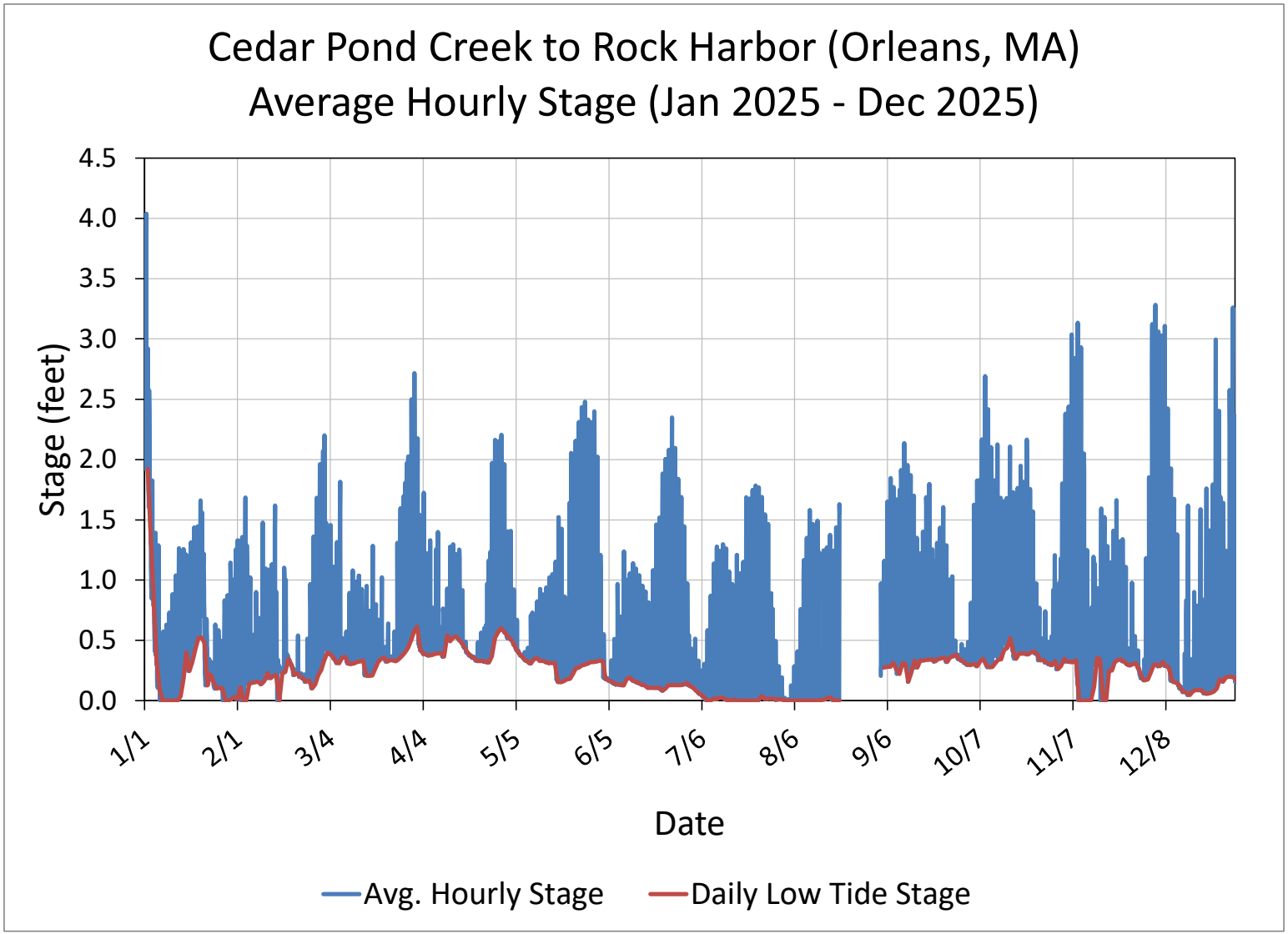


Figure III-18. 2025 Cedar Pond Creek Average Hourly Continuous Stage Record. Stage readings were recorded every ten minutes then averaged each hour at the same location in the creek where measurements have been collected since 2002. Low tide stage was when instantaneous flow readings were collected and represent outflow from Cedar Pond. Stage readings show that maximums and minimums varied by season and month. Minimal discharge was recorded for an extended period in July and August, which was consistent with instantaneous flow measurements, but was also noted in briefer periods in January, February, and November.

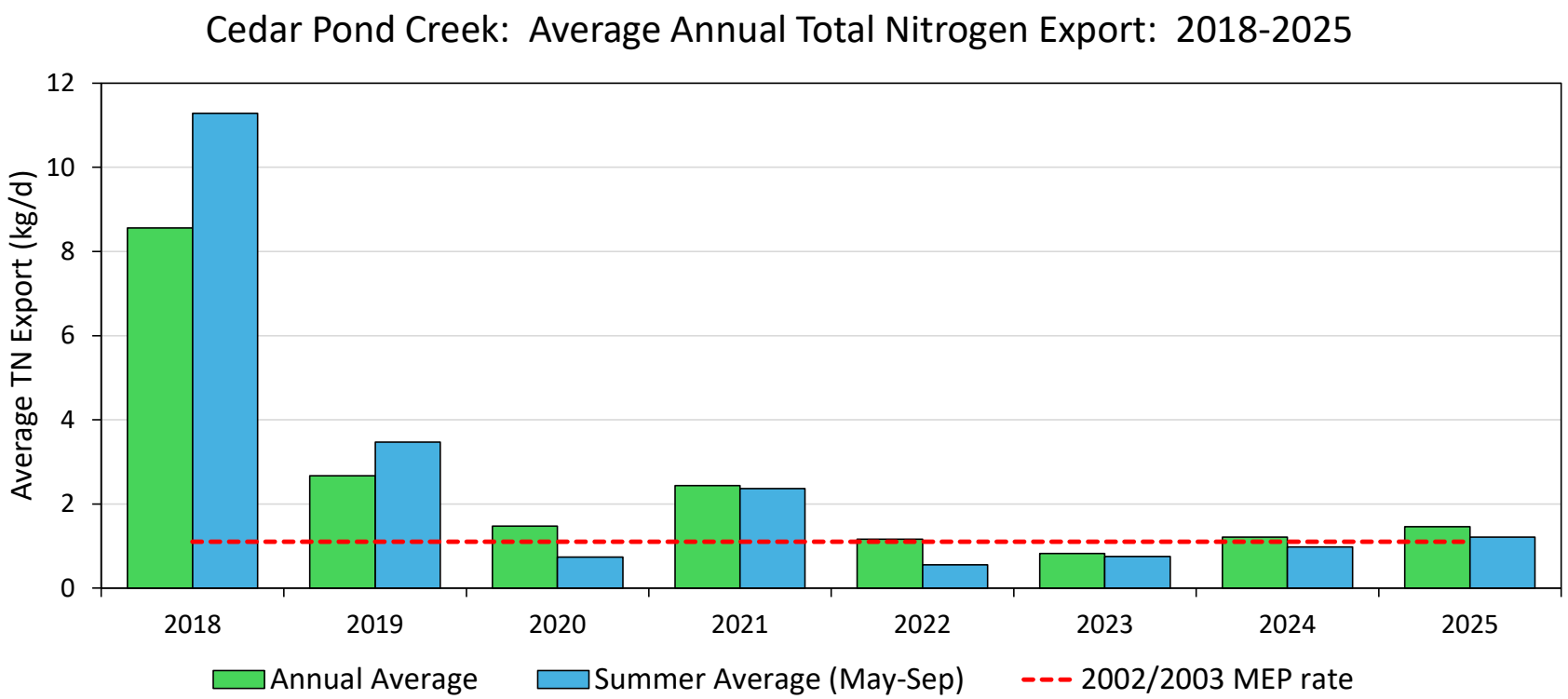


Figure III-19. Cedar Pond Creek Average Annual Monthly TN export (2018-2025). Average monthly total nitrogen (TN) exported from Cedar Pond in 2025 was 1.46 kg/d with a monthly range of 0.31 kg/d (August) to 3.57 kg/d (April). The 2025 average was slightly higher than the 2024 average (1.21 kg/d). The 2025 summer (May-September) average export was 1.21 kg/d, which was higher than the 0.97 kg/d in 2024. Maximum and minimum annual averages since 2018 were 8.56 kg/d (2018) and 0.82 kg/d (2023), respectively. Maximum and minimum summer averages since 2018 were 11.29 kg/d (2018) and 0.55 kg/d (2022), respectively. Among the annual averages since 2018, only 2023 (0.82 kg/d) had a TN export lower than the 2002/2003 MEP measurements (1.1 kg/d) that were the basis of the MEP Rock Harbor assessment (Howes and others, 2007). The MEP assessment calculated a 58% natural nitrogen attenuation/removal by Cedar Pond based on its watershed nitrogen loading.

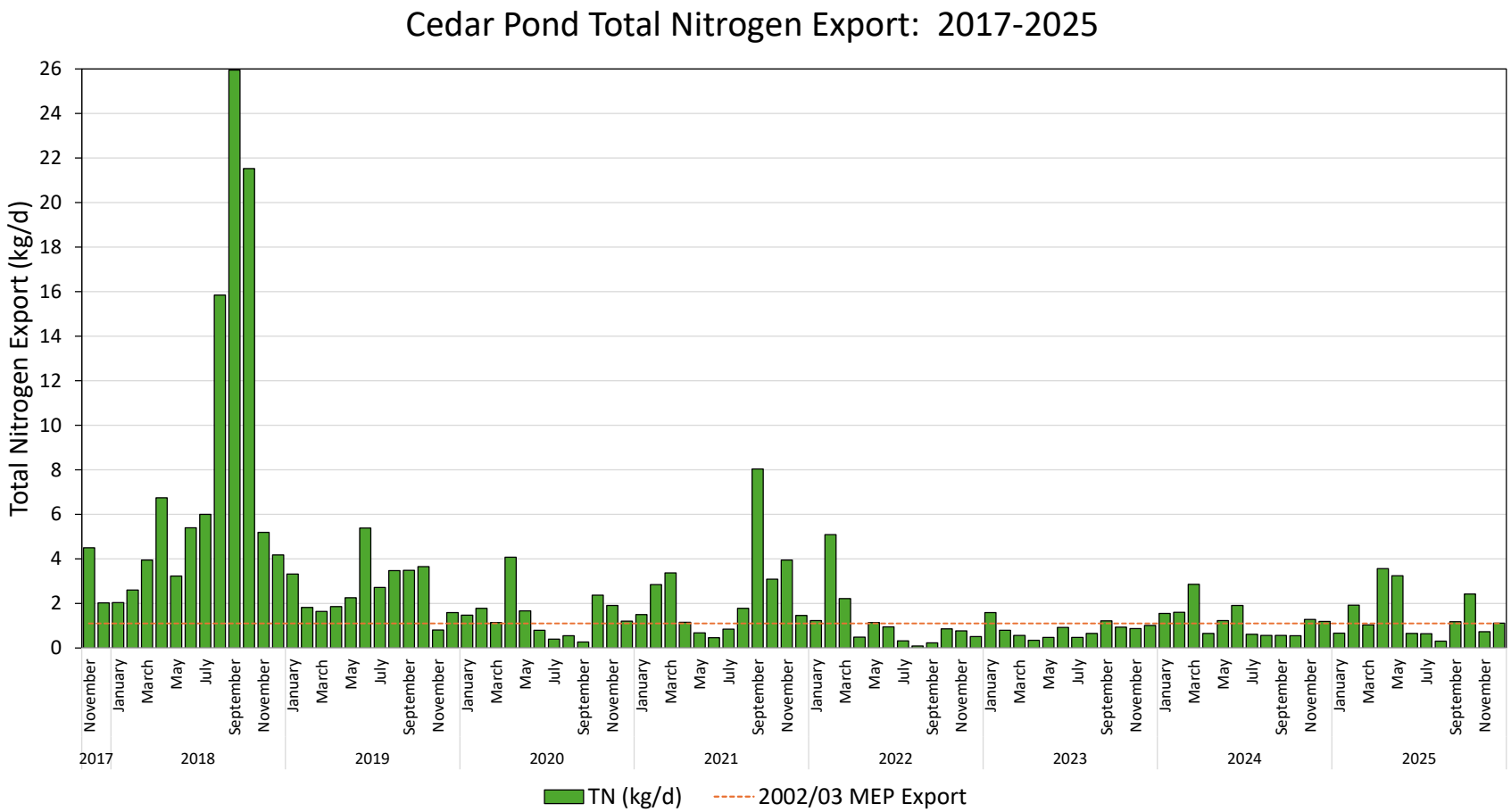


Figure III-20. Cedar Pond Creek Average Monthly TN export (2018-2025). Monthly TN export from Cedar Pond has been estimated since late 2017. Comparison of the monthly export to the 2002/2003 MEP average export (1.1 kg/d) showed that 2023 had the maximum number of months less than the MEP average (10 months), while 2018 had no months less than the MEP average. Six of the 12 months in 2025 had TN exports that were less than the MEP average with three of the six occurring during the summer (May-September).

III.B. Cedar Pond Outlet: Board Height and Water Levels

Boards were reinstalled at the Cedar Pond outlet as a strategy to gradually lower the salinity in the pond by enhancing the impact of natural watershed inputs. This approach was based on review of historical water quality data that showed that when Cedar Pond had lower salinity (7 to 11 ppt) conditions were impaired, but were more impaired in 2012 when salinity was 21 to 23 ppt.[33] The reinstalled boards would allow only the highest tides into the pond, while also allowing continuous natural watershed groundwater inputs to gradually lower pond salinities. Water quality measurements in previous years (2018-2024) showed that water quality conditions were much improved from those in the high salinity conditions in 2012, but the regular lowering of the boards during the summer to address the goals of the Fishway Plan also regularly increased the pond salinity. Reviews of past years also showed that higher winter board heights decreased spring salinity, starting the year at a lower salinity concentration, and keeping summer salinities lower. Further review of board heights and water salinity readings seemed to suggest that while the boards prevented the return to salinities in the low 20's ppt, the seasonal decrease in summer groundwater levels may also have been a contributing factor to the annual increase in summer salinities.

As noted above, 2025 began the year with higher salinity levels that any of the previous years (**see Figure III-9**). Groundwater levels during this period were exceptionally low with February setting a new all-time monthly minimum for records that extend back to 1976 (**see Figure III-3**). Groundwater levels in January through April 2025 were below the long-term average and lower than any of the previous years since the beginning of Management Plan monitoring in 2018. However, review of board heights also showed that the elevation of the boards at the outlet during the 2024/2025 winter were set at the lowest elevation recorded among all readings between 2017 and 2025 (**Table III-1**). Water levels at the outlet between February 1 and May 15 were almost all greater than the board height (**Figure III-21**) and shallow salinities were 18 ppt before gradually decreasing during the rest of the year (**see Figure III-9**).

The low board heights during the 2024/2025 winter apparently were due to vandalism of the outlet boards. During the data review for this Annual Report, the Town log of board heights showed they were last adjusted in 2024 on May 15 and were not revisited until March 15, 2025. Subsequent discussions with Town staff showed all the boards were removed between November 2024 and March 2025. Town staff will now regularly visit the boards monthly and CSP/SMAST staff will continue to use the GPS RTK to collect board elevations during each water quality run. Town staff will also evaluate options to secure the boards at the outlet. CSP/SMAST field staff will regularly report the recorded board elevations to senior CSP/SMAST staff.

The Fishway Plan was initially established in 2017 to have at least 6 inches (0.15 m) of water depth over the boards from March 15 to June 30 and 2 inches over the boards (0.05 m) from July 1 through November 15. Over the years of water level monitoring at the outlet, the board elevations and configurations have been altered to increase the original heights and add a 6 inch notch to the boards to try to maintain lower salinity water in Cedar Pond. Town staff added a 6 inch notch on March 15, but because the overall elevation was so low, almost all water level readings were greater than the opening elevation Because the boards were at such a low elevation in early 2025, 99.9% of the 14,376 water level elevations between February 4 (when

[33] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan.

the logger began recording) and May 15 (when the notch was removed and the overall board elevation was raised) were greater than the board elevation. Approximately 28% of the water level readings were 6 inches above the board elevation. After the board was raised on May 15, its elevation was not adjusted during the rest of 2025.

On May 15, the outlet board elevation was increased to 1.64 m, which was similar to past years since 2021, and this elevation was maintained through the end of 2025. During the Fishway Plan July 1 through November 15 period for young of the year to leave, water levels were 2 inches above the boards in 1.6% of the readings. More refined review of the readings during the 184 days between May 15 and November 15 showed that 62 days had water levels greater than the board elevation. Closer review of these occurrences showed that they tended to be grouped around spring tides, occurring approximately daily during clusters of 6 to 7 days. Water levels were greater than the board elevation for 1.5 hours on average, but had a range of 0.2 hours to 3.3 hours. Average elevation over the boards was 2.03 inches, while the average maximum was 3.22 inches with a range of 0.07 inches to 10.84 inches.

Collectively, these data show that the water levels over the boards were determined by both the elevation of the boards and the elevation of the pond. Groundwater levels were historically low early in 2025 (**see Figure III-3**), but so was the outlet board elevation. Even in this setting, when the board height was largely inconsequential, only 28% of the water level readings were 6 inches greater than the board height. This finding reinforces management decisions previously agree to among the Town and DMF that the spring board elevations could be higher and still meet the goals of the Fishway Plan.

These findings also reinforce the importance of maintaining higher board elevations during the winter. Salinity levels were near 18 ppt in January/February 2025, but decreased throughout the year. It has been difficult to synthesize the available data to definitively separate the impact of groundwater discharge and tidal inputs on salinity levels, but past monitoring has shown that lower winter salinities have occurred when board heights were higher. However, these have also occurred when groundwater levels have generally been above average. In 2025, groundwater levels in the first quarter of the year were well below average (the February reading was a new historical low), but the board height was also low. Once groundwater levels returned to seasonal averages in late summer, shallow salinity levels had returned to 12 to 13 ppt.

Table III-1. Cedar Pond Board Height Log: 2020-2025. During 2020-2025, Town staff adjusted the board elevations according to the Fishway Operations and Maintenance Plan (source of town adjustments: Nate Sears, Natural Resources Manager, Town of Orleans). CSP/SMAST staff often visit the site with a GNSS/GPS with RTK enabled to record board elevations. These readings were also used to determine 2020-2025 board elevations. Water levels over the notch and board elevations will vary depending on timing of visits and pond water levels at the time of the visits. 2025 readings show that the board elevation in May 2025 were that lowest recorded and subsequent discussions with Town staff showed that the boards were removed by someone other than Town staff sometime between November 2024 and May 2025.

	Date	Time	Low Tide	water over boards		Water Level (ft)	Fish noted	Board adjustment	Elevations (m NAVD88)		
				Initial (inches)	Final (inches)				Bottom Notch	Top of Boards	Pond Elevation
Town	4/13/20	10:45	10:36	0	3	2.25	No fish	Notch added	1.42		
Town	4/28/20	9:45	9:45	1	1	2.08	No fish	none			
SMAST	5/26/20	15:22					No fish		1.38	1.50	1.35
SMAST	6/25/20	14:20					No fish		1.37	1.48	1.38
SMAST	7/22/20	14:23					No fish		n/a		
SMAST	9/23/20	15:11					No fish		1.39	1.50	1.49
Town	9/28/20	14:30	16:15	0	1	2.58	No fish	Removed notch			
Town	3/17/21	14:45	8:38	0	0	1.6	No fish	Notch added	1.48		
Town	7/1/21	14:30	11:24	1	5	2.0	No fish	Removed boards	1.34		
Town	11/29/21	10:40	12:33	0	0	1.3	No fish	Boards added; removed notch		1.63	
Town	3/15/22	9:30	15:51	0	0	2.1	No fish	Notch added	1.48		
Town	5/15/22	9:00	5:05	1	0	2	No fish	Removed notch		1.63	
Town	3/15/23	13:45	13:15	1	5	2.5	-	Notch added	1.48		
Town	5/15/23	-	-	4	0	2.41	-	Removed notch		1.63	
SMAST	8/23/23			RTK					1.515	1.653	1.428
SMAST	10/26/23			RTK					1.508	1.659	1.365
Town	3/15/24	-	-	0	5	1.92	-	Notch added	1.48		
SMAST	4/16/24	13:04	13:06	RTK					1.3735	1.528	1.3228
Town	5/15/24	-	-	4	0	2.41	-	Removed notch		1.63	
SMAST	8/28/24	13:05	13:41	RTK						1.5445	1.4274
Town	3/15/25	9:30	6:47	0	0	1.38	-	Added notch			
SMAST	5/2/25	9:50		RTK		1.3865				1.2247	
Town	5/15/25	9:30	7:53	0	0	-	-	Added 18 in of board			
SMAST	5/20/25	9:50		RTK		1.3157				1.6397	
SMAST	6/17/25	11:55		RTK		1.2574				1.6155	
SMAST	7/17/25	12:11		RTK		1.3158				1.6265	
SMAST	8/14/25	11:21		RTK		1.3814				1.6084	
SMAST	9/3/25	15:55		RTK		1.2485				1.6509	
SMAST	9/15/25	12:35		RTK		1.2990				1.6563	
SMAST	10/15/25	13:21		RTK		1.4885				1.6477	
SMAST	11/13/25	13:09		RTK		1.5352				1.6381	
SMAST	12/9/25	10:52		RTK		1.5458				1.6391	

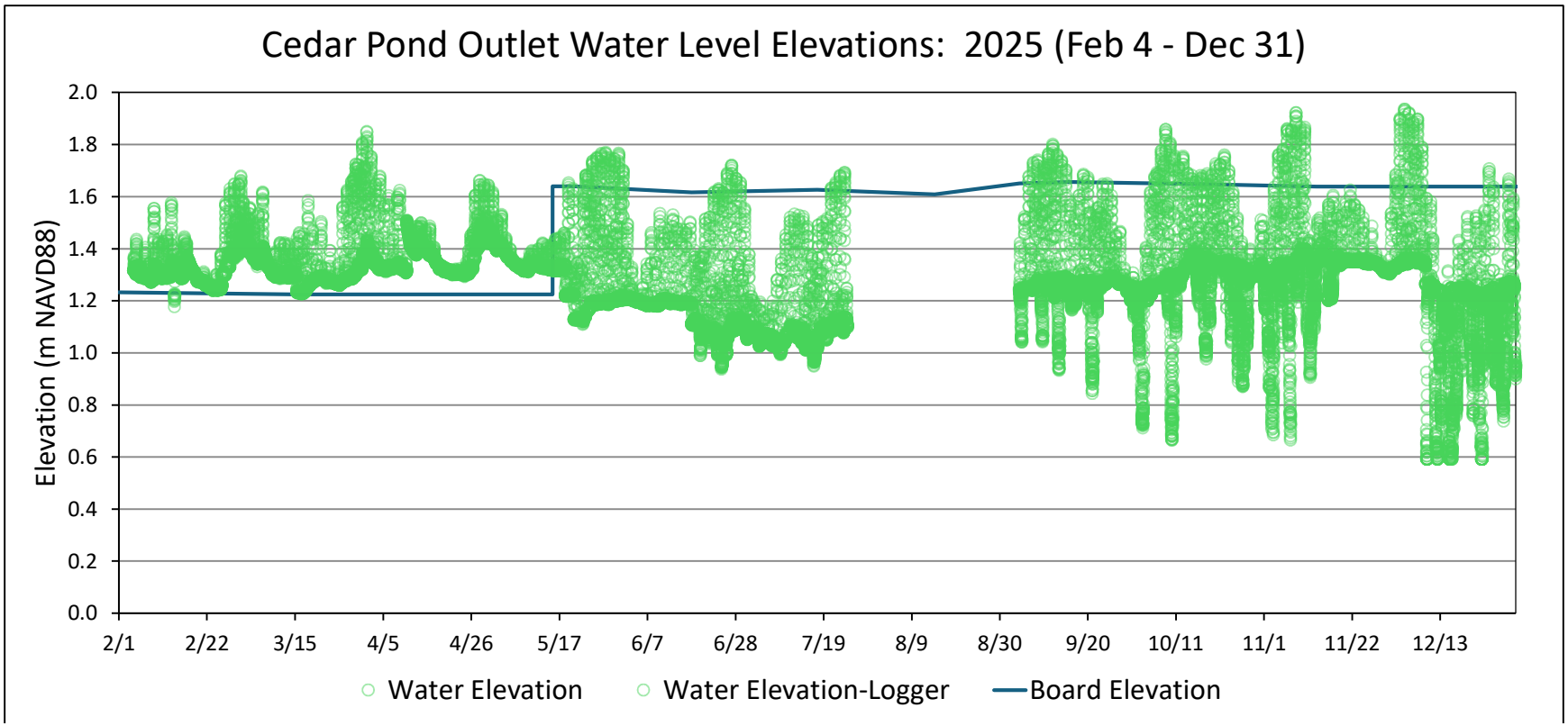


Figure III-21. Cedar Pond 2025 Water Levels and Outlet Board Heights. In 2025, CSP/SMAST staff installed an autonomous recording device programmed to record water levels every 10 minutes at the pond outlet on February 4 and the device was recording through December 31 (August had battery failure and corrupted data). During 2025, the outlet boards were set at a historically low elevation until May 15. Subsequent discussion with Town staff showed that this was vandalism/removal of the boards. During this portion of the year, 99.9% of all water levels were greater than the board elevation and 28% of the readings were 6 inches or more above the board elevation. On March 15, a notch was added to the boards, but did not have a notable impact given the low elevation. On May 15, the board elevation was increased to 1.64 m NAVD88 and this elevation was maintained throughout the rest of 2025. Review of water levels between May 15 and November 15 (the 184 days targeted in the Fishway Plan for herring young to leave the pond), 62 days had water levels greater than the board elevation. These days tended to occur in clusters of 6 or 7 days around the spring tide with elevations greater than the board height of 1.5 hours on average. Average elevation of water over the boards was 2.03 inches.

IV. Conclusions and Proposed Management Changes

The 2013 Town of Orleans Cedar Pond Management Plan focused on effective stewardship through three key goals: 1) restore water quality, 2) restore the historic herring run, and 3) protect the adjacent Atlantic White Cedar wetland.[34] The Plan proposed an adaptive management strategy with regular water column measurements (both monthly water quality sampling and continuous readings at selected depths), measurements of stream outflow, and continuous water column measurements. Monitoring results would be reviewed annually and options for adjustments would be discussed. Management efforts to address cormorants and, eventually, the pond sediments were also included in the Plan.

Recent water quality in Cedar Pond has improved significantly from conditions prior to the implementation of the Management Plan in 2017. These improvements between 2018 and 2025 have included:

- **Reduced nitrogen export to Rock Harbor.** Nitrogen exported to Rock Harbor has generally returned to levels measured in 2002/2003 during the MEP assessment.[35] At the time of the MEP assessment, natural nitrogen attenuation in Cedar Pond was 58% and no nitrogen reductions in the Cedar Pond watershed were in included in the MEP scenario to attain acceptable water quality in Rock Harbor.
- **Acceptable shallow dissolved oxygen concentrations.** When the boards were removed and salinity was high throughout the water column, DO concentrations were less than the MassDEP regulatory minimum throughout most of water column with occasional anoxia (*i.e.*, no DO) within 6 inches (0.15 m) of the surface. DO readings in the upper 1 to 1.5 m of the pond have consistently exceeded the MassDEP minimum during recent summers except for some vandalism of the boards in 2025.
- **Herring in Cedar Pond Creek.** With high salinity and low DO, the habitat for spawning herring was significantly degraded. As a result of better water quality conditions and reinstalling the outlet boards and managing their elevation, herring were caught in the creek by the Town and MassDMF in 2022.
- **Lower salinity in the shallow water column has provided some protection for the adjacent Atlantic White Cedar wetland.** The regular seasonal increase of salinity due to decreased board heights and reduced groundwater levels produces a challenge for sustaining lower salinities, but progress toward this Management Plan goals has been better defined by the regular monitoring. Monitoring has shown that higher board and groundwater elevations during the winter can reduce salinity levels sufficiently to keep salinity levels lower throughout most of the summer and through board adjustments for herring.

Although the regular monitoring of Cedar Pond has documented the significant improvements, it has also documented that deeper portions of the pond have continued to have significant impairments. Deep DO levels have continued to be regularly anoxic mostly throughout most years due to the pervasive sediment oxygen demand. Chlorophyll-a levels, which are a proxy for phytoplankton, have remained high and, as a result, water clarity has remained low. Shallow nitrogen and phosphorus levels have been consistently high and deep samples show that the

[34] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan.

[35] Howes B., S. Kelley, J. Ramsey, R. Samimy, D. Schlezinger, and E. Eichner. 2008. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Rock Harbor Embayment System, Orleans, MA.

sediments regularly release enough nutrients to create levels two to three times higher than shallow concentrations.

The low cost approach approved by the Town to reinstall the outlet boards has resulted in significant Cedar Pond ecosystem improvements, but the sediments in the pond continue to be an on-going source of ecosystem impairments. During the ecosystem characterization that led to the 2013 Cedar Pond Management Plan, CSP/SMAST divers collected sediment cores at eight locations and incubated those cores to determine the rates of nitrogen and phosphorus release during various DO conditions.[36] The Management Plan ecosystem characterization showed that the sediments were a significant cause of the pond impairments, but the strategy developed during implementation of the plan was that the sediments should be addressed after: 1) the cormorants roosting over the pond were moved (completed in 2019) and 2) the impact of the board changes and the associated resulting improvements were well characterized. It is recommended that it now time for the Town consider development of sediment management options.

It is further recommended development of sediment management options be completed by duplicating the 2012 sediment core collection and incubation. As was done in 2012, the incubation should measure rates of nitrogen and phosphorus release under aerobic, anaerobic, and transitional DO conditions using standard MEP procedures. Divers should also assess sediment depth. This information should be sufficient to provide the Town with a strong basis to evaluate sediment management options and their potential costs (*e.g.*, treat in place or excavation).

It is also recommended the Town combine the updated sediment information with regular water column sampling to develop a nutrient TMDL for Cedar Pond. Cedar Pond is listed as a Category 5 water ("Waters requiring a TMDL") in the most recent MassDEP-approved Integrated List.[37] Having a town-developed TMDL would assist the Town in CWMP implementation planning and provide the Town with an additional control over the process. A TMDL for Cedar Pond would also reduce the uncertainty associated with the TMDL status of Rock Harbor. The 2008 MEP Rock Harbor assessment indicated that the Harbor portion was significantly impaired, but MassDEP did not complete a nitrogen TMDL after the MEP report was finalized.

It is additionally recommended that the Town continue water quality monitoring to implement the Cedar Pond Management Plan. The Town is in a stable regulatory setting for Cedar Pond with: a) the 2017 MEPA and MassDEP approval of a Superseding Order of Conditions on the Management Plan Environmental Impact Report and b) the 2022 MassDEP Certificate of Compliance (COC) for the conditions. The COC included one on-going condition: that the Management Plan continue to be implemented if there continues to be a positive impact on the wetland resources. Monitoring allows the Town to document compliance with this condition. As part of the on-going compliance activities, Town Natural Resources staff have secured the

[36] Eichner, E., B. Howes, and D. Schlezinger. 2013. Cedar Pond Water Quality Management Plan.

[37] 2024/2026 Cycle: https://www.mass.gov/doc/massachusetts-draft-integrated-list-of-waters-for-the-clean-water-act-20242026-reporting-cycle/download (accessed 3/31/26)

outlet boards with a lock to prevent a repeat of the 2025 vandalism.[38] CSP/SMAST staff are available to discuss options with Town and MassDMF staff to reduce the level of data collection while ensuring sufficient information is collected to reliably discuss long-term system status and regulatory compliance.

The Town implementation of the Cedar Pond Management Plan has improved the water quality in Cedar Pond. These improvements have been documented through monitoring and have occurred through relatively low cost steps (*i.e.*, adding boards at the inlet, convincing Eversource to move the regional power lines). Water quality conditions in the pond remain impaired, however, and conditions deep in the pond are significantly impaired by the pond sediments. Following the above recommendations would allow the Town to establish long-term strategies with reduced long-term monitoring.

[38] Personal communication from Nate Sears, 4/2/26.

V. References

CSP/SMAST Technical Memorandum: Board Height Recommendation for Cedar Pond Outlet. October 10, 2014. From: Howes, B., E. Eichner, R. Samimy, J. Ramsey, and S. Kelley. To: G. Meservey, Town of Orleans, Director of Planning & Community Development and C. Kennedy, Chair, Marine and Fresh Water Quality Task Force. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 13 pp.

CSP/SMAST Technical Memorandum: Cedar Pond Board Adjustment. October 21, 2020. From: E. Eichner, Howes, B., and D. Schlezinger. To: G. Meservey, Director of Planning & Community Development and N. Sears, Natural Resources Manager, Town of Orleans. Coastal Systems Program, School for Marine Science and Technology, University of Massachusetts Dartmouth. New Bedford, MA. 6 pp.

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