Turbidity Control for SAV Recovery in the Lake Okeechobee Littoral Zone

September 30, 2025

Prepared for: South Florida Water Management District

Prepared by: DB Environmental, Inc.

This report was prepared in fulfilment of Agreement 4600004946-WO1R2





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Acknowledgements

Conceptualization, funding support, permitting and oversight of this project was provided by Stacey Ollis, Zach Welch and Holly Andreotta of the South Florida Water Management District. The investigation by DBE was led by Kevin Grace and Mike Jerauld; design assistance from Mark Blakslee and Patrick Owens; project installation, maintenance and removal led by Riley Urban, Dave Haselow, and Ben Lussier. Field monitoring was implemented by Dawn Finn, Justin Cheesman, Karen Hileman, Jenna Bodin, Devin Mathias, Luke Stoloff and Jessica Vacarre; lab analysis provided by Nancy Chan, Nichole Carr, Jaimee Henry, Lisa Nally, Angela Son and Estefania DeBernardo; Data analysis and visualization by Luke Evans; administrative support by Michelle Kharbanda and Suzie Larson. Recent SAV coverage data for the lake's nearshore was provided by Alyssa Jordan of the Florida Fish and Wildlife Conservation Commission. Andrew Ortega and Sam Weidinger of Aries Geospatial provided aerial imagery for the project.

1 Executive Summary

Experimental turbidity controls using custom curtains were deployed in the Lake Okeechobee nearshore environment to assess feasibility of improving light penetration through the water column with the goal of enhancing submerged aquatic vegetation (SAV) growth and recovery (Figure 1). This one-year pilot project was conceived and funded by the South Florida Water Management District (SFWMD) and designed and implemented by DB Environmental (DBE) from summer 2024 through summer 2025. Lake stage was high at the time of project development, and SAV coverage was near record lows (Figure 2). Effective turbidity reduction could promote SAV recovery on the lake under relatively deep-water conditions, so a scalable solution that is capable of functioning in the challenging, high-energy nearshore environment of this sizable lake would be beneficial. Lake stage favorable for SAV growth was briefly realized late in the 2024 SAV growing season, before stage rose again to above 16 ft (NGVD29) in October 2024, creating water depths of 5.5 to 6 ft in areas previously supporting SAV.

This Summary Report provides the approach, outcome, and lessons learned from this pilot project. The installation design, durability, and turbidity reductions achieved are described along with the SAV response in the project areas. Turbidity reductions were fairly consistent but modest relative to the magnitude of reductions that would be required to support photosynthesis on the lake bed when water depths exceed 3 ft. Regrowth of *Vallisneria* was observed in early March 2025 at one of the two project areas before recovery of the SAV community was observed across a wider area along the nearshore region of the lake. The controls were effective at reducing turbidity when wind speeds exceeded 15 mph, and the installation proved capable of withstanding tropical storm conditions and winds exceeding 50 mph with rapid recovery after storms passed. The controls required regular maintenance and some components were strained by the conditions at the pilot study locations, requiring minor repairs.

A target turbidity of 5 NTU or less was developed using vertical profiles of light attenuation and turbidity measured under a range of conditions on the lake during the study period. Under this turbidity threshold, light penetrating to the lake bed in 3 ft (1 m) water depth would exceed 29 $\mu mol/m^2/s$, the average daily level of irradiance below which no net growth of *Vallisneria* was established through previous SFWMD research (Grimshaw et al. 2002). While the controls did not reduce turbidity to below this threshold under all conditions, and had little effect on light attenuation by dissolved organic matter that imparts color to the water, they were effective at redirecting drifting surface films when algae blooms developed in the pelagic zone (Figure 3). The controls were also effective at reducing inorganic suspended solids that are transported into the nearshore environment by wind waves and lake circulation currents, especially under deeper, windy conditions. Incremental improvements in turbidity and protection during storms may have enhanced SAV recovery leeward of the controls in South Site study area (Figure 4).

An exclusion cage study within the project suggests that SAV recovery on the lake can be significantly affected by herbivory. Leaf lengths were significantly longer and plant dry weights greater within cages that provided protection from herbivores, compared to plants in open frames, while no difference was attributed to the position within or outside the turbidity controls. The ability to evaluate controls' effectiveness on *Vallisneria* growth in the cage experiment was somewhat limited by shallow water conditions during the period between April and July 2025 when that study was conducted. Curtains were reefed at lake stages below 12 ft (depth < 2 ft) to avoid contact between the lower edge of the curtains and the lake bed, which could trap wildlife or compromise the integrity of the curtain installation if a storm partially buries the curtain material under lake sediment. Modifications to curtain design were developed and tested to adjust curtain length and adapt to shallow conditions or fluctuating water depths, and could be incorporated into future deployments of turbidity controls under similar or alternate configurations.

Overall, the modest reductions in turbidity from projects like this pilot study would likely not be sufficient to substantially improve growing conditions for SAV under normal to high lake stages. While the concept was proven feasible, even lasting through extreme storm conditions, there was a considerable cost to deploy and maintain custom curtains like these for relatively minor improvements to water clarity. Observed effects were notably better when deployed within existing littoral vegetation, highlighting the importance of site selection for any similar future projects. Results suggest that turbidity barriers alone, when deployed on Lake Okeechobee are not likely to markedly improve water clarity, especially in areas with relatively high color or that are prone to algal blooms, or in more exposed, open water areas. However, the flexible barriers deployed in this study may have provided a cumulative benefit during storms and enough energy dissipation during Hurricanes Helene and Milton to protect SAV, suggesting other wave attenuation devices may be successful on the lake.

Figure 1. Turbidity controls deployed in Lake Okeechobee. Silt fence in the foreground extends from the lake bed upward, preventing turbid water from moving along the lake bed, but allowing surface water to pass over the fence during storms. The overlapping boom and barriers ("curtains") in the background float at the water surface and are effective at redirecting surface films and surface water flows, but leave a gap between the bottom of the curtain barrier and the lake bed for water and wildlife to pass through.

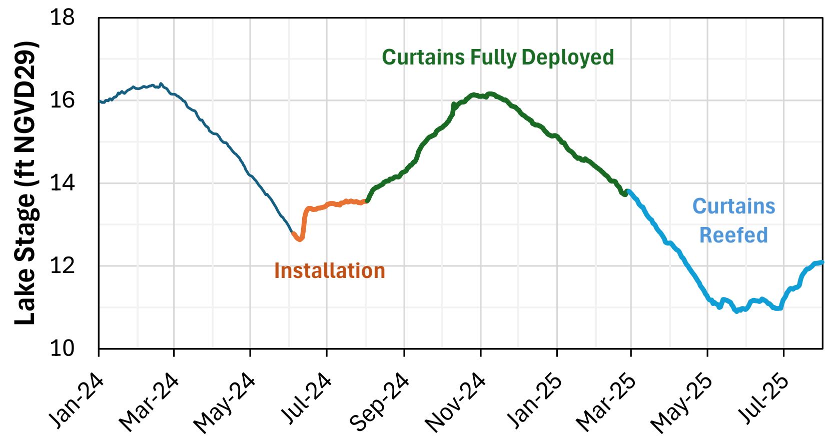


Figure 2. Lake stage during the project period followed a typical seasonal pattern, and decreased to water levels favorable for SAV growth in the nearshore environment. Controls were fully deployed at stages above 14 ft (NGVD29), partially reefed at stages between 12-14 ft, and fully reefed at stages < 12 ft.

Figure 3. Turbidity controls prevented the movement of surface films and algae blooms from drifting into the area protected by the installation, shown here at the South Site on August 6, 2025. Inset shows the Cyanobacteria algal bloom monitoring image for the same date, with higher cell densities in red along the Indian Prairie shoreline where the project was located. Image derived from Copernicus Sentinel-3 satellite data as processed and available from NOAA Coastal Centers for Ocean Science at https://coastalscience.noaa.gov/science-areas/habs/hab-monitoring-system/cyanobacteria-algal-bloom-satellite-lake-okeechobee-fl/

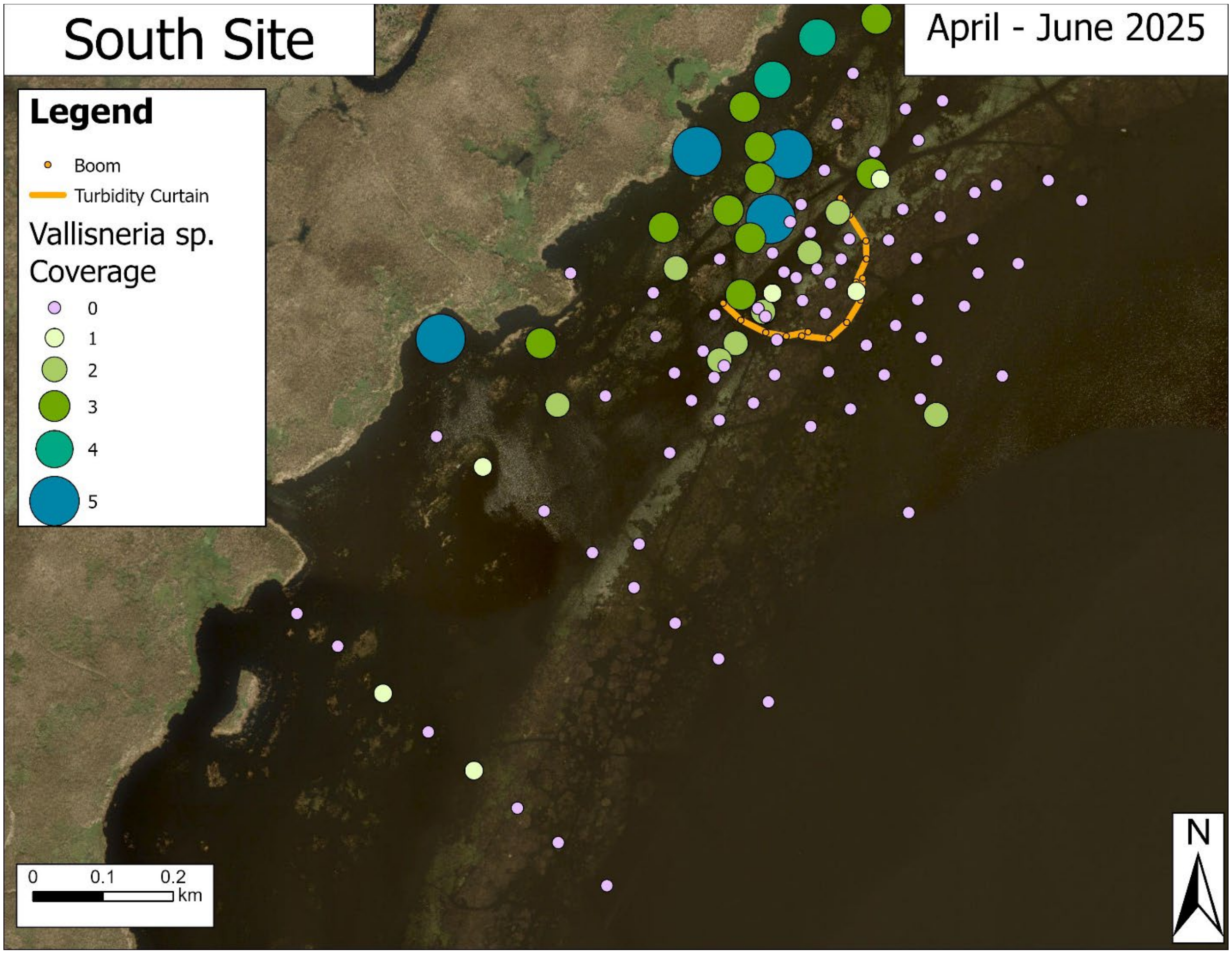


Figure 4. *Vallisneria* coverage at locations visited within and around the South Site project controls installation during the April–June 2025 period, where relative coverage is visually assessed on a semiquantitative scale (0: absent, 1: trace amount, 2: 1-10% coverage; 3: >10 and < 33% coverage; 4: 33 to 66% coverage; 5: > 66% coverage).

2 Background

The SAV in Lake Okeechobee provides critical habitat for fish and wildlife, stabilizes shoreline sediments, and supports attached algae that help to remove nutrients from the water. The spatial extent of SAV varies in response to changing water levels and water clarity, both of which affect light penetration in the water column. Steinman et al. (1997) described the loss of *Chara*, an important macroalgal component of the SAV community within lake Okeechobee, during periods of high lake stage, when light levels at the lake bed fell below the threshold determined in laboratory studies to be required for positive net growth. Similar light thresholds have been established for important rooted macrophyte species, including eelgrass (*Vallisneria americana)* based on SFWMD research in Lake Okeechobee (Grimshaw et al. 2002). Recent genetics research has suggested the populations in Lake Okeechobee may be *Vallisneria neotropicalis*, and through coordination with the Florida Fish and Wildlife Commission and University of Florida scientists, plant samples collected from the lake in the project area by DBE scientists were identified as *V. neotropicales*. In this report, the observed plants are referred to as the genus *Vallisneria* sp.

SAV coverage on the lake was minimal for several years preceding this project, due to high water and turbidity associated with Hurricanes Ian and Nicole during the 2022 hurricane season, resulting in a need to recover this critical fish and wildlife habitat (Figure 5). Rather than wait for potential climatic conditions that could lower lake stages and improve light availability near the lake bed, the District conducted this pilot study to test whether turbidity controls (e.g., turbidity curtains, silt screens, and/or other means) could improve water clarity, and thus light penetration to the lake bed, in this high energy environment to promote SAV recovery.

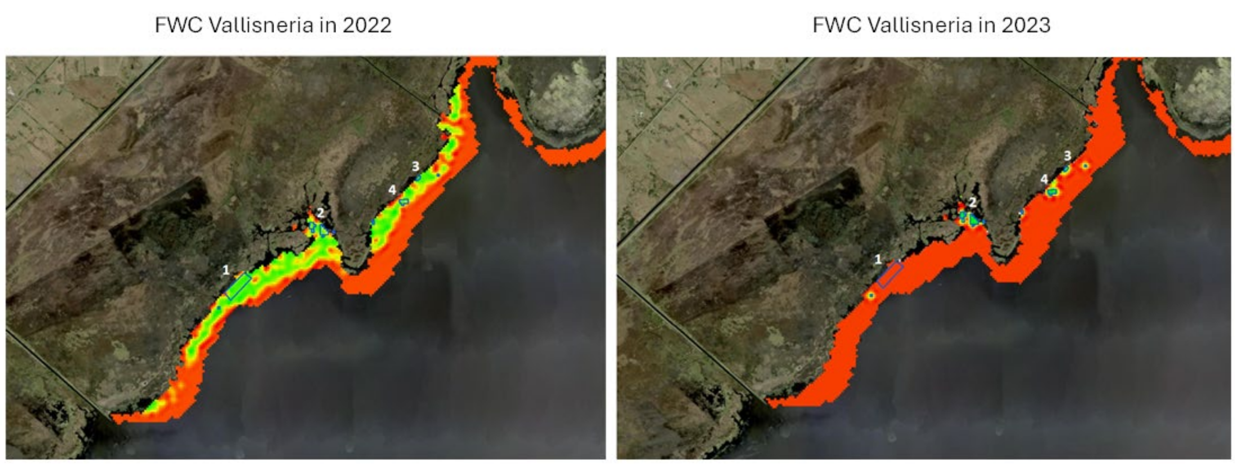


Figure 5. Presence of *Vallisneria americana* (green) along the nearshore region of Lake Okeechobee in 2022 and 2023 surveys conducted by FWC (Data provided by Zach Welch, District and Alyssa Jordan, FWC). Numbers correspond to sites visited during the project Recon trip on April 15, 2024. Red zone indicates the area surveyed where SAV was not found.

The littoral zone of Lake Okeechobee typically has bulrush and deep-water grasses growing at the outer edge of the marsh, which are occasionally at high enough density to improve water clarity through reduced wave action and sedimentation effects. Behind and within this lakeward-edge community, SAV flourishes under the right conditions (Figure 6). Water lilies frequently occur with SAV, but both give way to a dense wall of emergent vegetation (usually cattail or floating mats) shoreward at higher bottom elevations. By installing temporary turbidity controls within or near the grass line, improvements to water clarity may also improve the subsequent rebound of SAV.

Algal blooms are common in this area of the lake during the warmer summer months (Figure 3), yet water clarity is largely due to inorganic suspended matter, and phytoplankton growth can be light limited. Reducing turbidity by slowing water movement to increase settling, or by redirecting mass transport of suspended particles into the nearshore, may improve water clarity but may also exacerbate blooms and partially offset expected water clarity improvements. Resuspended sediment particles transported from the open water pelagic zone of the lake, as well as some color from the Kissimmee River and Indian Prairie Canal, contribute to light attenuation in the area even in the absence of blooms. Suspended material may be thixotropic mud or a mixture of algal biomass and suspended sediments. Generally, turbidity in the region does not quickly settle out.

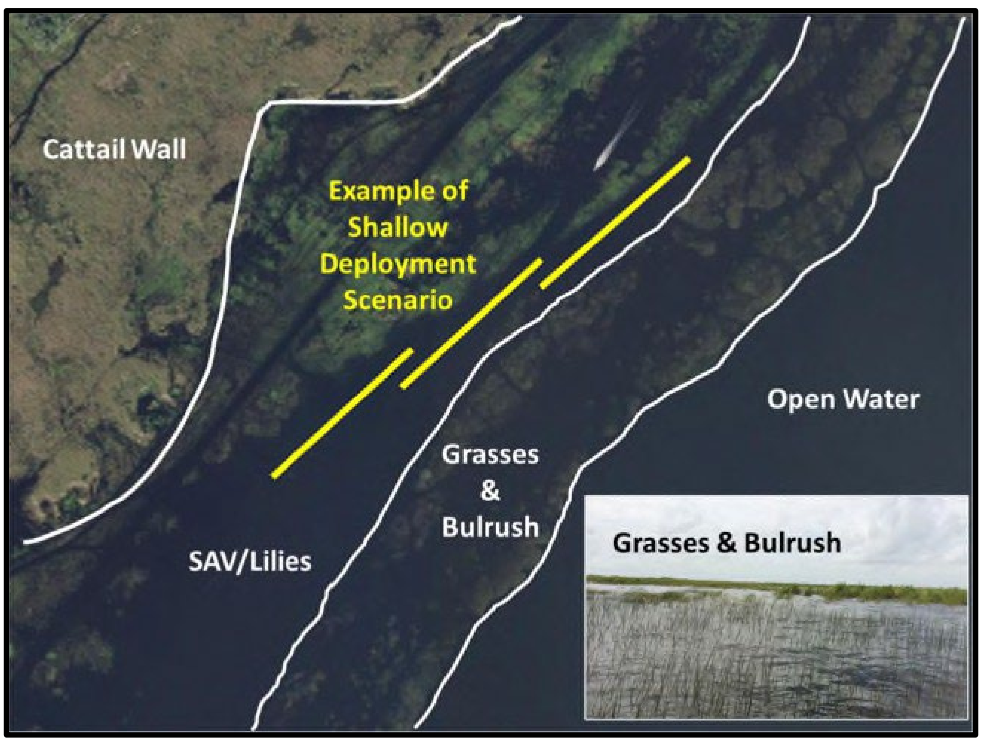


Figure 6. Typical shoreline communities in study area; dense emergent plants (cattail) along the shallow edge, transitioning to SAV or water lilies and sparse vegetation, and then to a sparse community of deep-water grasses and giant bulrush on the outer edge of the marsh. The example deployment scenario depicted was an early conceptual design, not utilized in the final design of the deployed pilot project.

3 Objectives

The management goal of the project was to develop tools for improved light penetration to support SAV recovery when lake stage is high. To accomplish this, a pilot study was developed to test the feasibility of turbidity reduction technology to improve water clarity where SAV (especially the rooted macrophyte *Vallisneria* sp.) normally occurs, and to gauge whether temporary improvements in light penetration can reestablish a resilient SAV community in the near term. This study assessed the efficacy of installing temporary turbidity controls in two areas along the Indian Prairie (northwest shoreline) where SAV beds were documented prior to Hurricanes Ian and Nicole (Figure 5) in a large enough area to be resilient to herbivory effects. In spring 2024, SAV coverage was minimal in most other locations on the lake, which may have intensified grazing impacts on remaining SAV, reducing potential nesting locations for fish within the lake. To test for herbivory effects, several exclusion devices were installed in the study area.

4 Project Area – Conditions and Design Considerations

The turbidity controls were deployed at roughly 10.5 to 11 ft NGVD29 in elevation, between dense emergent cattail on the shoreward edge, and sparse grasses/bulrush on the lakeward edge. The two locations are at the South Site (27.05500° N, 80.91145° W, Figure 7) and North Site (27.07640°N, 80.87095°W; Figure 8), northeast of the mouth of Indian Prairie Canal. These locations were selected based on (1) the presence of emergent vegetation, which may provide some initial reduction of wind-wave energy and protection of the project area from the full force of wind waves across the 20+ mile fetch, (2) appropriate sediments for anchoring and SAV regrowth, (3) recent presence of *Vallisneria*, and (4) separation from ongoing vegetation management activities. Additional details on the site selection were provided in the Final Work Plan for this study (DBE 2024).

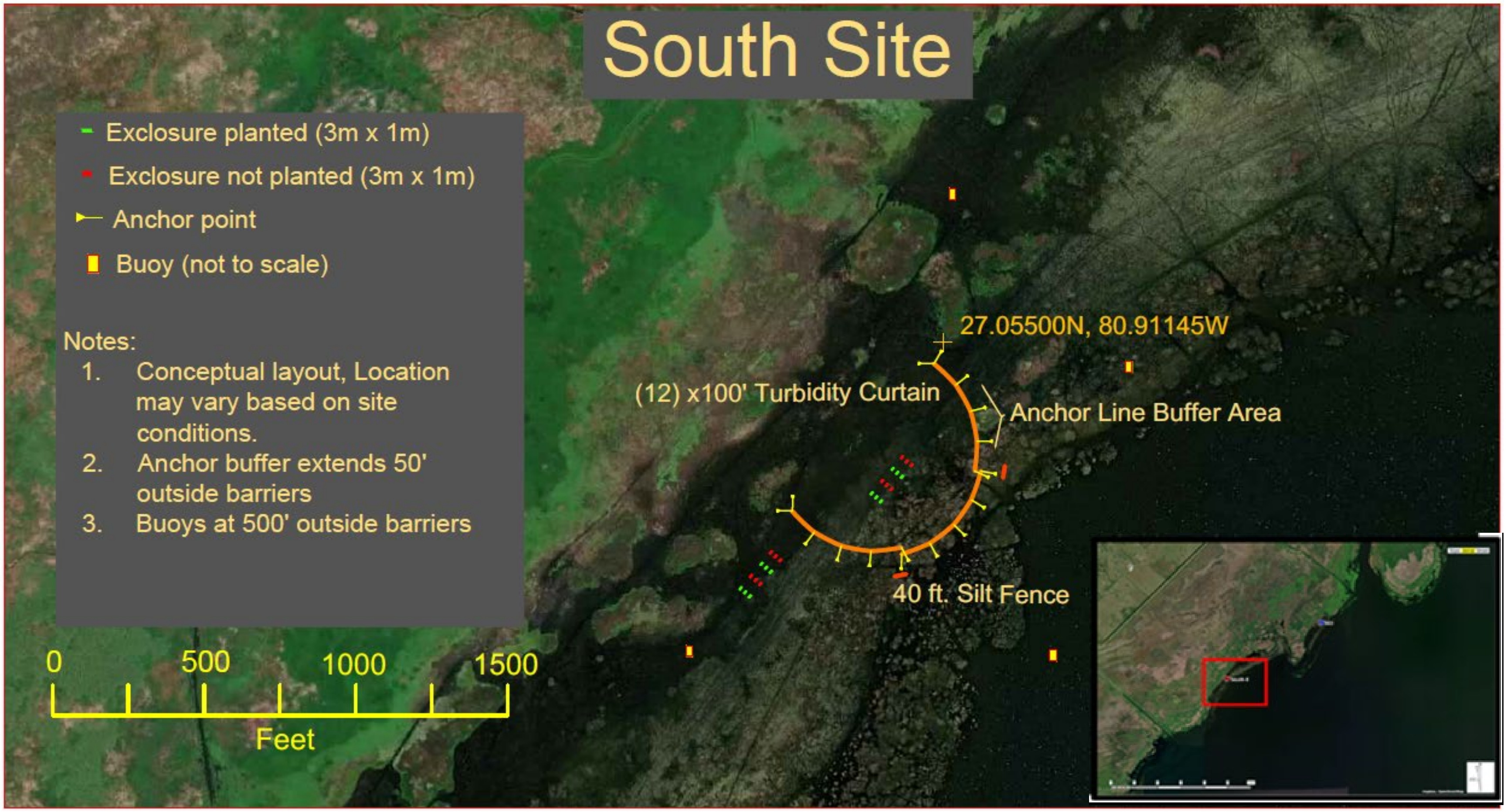


Figure 7. Schematic and planned location of the turbidity controls at the South Site for improving light conditions for SAV recovery. Items to scale except the size of the buoys.

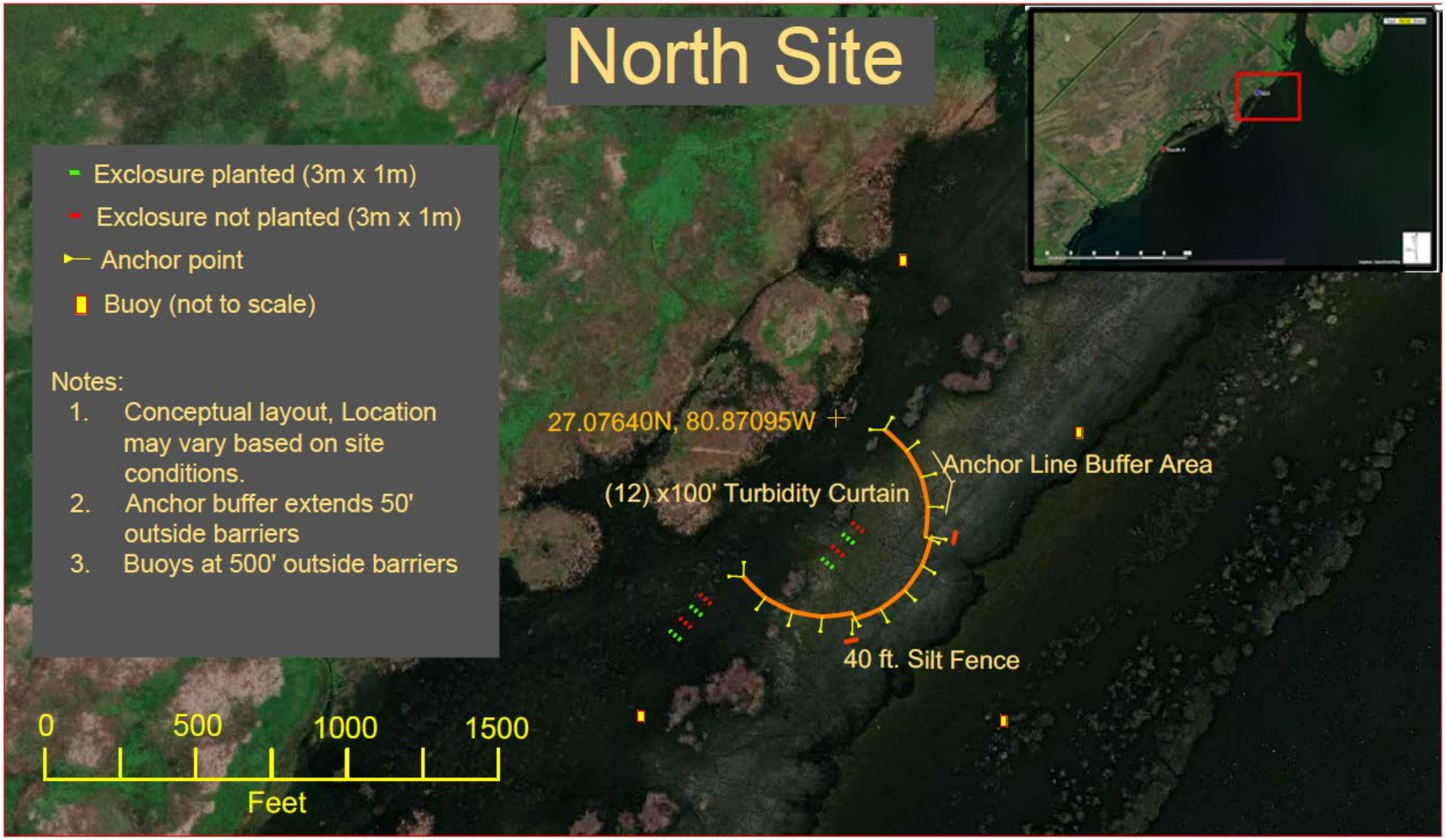


Figure 8. Schematic and planned location of the turbidity controls at the North Site for improving light conditions for SAV recovery. Items to scale except the size of the buoys.

5 Summary of Completed Work

5.1 Task 1 – Navigation Installation and Turbidity Control Supplies

Navigational buoys conforming to the U.S. Aids to Navigation requirements were installed upon receiving U.S. Coast Guard approval of Private Aids to Navigation Application (CG-2554) PA 24-018, which authorized the temporary establishment of (8) special purpose lighted buoys to mark four corners of the two project areas where the study of SAV restoration took place (Figure 9). Additional signage at nearby boat ramps and public recreational forums increased awareness of the project activities (Figure 10).

Figure 9. Lighted navigational buoys were deployed around the project area to increase visibility to boaters.

Figure 10. Signage at nearby boat ramps provided project information to the public.

5.2 Task 2 - Turbidity Controls Installation

Once the navigational aids were in place, installation was initiated beginning with an array of anchors. Over eight field days in June and July 2024, the primary anchor system was completed and the first turbidity control curtains were installed on July 22, 2024. On August 1, 2024, the inspection of the completed curtains installation was conducted by DBE and SFWMD scientists. Lake levels had declined during the installation period, and were lower than had been expected at the time of curtain design, so the curtains were temporarily kept fully reefed under the floating booms. However, Hurricane Debby passed August 4-5, and by August 14, lake depth was sufficient (4 ft) to release curtains and install silt fences. By September 5, all curtains were released. Aerial views highlight differences in vegetation between the two sites (Figure 11).

Figure 11. Aerial view of the installed turbidity controls on November 14, 2024, at the North Site (top photo) and South Site (bottom photo) project areas, looking generally southward. Aries Geospatial provided imagery support for this project.

5.3 Task 3 - Maintenance and Monitoring

Routine visits were made during the project monitoring period to ensure that the controls operated safely and effectively during the project duration. These visits occurred weekly or more frequently as needed to follow up on minor adjustments to the anchor system. Frequent activities included securing anchor lines and buoys, checking on shackles and shackle pins. Shackle pins were prone to backing out in the high-energy environment; stainless steel aircraft lockwire was added to secure shackle pins in place. The weekly visits also incorporated monitoring activities to evaluate effectiveness of the turbidity controls during the project period (Figure 12). A maintenance log was kept of all activities (see Appendix Section A.7), and a summary of the monitoring efforts that followed the Final Work Plan for this study (DBE 2024) is provided in Section 6.3.

Figure 12. Weekly inspection and maintenance activities also allowed monitoring opportunities. Storm damage and boat interactions with anchor lines led to constant wear, tear, and repair.

5.4 Task 4 - Major Repair or Replacement Activities

No major damage (lost curtains or pulled anchors) was sustained during Hurricanes Debby, Helene, or Milton. Note that maximum sustained wind speeds on the lake at station L001 (DBKey: IX847) during these storms were 32, 38, and 51 mph, respectively, so less than tropical storm force with the exception of Milton. Two spare curtains were on hand and rotated on the lake as needed throughout the project to repair damaged curtains. Modifications were made in March and April 2025 to install grommets for partial reefing and fish evacuation system (FES) components to adapt the installation to shallow water conditions (Figure 13). This provided additional protection for recovering SAV community within and around the turbidity controls.

Figure 13. Installation of Fish Evacuation System to avoid entrapment of fish in shallow water when lake levels recede.

5.5 Task 5 - Removal and Reporting

Communications were maintained between DBE and the SFWMD science team throughout the project, including before and after major storms. Meetings to discuss project progress, status, and preliminary findings were held in December 2024, March 2025, and August 2025. After consultation with SFWMD scientists and Project Leads on August 4, 2025, removal of the turbidity controls was initiated (Figure 14). All equipment associated with the turbidity controls, including curtains, anchor lines, anchors, buoys, PVC markers, SAV exclusion cages, and signage at boat ramps was removed from the lake between August 4 and September 26.

Figure 14. Anchor removal using engine hoist and tripod. Scale confirmed anchor holding power during anchor testing, installation and removal.

6 Evaluation of Project Success

6.1 Criteria for Success

To evaluate project success, criteria were set forth in the Final Work Plan for this study (DBE 2024). For this pilot study, the project was considered successful if the technology platform for turbidity control reduces turbidity (Does it work?); results in increased plant growth; survives typical conditions on the lake, does no harm, and serves as a scalable building block towards future success. An alternative successful outcome was also acknowledged: it will be useful information for lake managers if this pilot project establishes that this is not a viable approach to restoring SAV. Where possible, areas were identified where the technology can be improved or reconfigured as needed.

6.2 Evaluation of Technological Approach

The pilot study installation was a valuable research platform to gain insights under field conditions for the nature of light-attenuating particles in Lake Okeechobee during the SAV growing season and throughout the year. The project provided an opportunity to evaluate reduction of settleable turbidity achieved by the control measures and feasibility of improving light penetration to the bottom of the water column. The project was also a technical challenge for designing a temporary control measure that could be deployed and retrieved as needed, be large enough to improve conditions for SAV over areas that would not quickly succumb to herbivory, and could remain anchored and otherwise withstand the harsh environment of the lake's nearshore environment. The long fetch of Lake Okeechobee allows wind waves to form and move through shallow water, and rapid water depth changes of several feet occur during storm seiche events.

To evaluate the technology deployed in this pilot project approach, the platform performance and durability during the study period are briefly described. It is then examined whether SAV recovery was observed at the field scale, perhaps in response to deployment of the controls and enhanced by improved light penetration, or is constrained by other factors such as herbivory. The effectiveness of the controls was also evaluated through water quality monitoring and changes in measured parameters. Details on the installation components and required maintenance are provided later in the Appendix.

6.2.1 Platform Performance, Durability, and Scalability

Design features allowed the anchors to hold during major storm events while the tension on the curtains was released at planned fail points using breakaway links. Once released, the curtains were no longer subject to the full force of wave energy, but remained anchored on one end to maintain position. This allowed curtains to flag, or align with the direction of the wind and wave energy, rather than transverse to it. After storm energy dissipated, the team was able to reattach the curtains to anchor points for continued performance of the controls. The overall design performed as intended and no anchors failed during this pilot project.

These features enabled the turbidity controls to survive waves from winds in excess of 50 mph and stage fluctuations of several feet within hours during the passage of Hurricane Milton while sustaining only minor damage (Figures 15 and 16). The breakaway links broke during the storm at the more exposed North Site (Figure 17), but held at the South Site where grass line vegetation provided additional protection. During Milton, several links broke under forces that exceeded 1000 lbs to release the tension from the curtains before the anchors pulled. Anchors held under forces in excess of 3000 lbs during vertical pull tests.

This pilot installation is scalable, and the number of curtains could be adjusted as needed to alter the area within the controls as needed for a given lake region. Additional factors that could be examined by this platform include deployments in deeper water, multiple layers of curtain, and varying the overall size of the enclosed area. For this pilot project, with wind-wave energy potentially coming from multiple directions and a large fetch for wind-wave development, it was determined that protection from the south, east, and north was prudent to provide turbidity reduction and improve light conditions for SAV recovery.

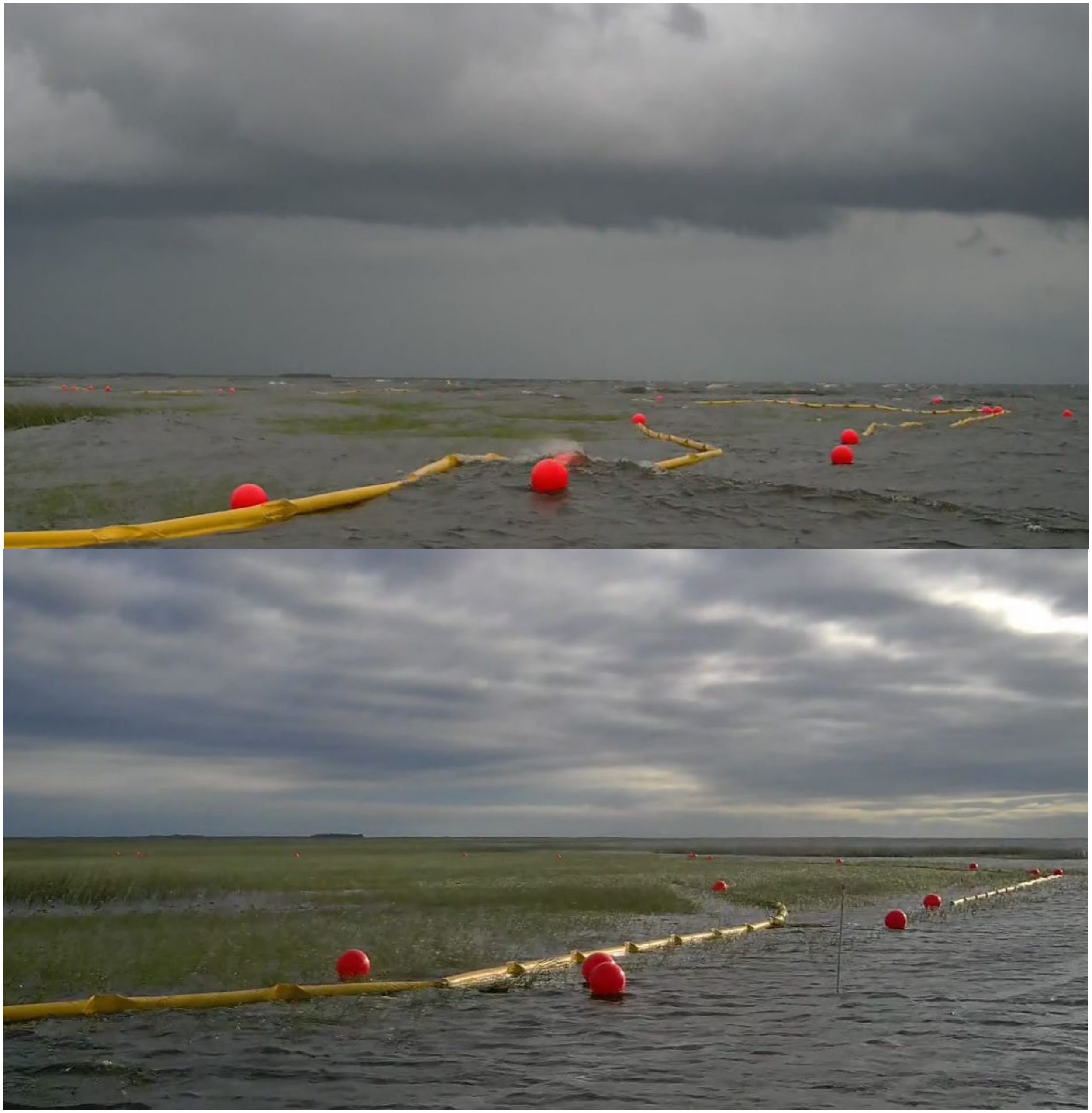


Figure 15. Controls at the South Site location during and after passing of Hurricane Milton. Top photo at 10/9/2024 (17:30) and bottom photo after the storm passed, 10/10/2024 (08:35).

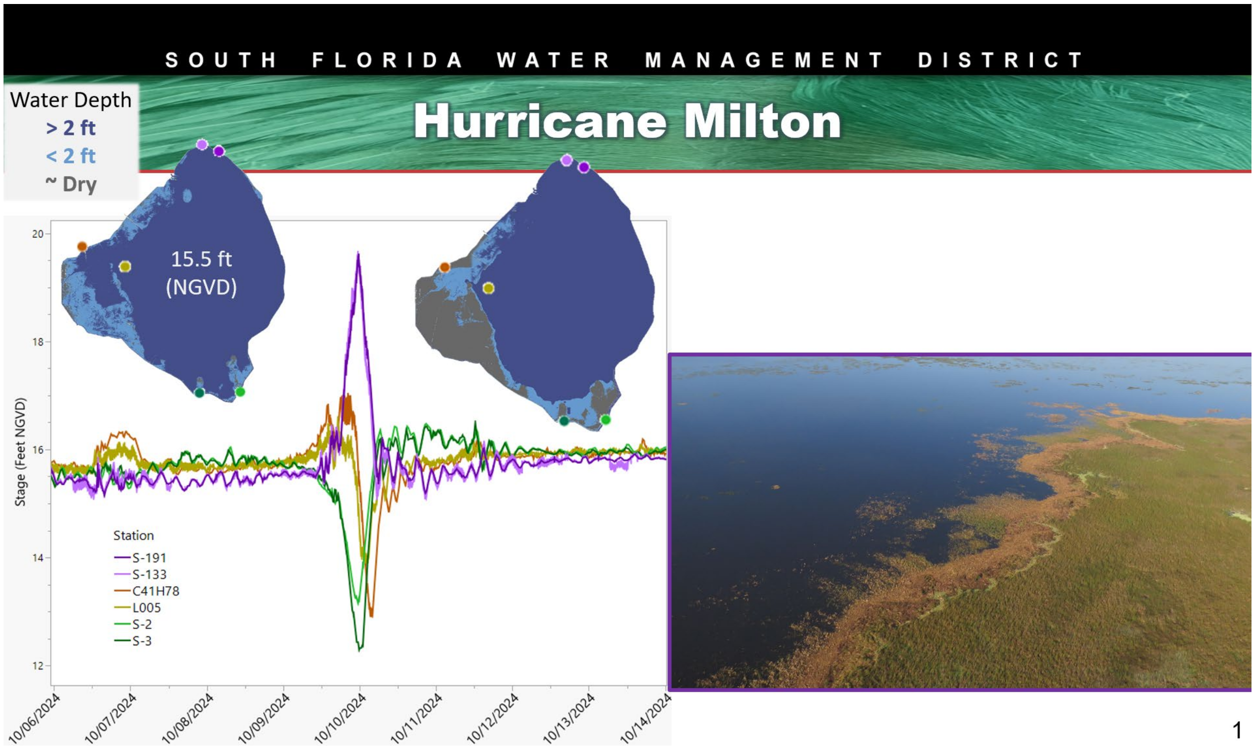


Figure 16. Seiche effect on Lake Okeechobee during passage of Hurricane Milton, as captured by stage recorders at several locations in the south, west, and north regions of the lake.

Figure 17. Broken links allowed the turbidity curtain to flag during the passage of Hurricane Milton, and remain anchored at one end for rapid reattachment.

6.3 Assessment Approach for Evaluating Effects on Turbidity and SAV Growth

The monitoring approach for the current project was multifaceted, combining SAV observations during each visit to established monitoring stations, with a field experiment where herbivore exclusion cages were planted with *Vallisneria*. Biweekly field measurements were conducted to characterize turbidity and monthly water sampling provided other supporting measures of water clarity. Finally, high-frequency collection of field measurements including turbidity was accomplished using multiparameter sondes deployed at key locations. Each of these study components is described in the following sections.

6.3.1 Photo-documentation

Photos representative of site conditions from within and adjacent to the project area were taken during site maintenance visits. The conditions within the project area, as influenced by the turbidity control system, were recorded through these photos and coincident field measurements of water clarity. Observations of wildlife trapped by and released from within herbivore cages were documented with photos. One gar was found trapped in an exclusion cage.

Overhead drone photos or flights were collected at the beginning, middle, and end of the study, capturing the entire study area and a buffer extending at least 100 m beyond the curtain area in all directions (Figure 18). The first of these events was conducted on June 5, 2024, in order to guide installation of the controls and anchoring systems. The second flight occurred on November 14, 2024, and the third flight occurred on April 29, 2025.

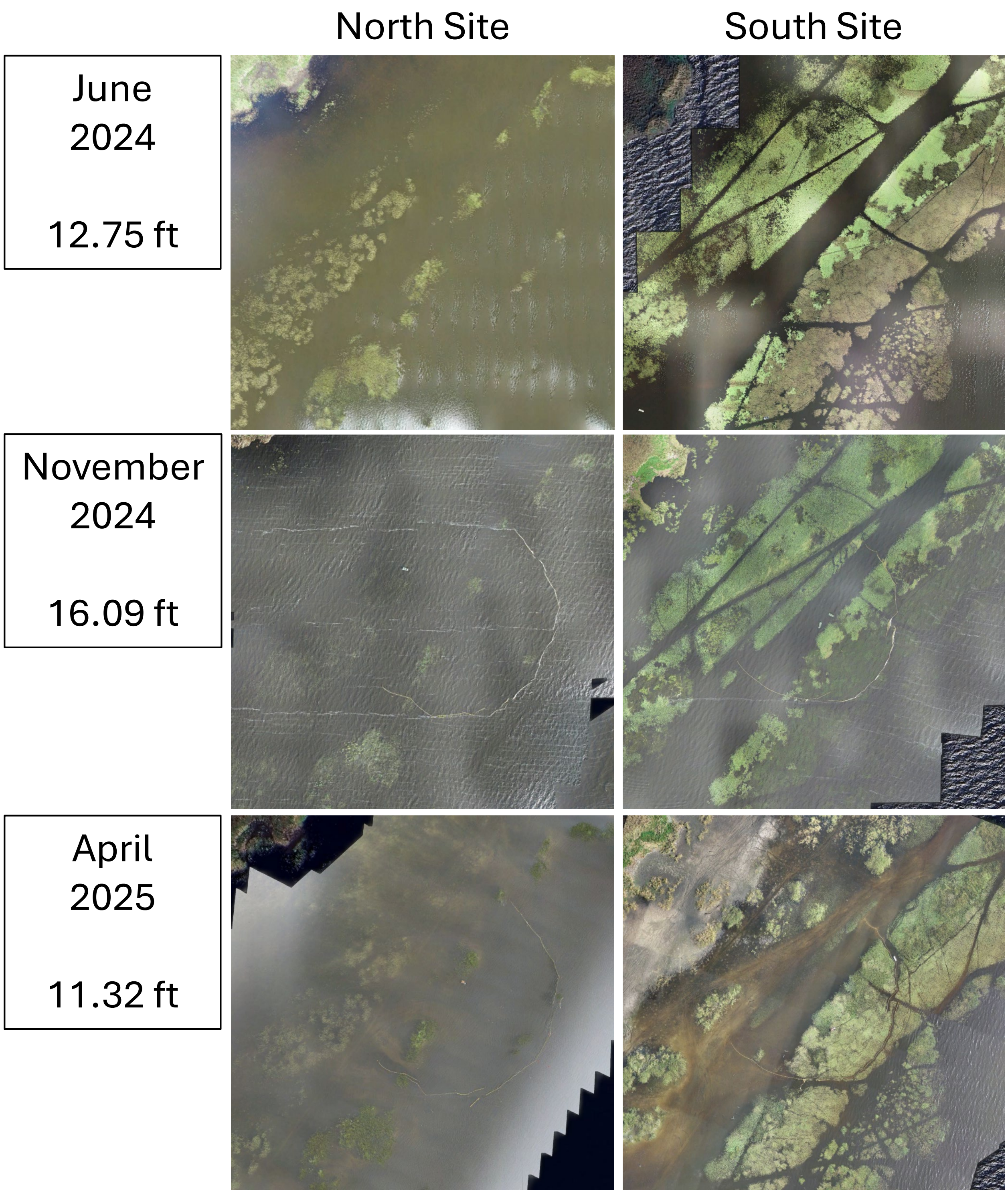


Figure 18. Aerial imagery of the North Site and South Site locations on three dates, corresponding to the initial planning period prior to installation (June 2024), high water conditons (November 2024) and low water conditions at the end of the project (April 2025). Lake stages are daily mean values in NGVD29.

6.3.2 Observations of SAV in and around the Project Area

6.3.2.1 Methods

Center-line transects containing five stations each were established ~perpendicular to the shoreline from the protected area behind the curtains (C1 In) to the nearshore region beyond and outside the curtains (C5 Out) at both the North Site and South Site (Figure 19). A transverse transect perpendicular to the center line (~parallel to the shoreline) was also established at each site at similar position relative to lake exposure, and distance from edge of littoral marsh. These transverse transects also included five stations: A2 out, B2 In, C2 In, D2 In and E2 Out. One station, C2-In, was included in both transects. The average value of stations "inside" and "outside" the turbidity controls installation was compared to assess efficacy. These stations along the center line transect and transverse transect were considered "primary" monitoring stations, routinely sampled and monitored throughout the project.

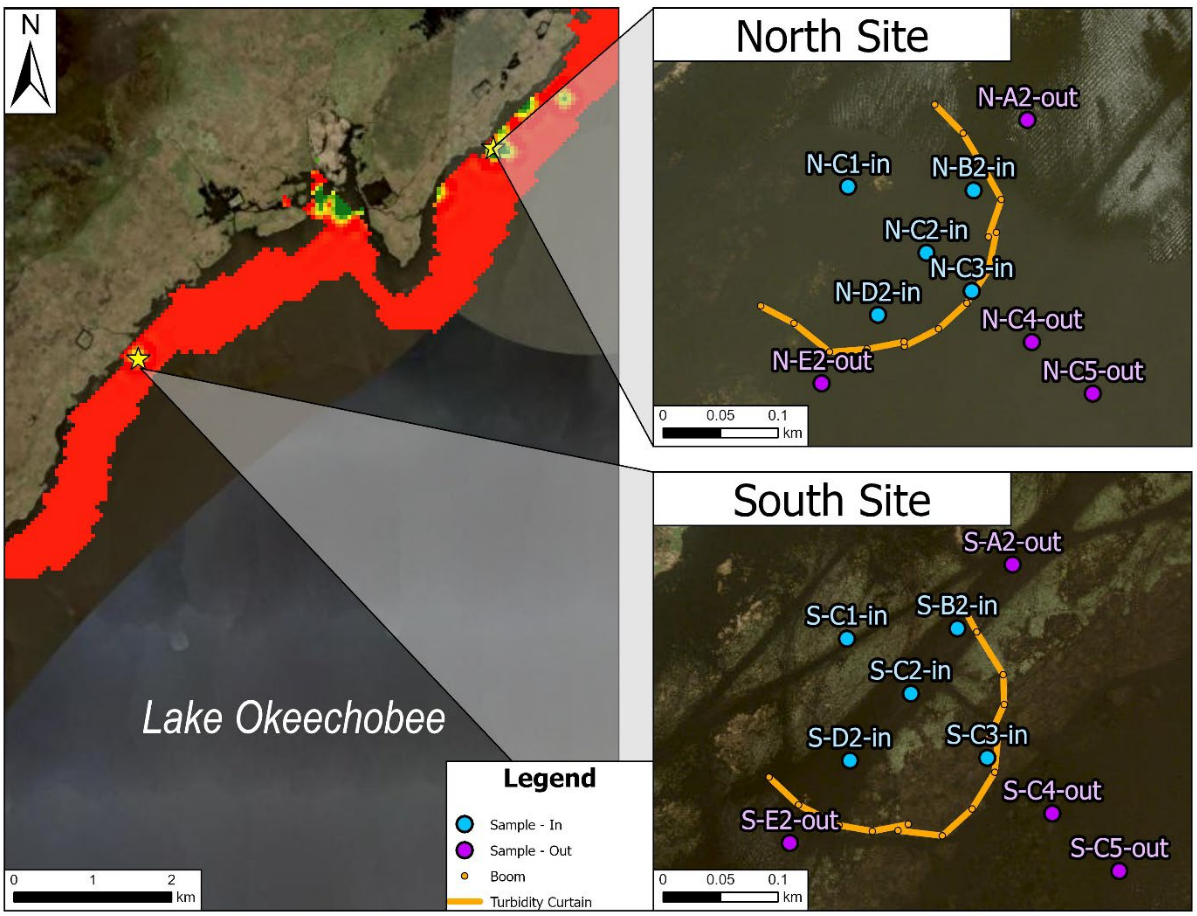


Figure 19. North Site and South Site locations selected for turbidity curtain installation along the northwest Lake Okeechobee nearshore region. Both sites are located near previously observed SAV beds from 2023 surveys conducted by FWC (Data provided by Zach Welch, District and Alyssa Jordan, FWC). North Site was located in more open waters with less emergent vegetation, while South Site had much denser emergent vegetation cut by antecedent boat routes.

At each station, presence of SAV was recorded in conjunction with Secchi depth readings, using a semi quantitative scale of relative abundance (0: absent, 1: trace amount, 2: 1-10% coverage; 3: >10 and < 33% coverage; 4: 33 to 66% coverage; 5 > 66% coverage), which has been used to quantify SAV coverage in the Everglades Stormwater Treatment Area (STA) wetlands for many years. The advantage of this approach is the ability to differentiate trace amounts of SAV from more established patches when coverage is < 33%. This 0-5 scale was used in the field to record observations of SAV coverage, and for presenting spatial coverage throughout the project areas on for specific events (Figure 20). In the STAs, the categories of <1%, 1-10% and 10-33% are aggregated into a single category (present at <33% coverage) so that a scale from 0-3 is used to represent equal-sized categories or "bins" for data analysis over space and time, where 0: absent; 1: present at < 33% coverage; 2: 33 to 66% coverage; 3: present at > 66% coverage (e.g., Dombrowski et al. 2023). For SAV coverage trends over time in the current project, the same approach was used to average coverage values from primary stations inside and outside the turbidity curtain installations.

An adaptive approach incorporated additional stations to increase coverage throughout the project area (secondary "random" locations) and adjust to changing conditions on the lake. For example, additional locations were added upon request by District science team at the December 2024 project update meeting (Task 3a). These transects were established southwest of the two project areas, and ran parallel to the center-line transect that bisected the controls installation ("C" transect). These outer transects provided a comparison of the conditions through the nearshore environment further away from the installed turbidity controls.

6.3.2.2 Results

In December 2024, no *Vallisneria* was observed within the primary stations in or around the North Site installation in December (Figure 20). *Vallisneria* was observed only at two locations along the added outer transects at the North Site, and only at minimal coverage (trace, < 1% coverage). At the South Site installation, *Vallisneria* was observed at two locations along the outer transects, and two locations within the turbidity control area.

During the period between April and June 2025, multiple monitoring trips were made to each site as part of the project monitoring plan, and to additional stations to document SAV coverage. During this period, *Vallisneria* was observed at many locations to the north and west of the controls at the South Site, shoreward of the controls (Figure 21. and Figure 22), while only a few observations at trace levels were made along the outer transects there. While not sampled earlier in the study, the additional sample sites added in the spring/summer of 2025 documented a substantial SAV presence within and extending north of the southern project site, some of which was part of a known patch that survived Hurricane Milton (SFWMD staff observations). This area dried out during the low stage period between late April and early July 2025, and a seasonal minimum lake stage of 10.9 ft on May 24, 2025 left many areas temporarily dry and inaccessible for further observations or water sampling.

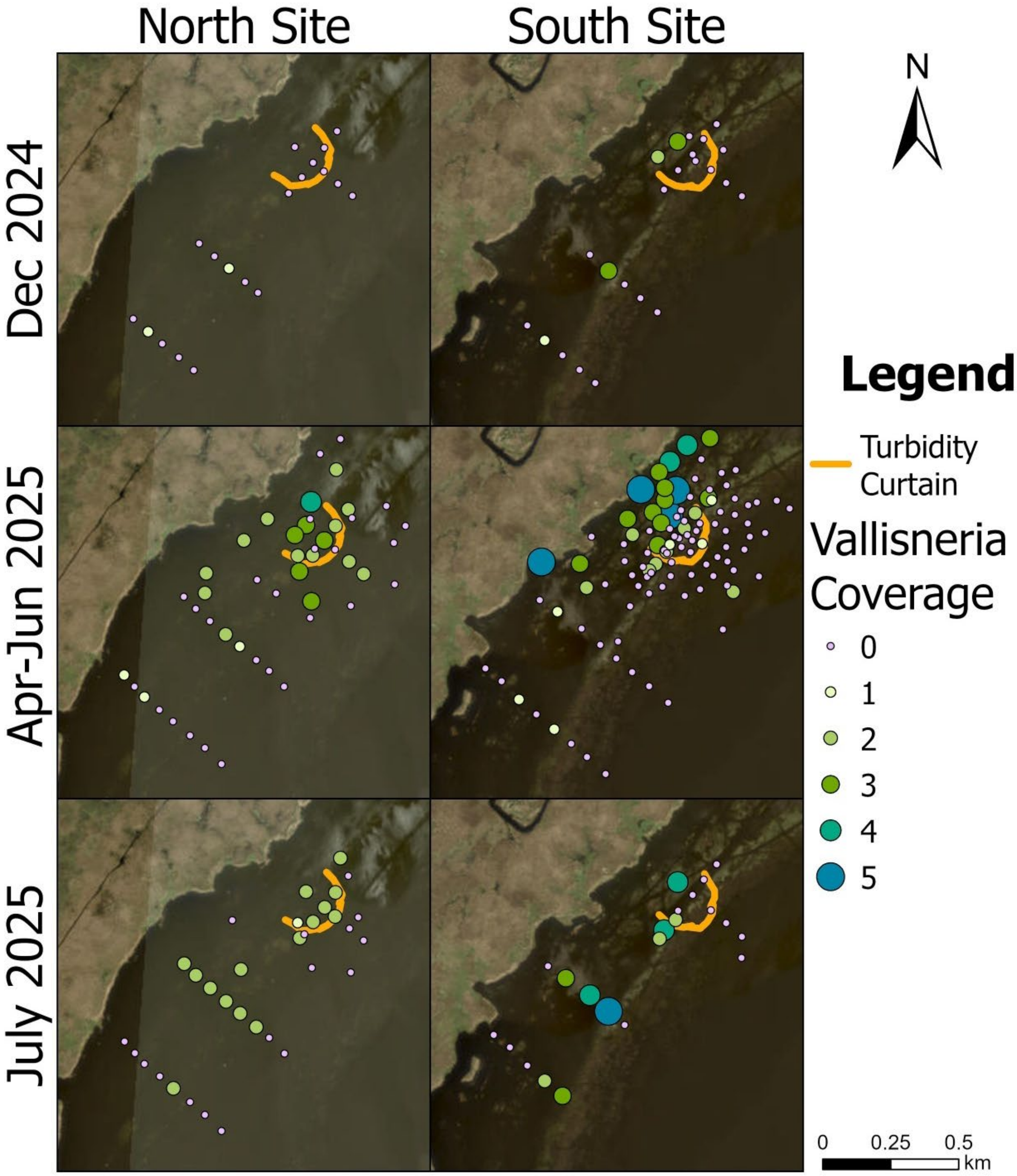


Figure 20. Relative coverage of *Vallisneria* at locations monitored during December 2024, April–June 2025, and July 2025 periods, at two project areas in Lake Okeechobee.

Figure 21. Station SR048 toward the edge of the littoral marsh northwest of the turbidity controls at the South Site, on April 16, 2025, when lake stage was 11.94 ft NGVD29 and water depth was 7 cm. This area was dry within weeks.

Figure 22. Station S-C1 In at the South Site on June 18, 2025, showing natural recruitment of Vallisneria in shallow water (6 cm) when lake stage was at 11.09 ft NGVD29. This location with inside the turbidity controls.

The same patch of Vallisneria was visible in FWC's SAV map from 2023 and was part of the rationale for locating the project site there (Figure 23a). When wind data is overlayed with the SAV data, it appears that the turbidity controls may have provided some protection from the greatest fetch as the storm passed (Figure 23b), with winds increasing in speed from the east, southeast, and then south, before becoming westerly and buffered by the marsh (Figure 24). These are anecdotal data but may explain why the SAV patch just on the north edge of the project site was the only one known to have survived over the winter. At the North Site, where less littoral protection existed, SAV present in FWC's 2022 SAV map (Figure 19) did not appear to survive the storm, with only two samples having small *Vallisneria* in the project area in December 2024 (Figure 19), and SFWMD staff noting only barren, sandy shores in the area by spring 2025. However, by the end of the monitoring period (July 2025), multiple locations showed small *Vallisneria* plants reestablishing in the area (Figure 20).

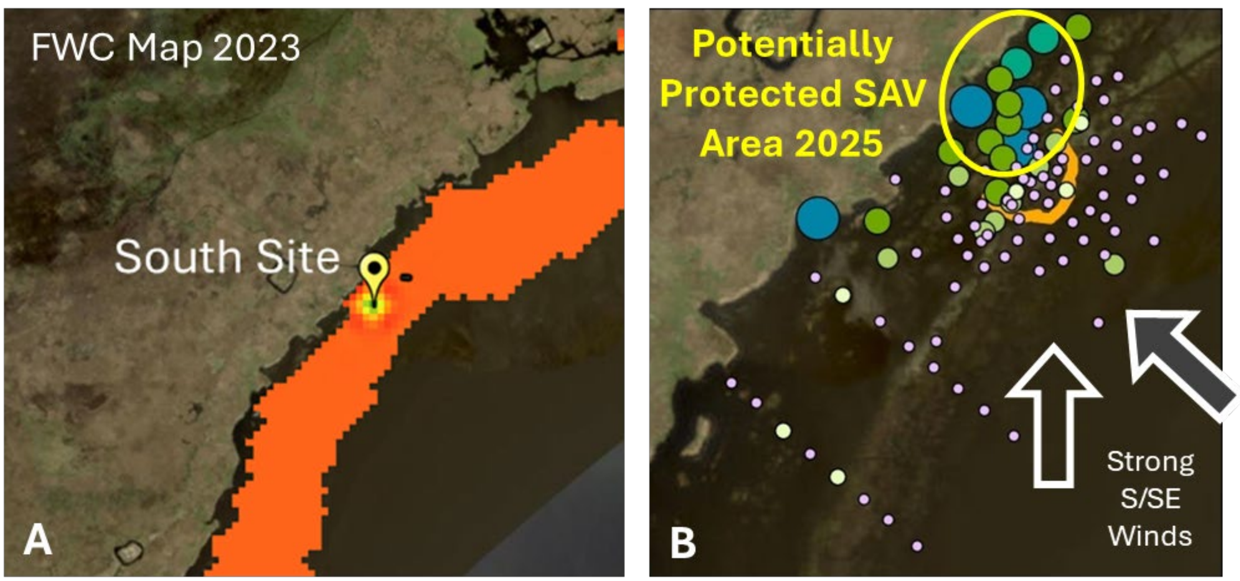


Figure 23. (A) Location of a dense, higher abundance SAV patch that had survived 2022's Hurricane Ian, documented in a 2023 FWC survey. (B) The same location and SAV abundance in the summer of 2025, relative to direction of strong winds across the largest fetch that occurred during Hurricane Milton (October 2024).

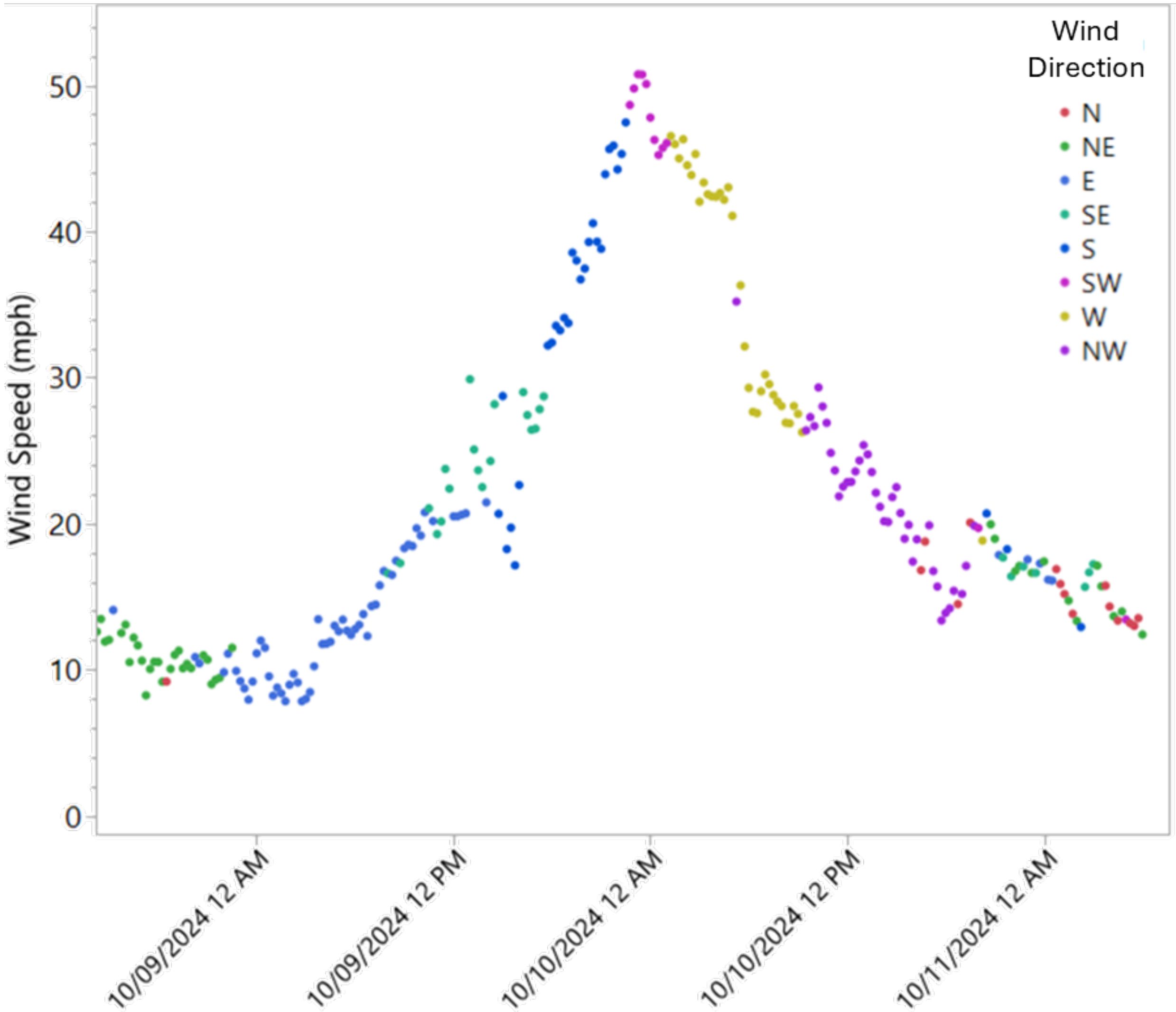


Figure 24. Wind speed and direction on Lake Okeechobee during Hurricane Milton in October 2024, as measured at the L001 platform. Peak winds from the SW and W were buffered by marsh vegetation and lower fetch in the project area.

6.3.3 Plant Growth Experiment

6.3.3.1 Methods

SAV recovery within the study area was anticipated if a reduction in turbidity was achieved by the project and light penetration increased. To understand whether regrowth was hampered by lack of viable propagules or herbivory, a plant experiment was conducted. This understanding would guide follow-on restoration efforts. Twelve exclosure cages were placed on the lake bottom on September 17, 2024, to prevent large herbivores from feeding on SAV that begins to regrow should light conditions improve (Figure 25).

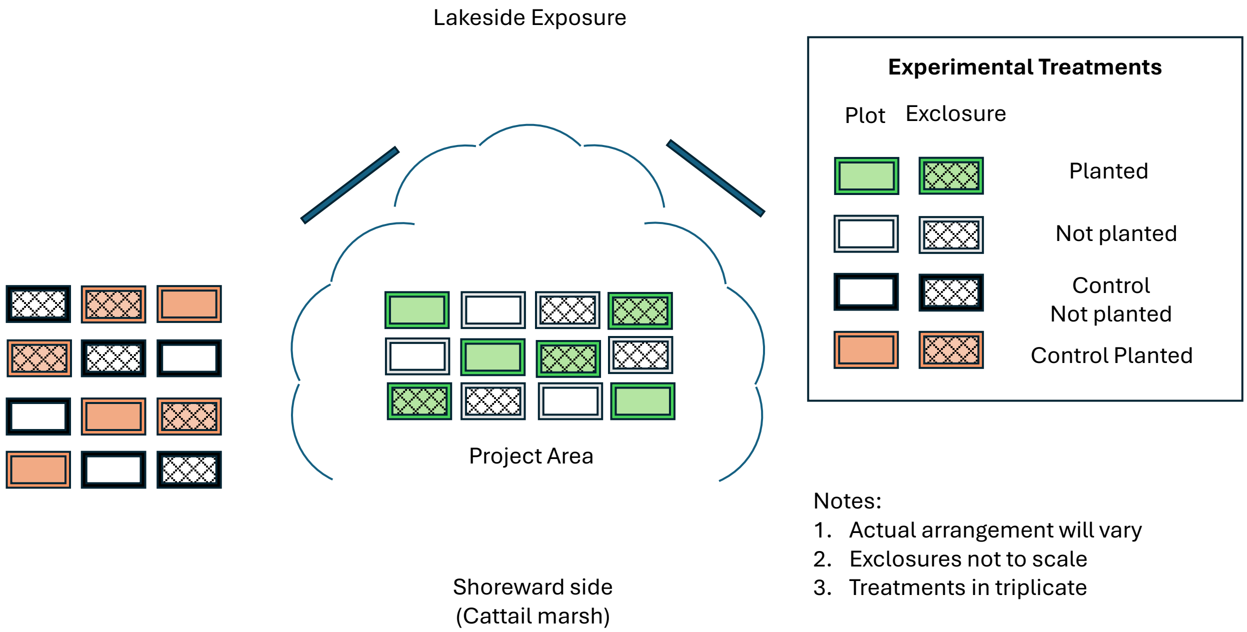


Figure 25. Schematic of exerimental treatments for evaluating turbidity control and herbivory influence on SAV recovery.

Each exclusion cage ("Cages") was constructed to enclose approximately 3 m x 1 m area of lake bottom, with a 1" mesh at approximately 2 ft off the lake bottom. SAV growing beyond the mesh was subject to grazing pressure, but the protected area within cage allowed plant development if conditions were otherwise conducive.

During the initial deployment, one subset of cages inside the turbidity controls project area was planted with *Vallisneria neotropicalis*, to ensure that some SAV biomass was present to allow determination of growth under suitable conditions. Each planted cage or frame was planted with two planting units, which consisted of *Vallisneria* plants in a 1-gal potting media, enclosed in a cotton sack for placement into the lake experiment. If plants did not survive in the exclusion cages, it was hypothesized that light conditions were not sufficiently improved by the turbidity controls to support SAV. Another set of cages were left unplanted to assess the seedbank and regrowth potential of the project area. Planted and unplanted plots of similar size but without the full mesh enclosure ("Frames") were included (a 2 x 2 factorial design) to determine if the response of plants and/or regrowth from sediment is the result of herbivore exclusion rather than light availability. If light conditions sufficiently improved within the project area ("Inside"), plant survival and growth was expected within the planted Cages where the top mesh prevented herbivory, even if no seed bank or SAV regrowth was observed within the project area.

Since the focus of the current project was on evaluating the effects of turbidity controls, plots outside the turbidity curtains ("Outside") were established by placing additional Cages and Frames on the lake bed with or without plants added. Direct planting without the protection of turbidity controls and/or herbivore exclusion cages was not expected to result in survival of the SAV. However, treatments with plants added outside the turbidity controls, where the light environment has not been improved by the turbidity controls, assessed whether a lack of biomass was the main limitation to SAV recovery. In this case, the “controls” of this experimental design were outside the “turbidity controls” defining the project area.

Each treatment (Planted and Unplanted, Cages and Frames) was established in triplicate. This design was deployed Inside and Outside the curtains and repeated at both the North and South project sites. Unfortunately, Hurricanes Helene and Milton dislodged the plant experiment cages and frames, so the experiment was abandoned until spring 2025, when a subset of treatments was reinitiated.

On April 28, 2025, six Cages and six Frames were reestablished at the South Site project area, three of each both Inside and Outside the turbidity controls (Figures 2626 through 29). Each Cage or Frame was planted with two planting units, which consisted of *Vallisneria* plants in a 1-gal potting media (313 mg/kg P; 0.3% N; 93% ash-free dry weight; 1.0 g/cm^3 bulk density), enclosed in a cotton sack for placement into the lake experiment. Initial plant metrics were based on measurements of 5 planting units (pots). The experiment was not repeated at the North Site, and unplanted treatments were not included in the follow-on study. However, it was observed that small patches of *Vallisneria* were becoming established within and around the project area. Observations of the *Vallisneria* Cages and Frames were conducted on several occasions from the time of planting to the time of final plant collection. During these observation events, new growth of leaves and overall condition were recorded for each planting unit. On July 9, 2025, all plant material was collected from Cages and Frames to determine dry weight, shoot length and number of leaves per ramet from each treatment after 72 days on the lake.

Some amount of planted material was recovered from all planted units during the spring 2025 experiment. For each Cage or Frame, the collected plant material was associated with one of the two planted units. Where no association was apparent to an initial planting unit, the biomass was assigned to a third sample (“Other”). Any SAV other than the planted taxa (*Vallisneria neotropicalis*) were collected in aggregate from the entire Frame or Cage. This sampling approach resulted in two individual plant samples from most Experimental Units (individual Frames or Cages), while several had additional SAV samples from non-planted taxa. For each plant sample, ten random ramets were selected to determine number of leaves per ramet and length of tallest leaf per ramet. Subsequent to these measurements on the subset of 10 ramets per sample, plant biomass was dried from the entire sample to determine dry weight. For statistical testing, the replicate plants (N=2) per treatment unit and replicate units (N=3) per treatment were combined for a total of 2 x 3 x 10, or N=60 measurements of leaf length and number of leaves per treatment. The dry weight from both plant samples per treatment unit (each replicate Cage or Frame) was combined. This resulted in N = 3 per treatment for dry weight.

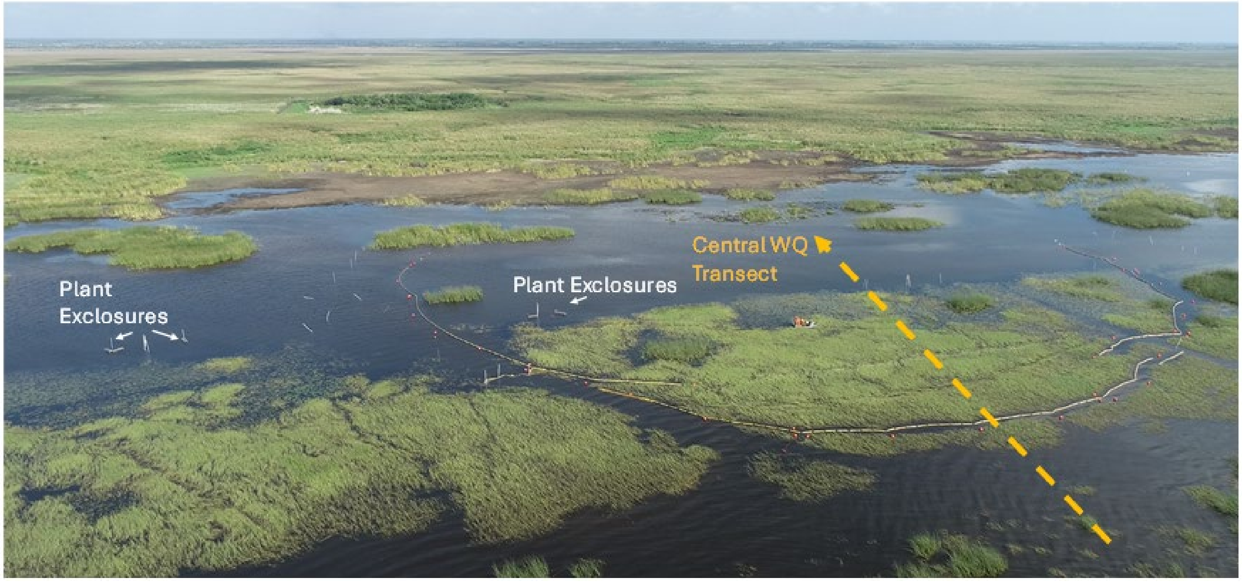


Figure 26. Planting units were deployed into Exclosure Cages and Open Frames inside and outside the turbidity controls.


Figure 27. Each planting unit consisted of multiple ramets within a cloth sack containing soil.

Figure 28. Open Frames with planting units being deployed on April 28, 2025 at the South Site project area.

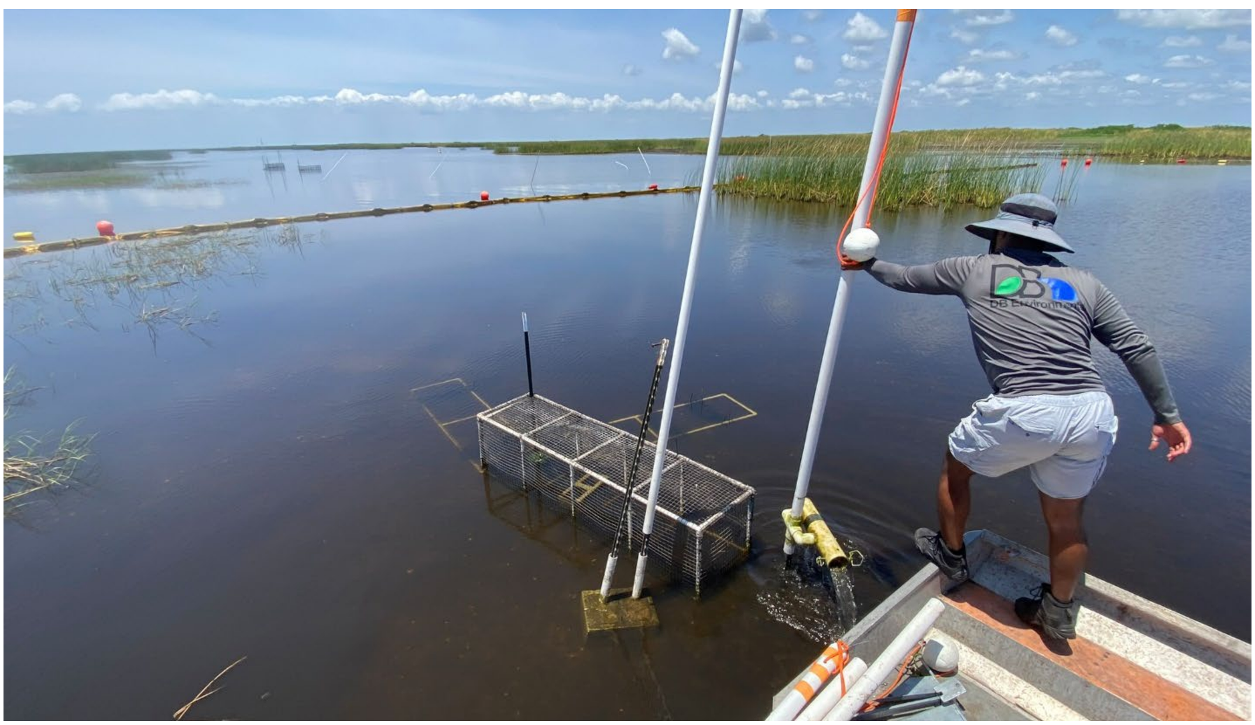


Figure 29. Frames and Cages were nested at multiple locations, with each treatment established in triplicate.

6.3.3.2 Results

Metrics of plant growth in herbivore exclusion Cages and open Frames evaluated the potential for herbivory to impair SAV recovery. Visually, plant biomass development was far greater within the exclusion Cages than in open Frames (Figures 30 through 33).

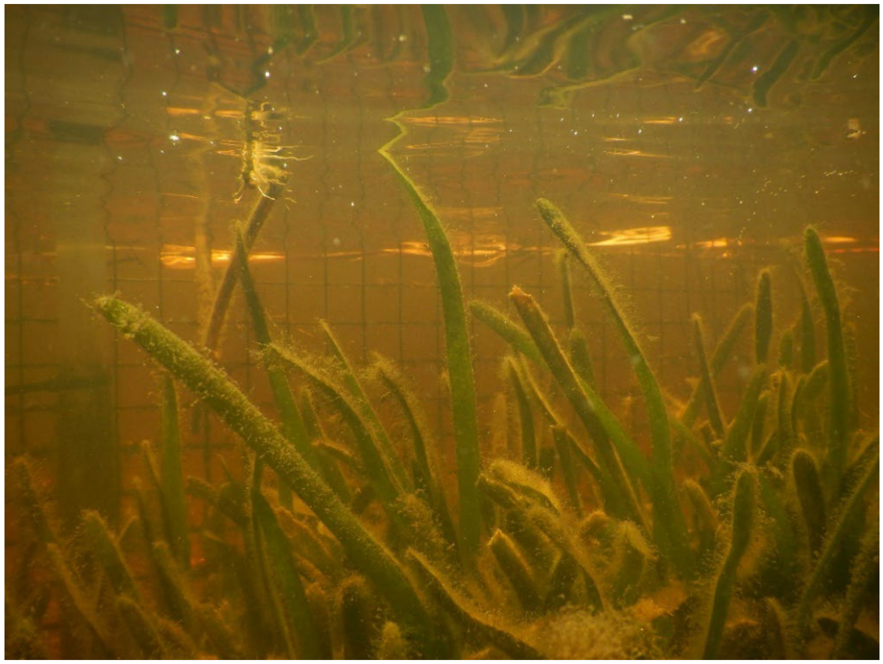


Figure 30. Underwater view of *Vallisneria* within herbivore exclusion cage.

Figure 31. Underwater view of *Vallisneria* within planted Frame, open to herbivory. Mesh held the planting unit, which was comprised of plants rooted within soil in a cloth sack, in place on the lake bed to allow root growth and plant expansion while providing only limited protection from herbivory. Leaves extending beyond the protection of the mesh around the soil sack were subject to grazing.

Figure 32. Plant biomass collected from Cage at completion of the Plant Growth Experiment on July 9, 2025. Note the plant bed did not extend outside the rectangular dimensions of the protected cage area.

Frame Only (Not Fully Caged) | Herbivore Exclusion Cage

Figure 33. Plants collected after 72 days of growth in Lake Okeechobee from open Frames (left) and exclusion Cages (right).

Quantitatively, initial plant biomass was 3.0 ± 1.0 g dw/pot or 6 g dw per experimental unit (Cage or Frame, which received two pots on Day 0). At the end of the 72-day study, clear differences in plant dry weight were observed between Cages and Frames (Figure 34). These differences were consistent with greater length of the leaves and number of leaves per ramet in Cages than Frames (Figure 35).

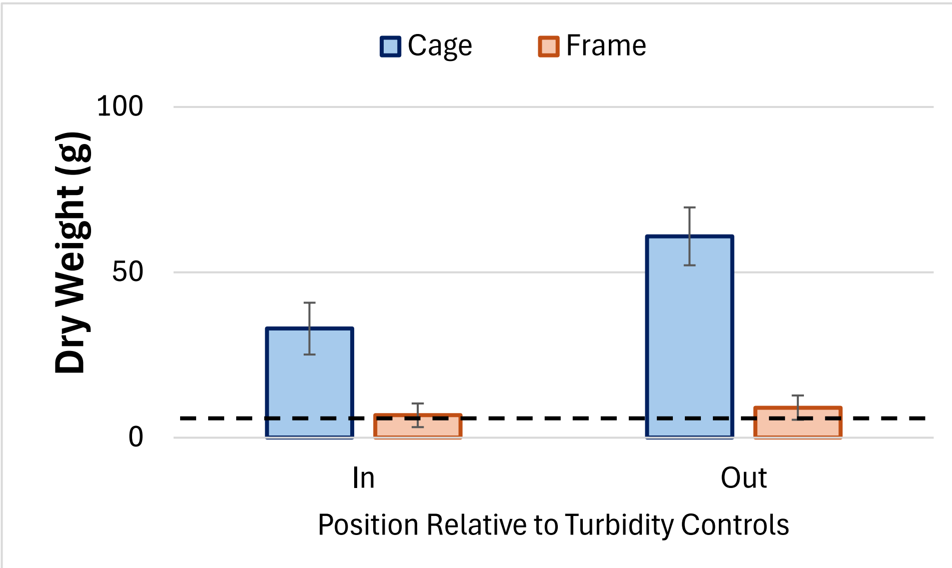


Figure 34. Dry weight of plant biomass within exclusion Cages and Frames after 72 days, compared to initial dry weight of plants added. Error bars denote standard error around the mean of triplicate experimental units (Frames or Cages).

Mean (± SE) number of leaves per ramet and length of tallest leaf per ramet for *Vallisneria* for plants (N=60 per treatment group) and dry weight (N=3 per treatment group) recovered from locations inside and outside the turbidity controls were significantly different between Cages and Frames (two-way ANOVA $p<0.05$ for leaves per ramet, leaf length, and dry weight), while location was not a significant factor (two-way ANOVA, $p = 0.38$ for leaves per ramet, $p=0.85$ for leaf length, and $p = 0.08$ for dry weight). Thus, overall plant growth was improved within the protection of the cage (Figure 36). Importantly, the additional leaf length in caged plants would provide increased access to light higher in the water column. The benefits of exclosure cages to *Vallisneria americana* transplants has been previously shown, where protection during the first year led to successful reestablishment in later years despite herbivore pressures (Carter and Rybicki 1985). *Vallisneria* forms belowground, overwintering propagules to store energy reserves that allow rapid leaf elongation in the spring. The potential for exclusion cages to reestablish plants (including belowground reserves) after several years of unfavorable conditions and low plant coverage is a key finding from this pilot project and deserves further consideration.

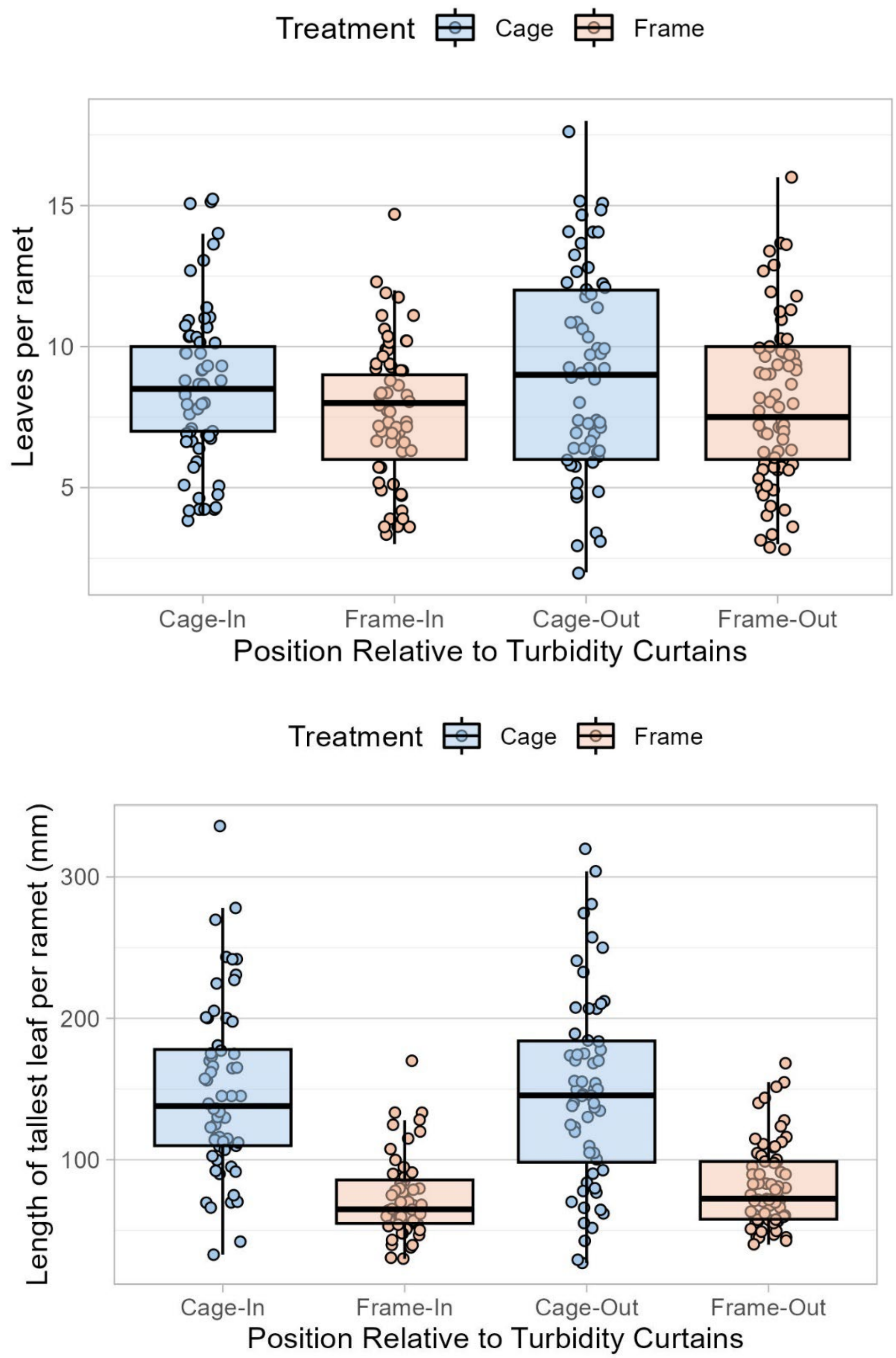


Figure 35. Mean (± SE) number of leaves per ramet (top panel) and length of tallest leaf per ramet (bottom panel) for *Vallisneria* for plants (N=60 per treatment group) recovered from locations inside and outside the turbidity controls.

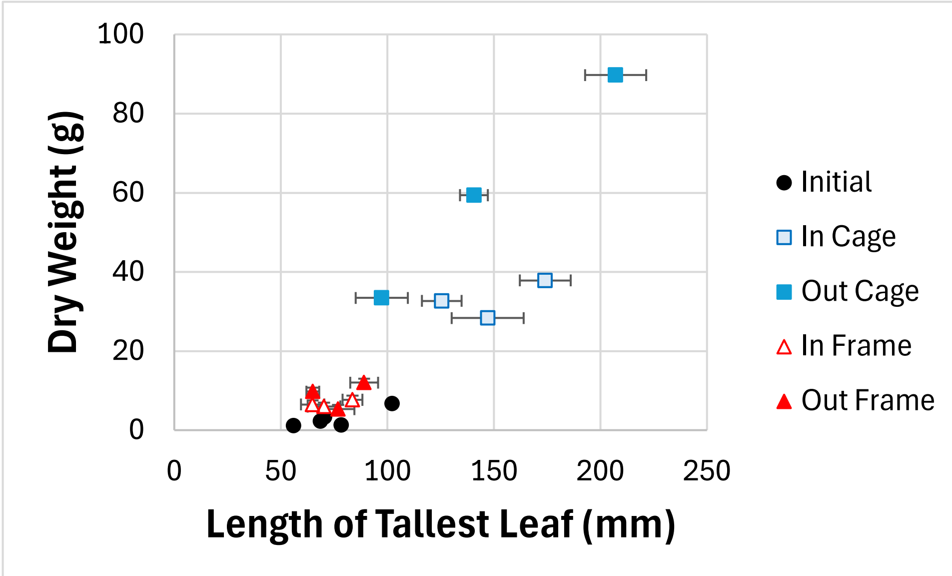


Figure 36. Relationship between leaf length and dry weight for initial (Day 0) and final (Day 72) *Vallisneria* plants. Error bars denote the standard error around the mean of leaf lengths for N=20 ramets per treatment for each of three replicates under each treatment. Initial dry weight is represented by individual planting units (one pot), while final dry weights represent the total biomass per replicate experimental unit (Cage or Frame), each of which initially received two pots planted on Day 0 (April 28, 2025).

6.3.4 Light Attenuation in Lake Okeechobee Surface Waters

6.3.4.1 Methods

Photosynthetically active radiation (PAR) at 400-700 nm was measured with a LI-COR LI-250A light meter with spherical quantum sensor (SPQA4133) above and below the water surface and near (27 cm above) the sediment surface at primary monitoring locations where vegetation observations were made, and water samples were collected. Along with PAR, measurements of total water depth, Secchi depth, and turbidity at the primary stations were recorded twice monthly during daytime site visits to both North and South Sites. Additional PAR measurements were made to determine vertical light attenuation with depth and calculate the light attenuation coefficient, k (Figure 37). $I_z = I_0e^{-kz}$, where I_z is the light intensity at depth, z, and I_0 is the light intensity immediately below the surface (depth = 0).

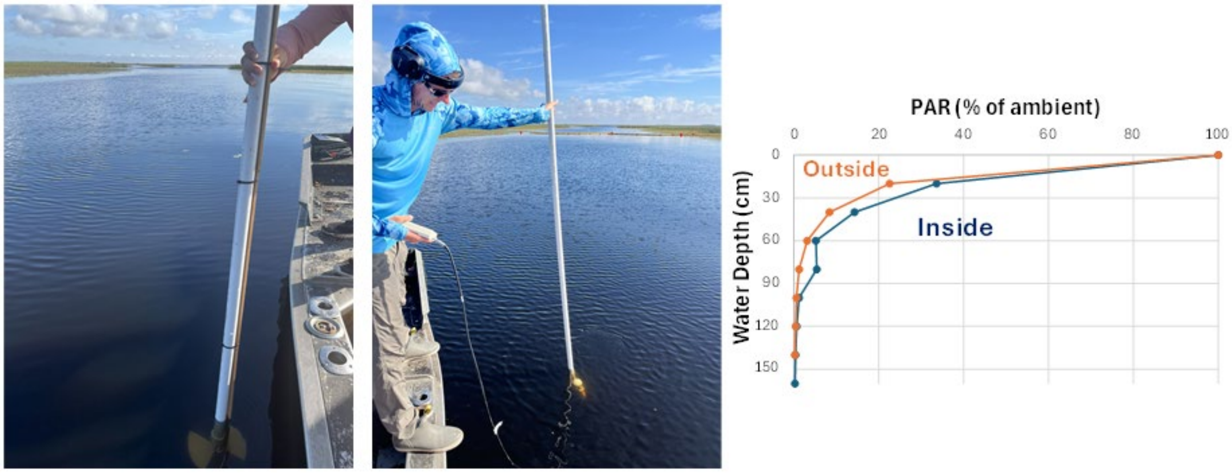


Figure 37. Example of photosynthetically active radiation (PAR) changes with depth at a pair of locations inside and outside the turbidity controls. Secchi depth was measured along with PAR to characterize light conditions within the water column.

A relationship between light attenuation coefficient and turbidity was established using vertical profiles of PAR throughout the project area and period of record, under a range of turbidity levels. Using that relationship, a target turbidity level was developed where light penetration through 1 m water would provide 1% of ambient light levels, approximately equivalent to the PAR threshold for net growth of *Vallisneria* established by previous work in Lake Okeechobee (Grimshaw et al. 2002). The outcome of this effort is described further below, in Section 6.5.

Water sampling focused primarily on water clarity parameters within the project area, and leveraged the monitoring effort and data collected by existing SFWMD sampling programs. Monthly sampling characterized the nature of particles within and external to the project area. Total suspended solids (TSS), non-volatile suspended solids (NVSS), color, and chlorophyll *a* (Chl-a), were sampled at primary monitoring locations (Table 1). The turbidity, bottom PAR and WQ constituents were examined spatially with this network of monitoring stations, to test whether water quality inside the curtains was different than outside the curtains.

Table 1. Surface water chemical parameters analyzed for this project along with their associated analytical methods and method detection limits (MDL).

Analyte	Method	MDL
Color - Apparent	SM 2120 B-2011	5 PCU
Total Suspended Solids	SM 2540 D-2015	1.0 mg/L
Non-Volatile Suspended Solids	SM 2540 E	0.4 mg/L
Chlorophyl *a*	SM 10200H	0.3 µg/L

6.3.4.2 Results

A decrease in turbidity, TSS, NVSS, and apparent color was often observed along the center line transect from C5, outside the curtains, toward C1, within the protected area behind the curtains.

For example, at the South Site on November 12, 2024, this trend was observed (Figure 38). At the same time, Chl-a and true color increased along the same transect. True color reflects the contribution of dissolved constituents in the water that absorb light. Phytoplankton is another component of the light-absorbing constituents within the lake water column, but is also a potential response variable to the turbidity controls. Using Chl-a as a proxy for phytoplankton biomass, increasing Chl-a with proximity to the littoral marsh was consistent with a phytoplankton response to the reduced turbidity and increased light availability. As TSS and inorganic NVSS decreased, Chl-a increased in response to the improved light availability.

Turbidity along both center-line and transverse transects are shown for several dates in Figure 39 (9/30/2025, before Hurricane Milton), Figure 40 (10/15/2025, after Milton passed north of the lake), and Figure 41 (March 5 and 19, 2025). On September 30, 2024, turbidity at the North Site was nearly twice that of the South Site, and nearly uniform along both transverse transects at either site. A reduction from 6 to 3 NTU was observed along the center-line transect at the South Site (Figure 39). After Milton, similar trends were observed, with turbidity being reduced by about half at the South Site, yet little change was observed at the North Site (Figure 40). Turbidity at both sites had nearly doubled on October 15, as compared to the September 30 sampling event. While Milton was a high wind event, the conditions at the time of sampling were mild, with wind speeds less than 10 mph as recorded at nearby L001 and L005 monitoring locations (see insets in Figure 40).

Sampling events in March 2025 showcase the efficacy of the curtains under windy conditions at the time of sampling. On March 5, the lake stage was at 13.61 ft and water sample collection at the North Site occurred during ENE winds at 15-20 mph. Turbidity was very high in March (Figure 41), compared to the events on September 30 or October 15, 2024, or any other daytime sampling event during the monitoring period (Figure 43). Despite relatively shallow water, bottom PAR was low at the North Site on March 5 due to extreme turbidity (Figure 42). Light levels were slightly higher within the curtains than outside, and above the threshold of 29 µmol photons/m^2/s below which no net growth was observed for *Vallisneria* in previous research (Grimshaw et al. 2002).

On March 19, 2025, when water sampling occurred at the South Site, the lake stage was at 13.03 ft and the bottom was clearly visible under shallow conditions. Turbidity was reduced from 27 NTU at the lakeward station to 9 NTU inside at station S-C1-In (Figure 41). Smaller reductions were seen when the inside locations were compared to outside locations along the transverse transect. Bottom PAR readings increased from 8 to 380 µmol photons/m^2/s along the center line transect at the South Site on March 19, a marked improvement in light conditions for SAV growth (Figure 42). PAR values were elevated all along the transverse transect on that date, and were high at both the two outside stations (244 and 305 µmol photons/m^2/s) and the inside locations (171 – 300 µmol photons/m^2/s) of that transect.

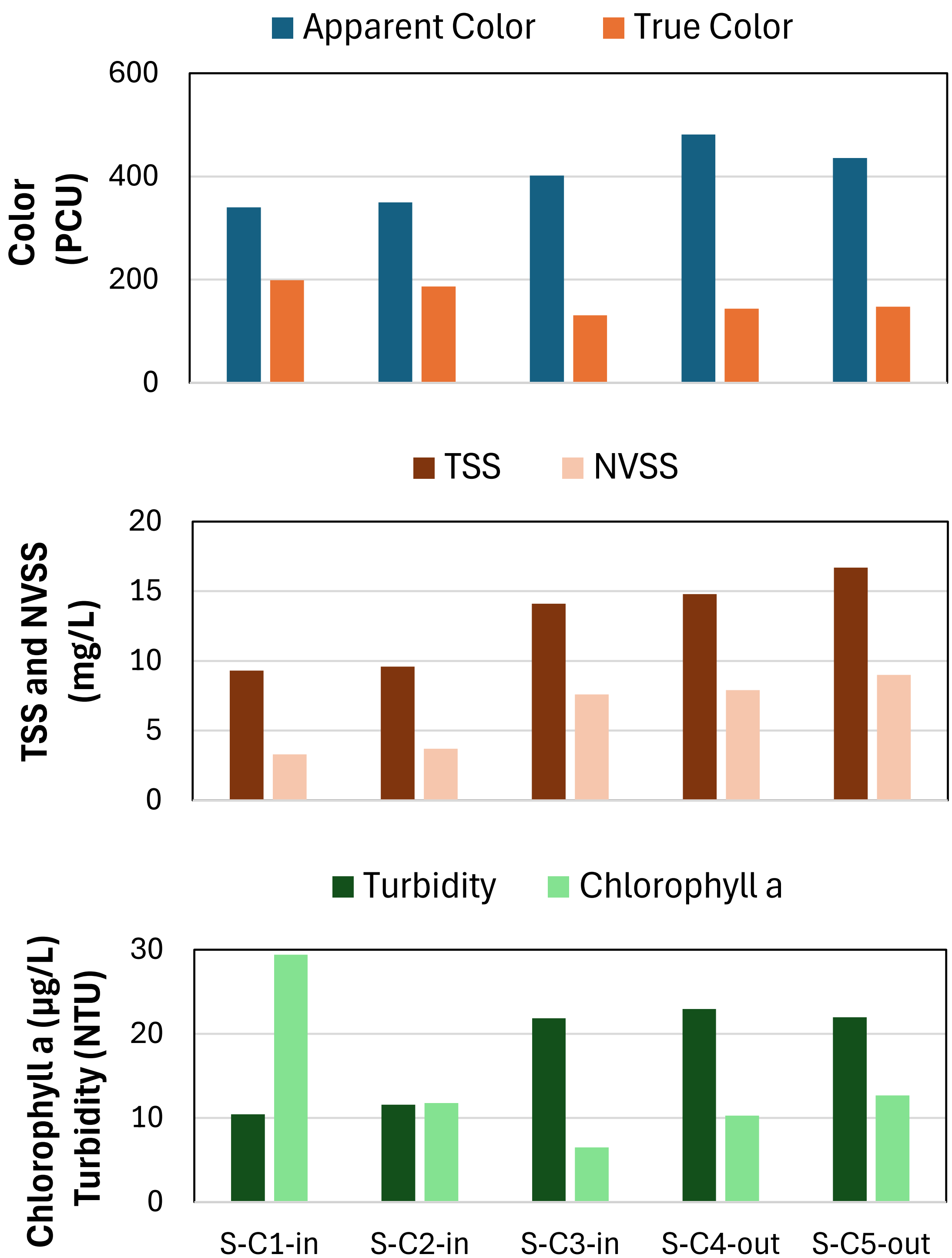


Figure 38. A center-line transect sampling event on November 12, 2024, at the South Site location showed changes in water quality parameters from the station furthest inside the turbidity controls (C1 In), extending lakeward to C5 Out.

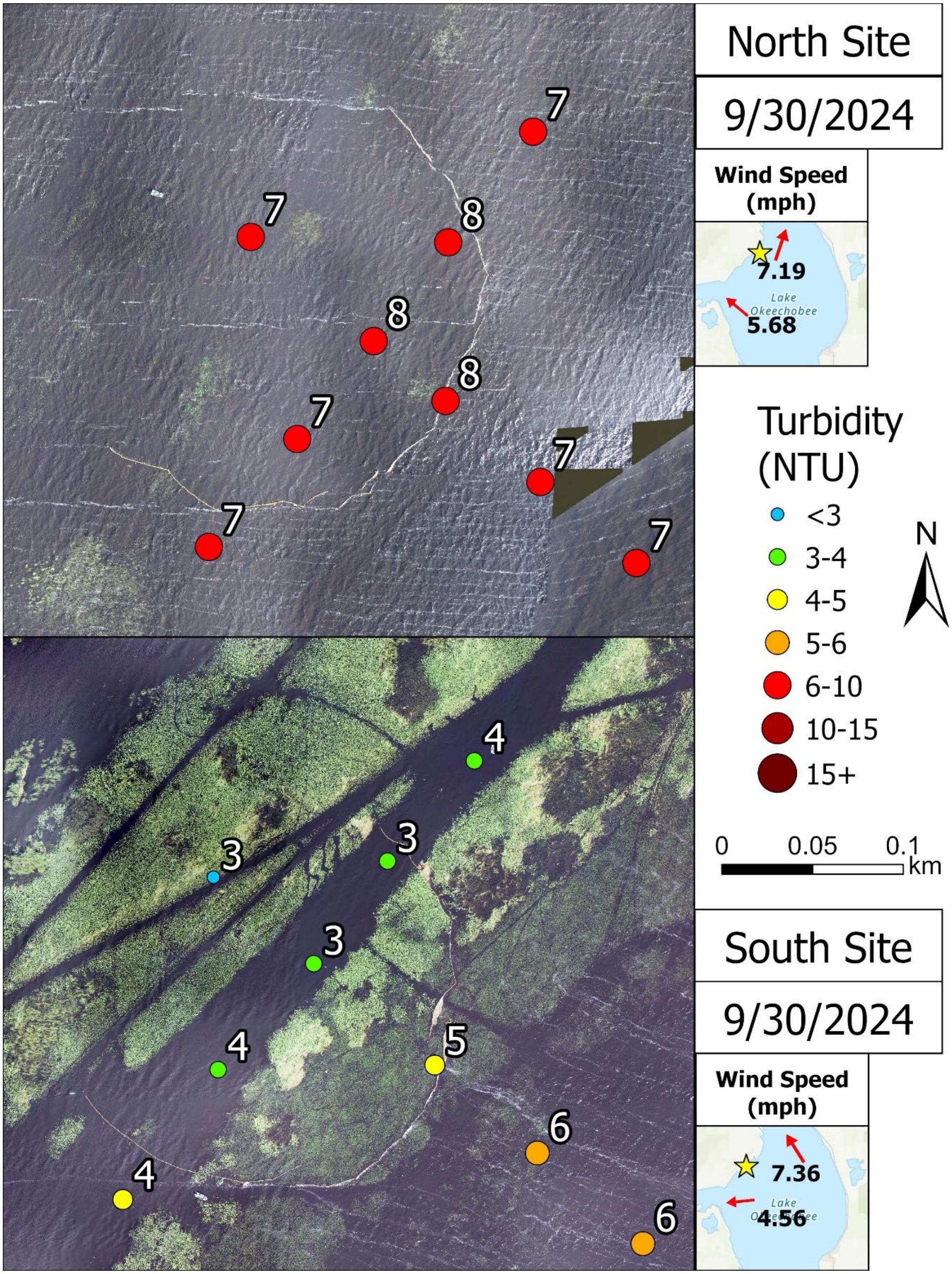


Figure 39. Turbidity at stations along centerline and transverse transects through North Site and South Site locations on September 30, 2024, four days after the passing of Hurricane Helene. Inset shows wind speed and direction during the time of sampling, as measured at two District monitoring locations (L001 and L005).

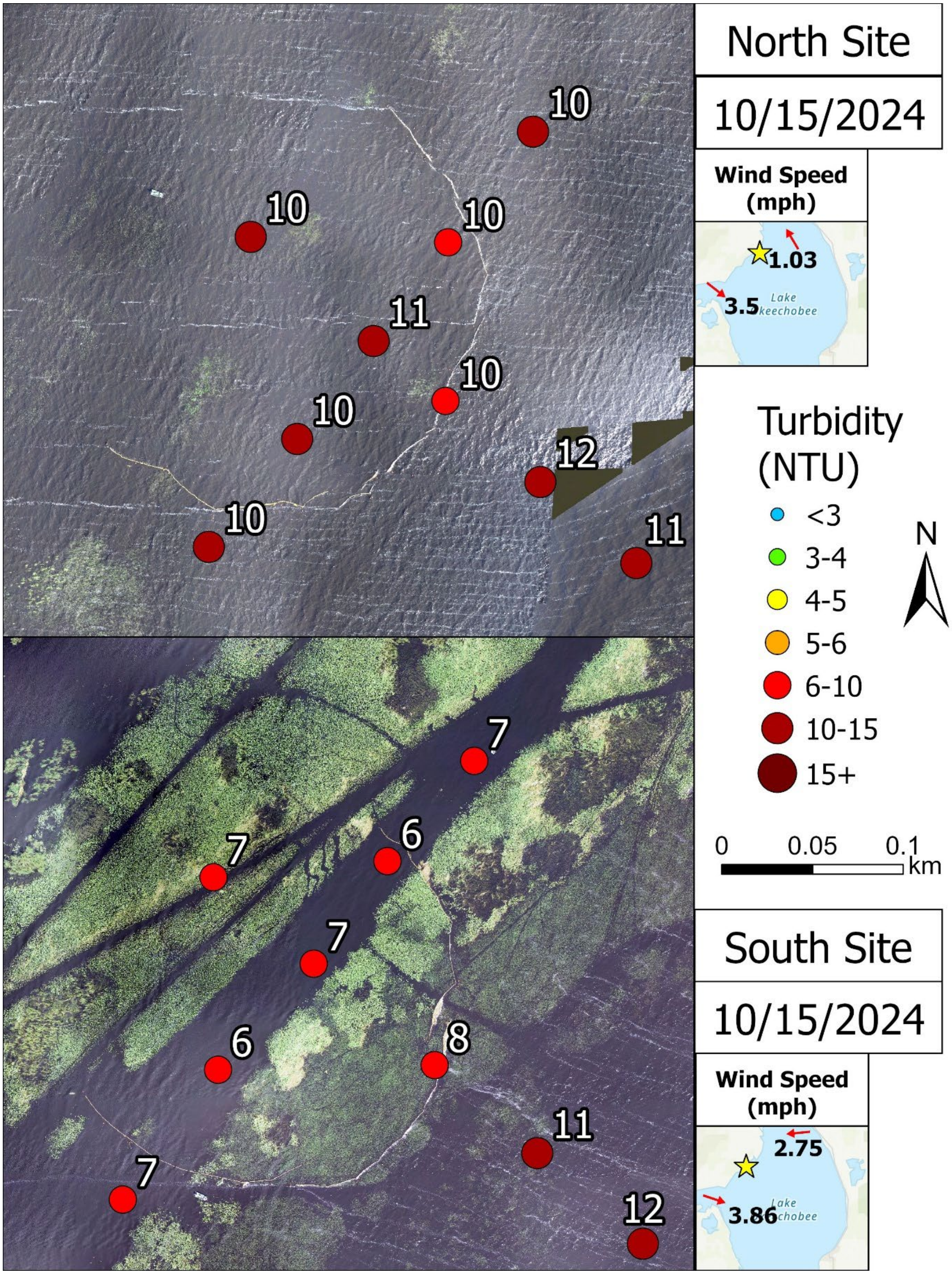


Figure 40. Turbidity at stations along centerline and transverse transects through North Site and South Site locations on October 15, 2024, five days after the passing of Hurricane Milton. Inset shows wind speed and direction during the time of sampling, as measured at two District monitoring locations (L001 and L005).

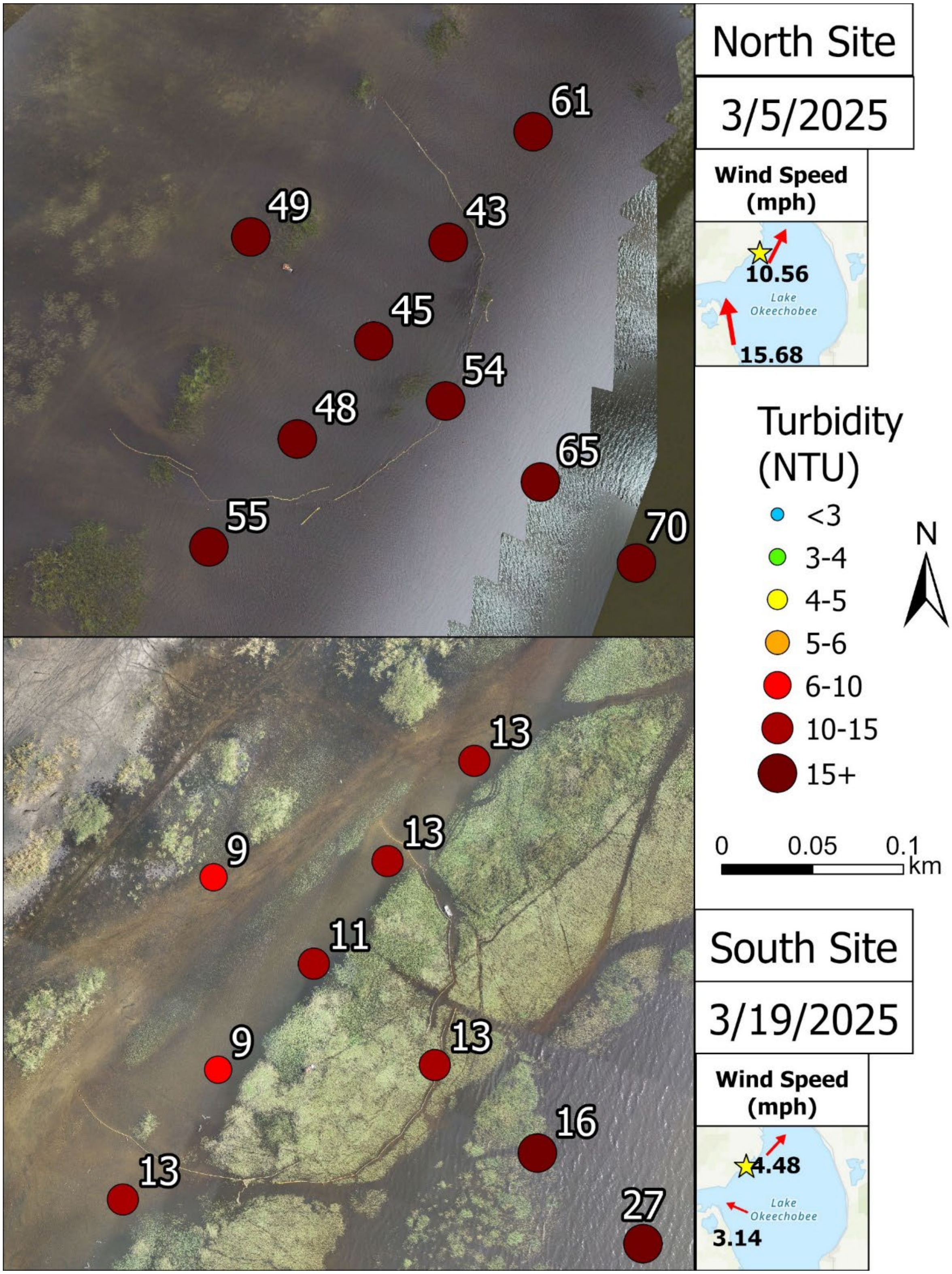


Figure 41. Turbidity at stations along centerline and transverse transects through the North Site on March 5, 2025 and on March 19, 2025 at the South Site. Inset shows wind speed and direction during the time of sampling, as measured at two District monitoring locations (L001 and L005).

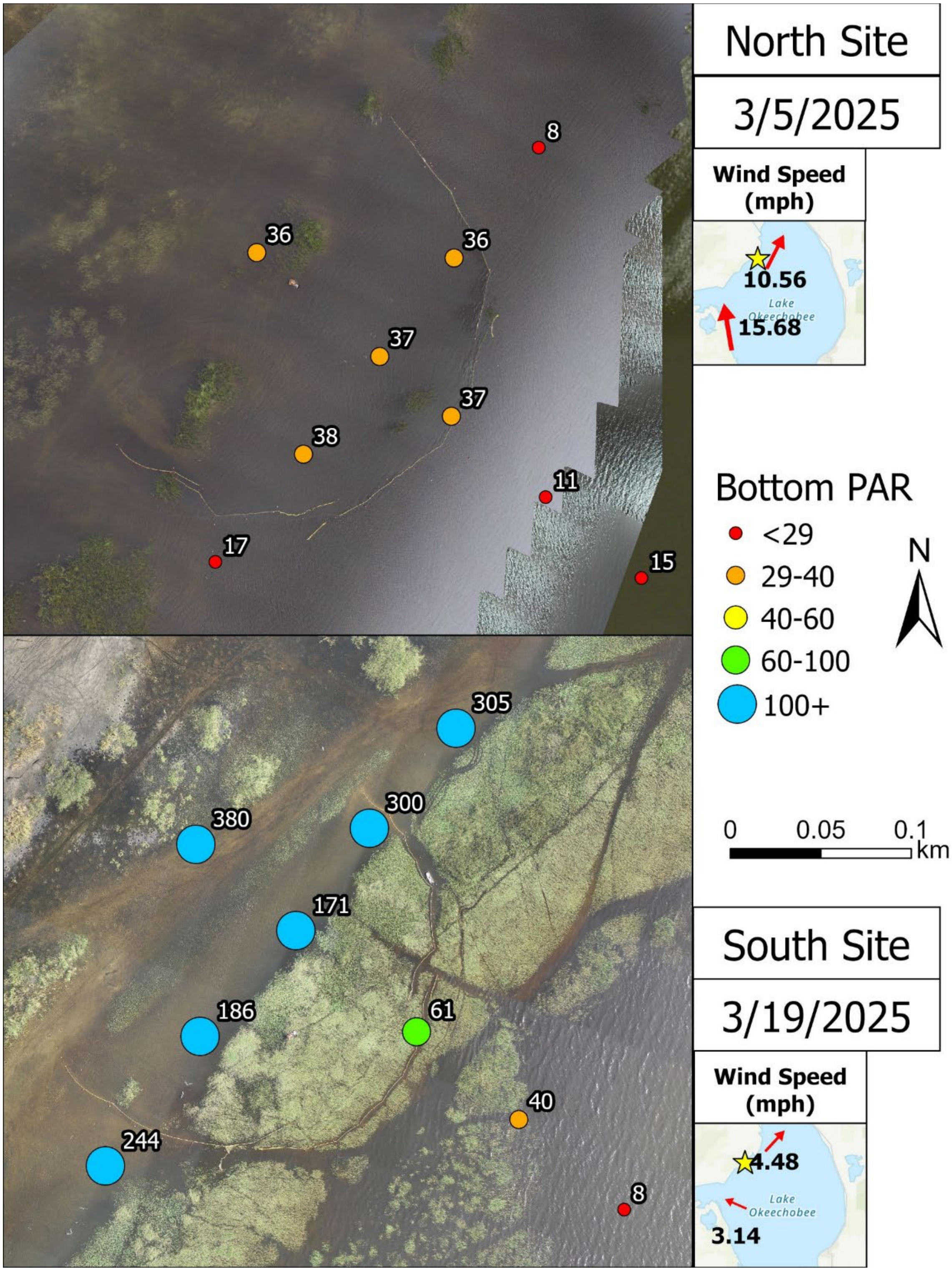


Figure 42. Measurements of photosynthetically active radiation (PAR, µmol photons/m^2/s) at the bottom of the water column (27 cm above the lake bed) at primary stations along a center line transect extending from inside the curtains toward the open water part of the lake, and a perpendicular transect across the controls inside and outside the controls. The inset shows wind speed and direction for the time of sampling from two nearby monitoring stations (L001 and L005).

Figure 43. Turbidity, water depth, and SAV coverage at the lakeward station (C5 Out) and location furthest inside the controls closest to the emergent marsh (C1 In), as well as the average (±SE) of values for all inside and outside primary stations during the monitoring period.

The nature of the particles changed over the course of the project, affecting the way controls would provide turbidity reductions. In early March, the North Site experienced windy conditions and increased levels of TSS (53-91 mg/L) within samples at the primary monitoring locations, while Chl-a concentrations remained below 30 µg/L (Figures 44 and 45). By contrast, by late April the same stations showed elevated Chl-a concentrations at or above 50 µg/L as a result of algal bloom conditions and drift into the project area, with only moderate levels of TSS (29-64 mg/L). As the spring growing season progressed and water levels continued to decline, both TSS and Chl-a values declined, and the ratio of NVSS/TSS decreased to indicate less mineral material in the suspended matter in June and July samples. Note that the C1 station (closest to the marsh) was too shallow to sample in May and June at either site.

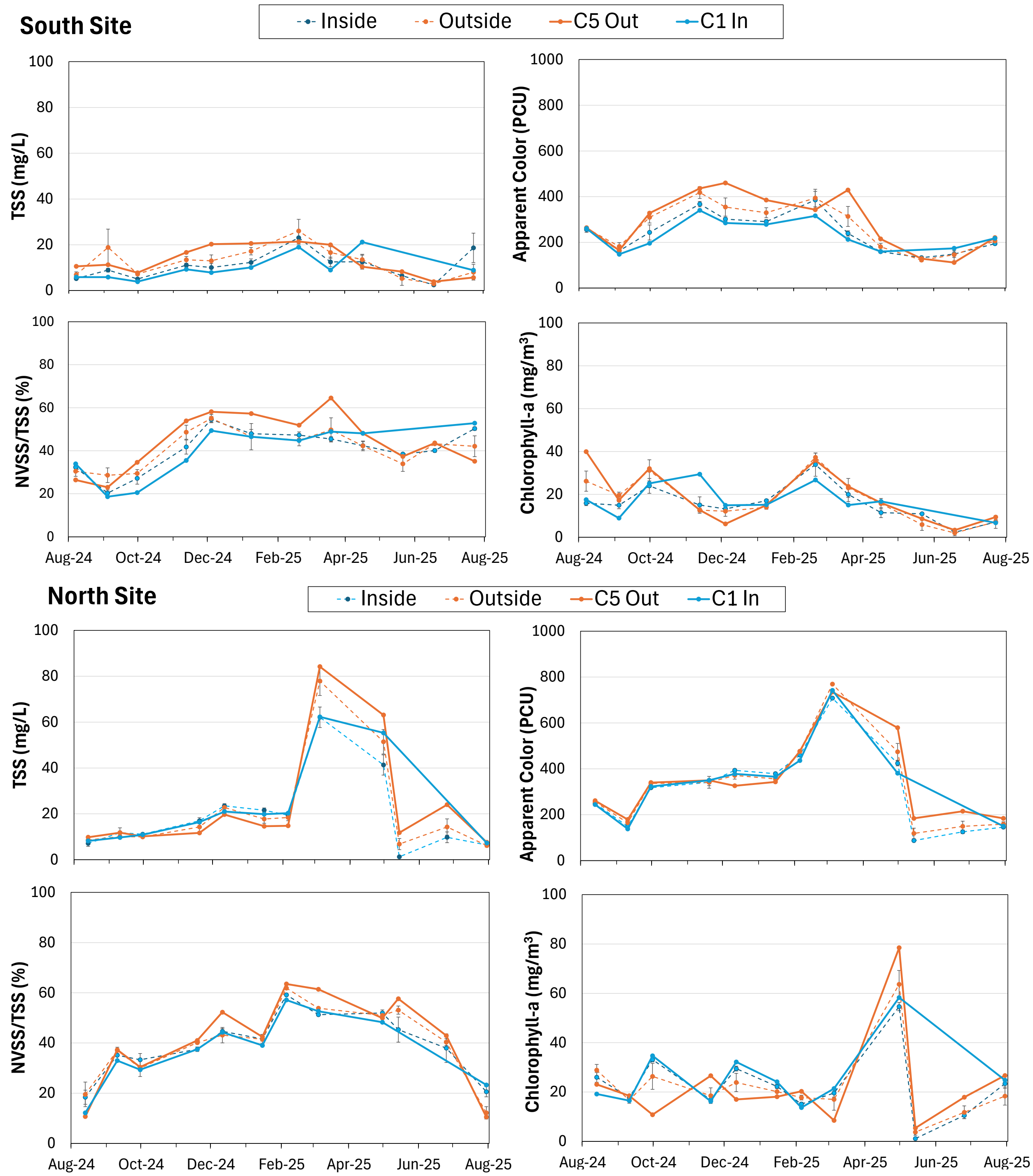


Figure 44. Water quality constituents during the project period showing the lakeward station (C5 Out) and location inside the controls closest to the emergent marsh (C1 In), as well as the average (±SE) of values for all inside and outside stations sampled during monthly events over the project monitoring period.

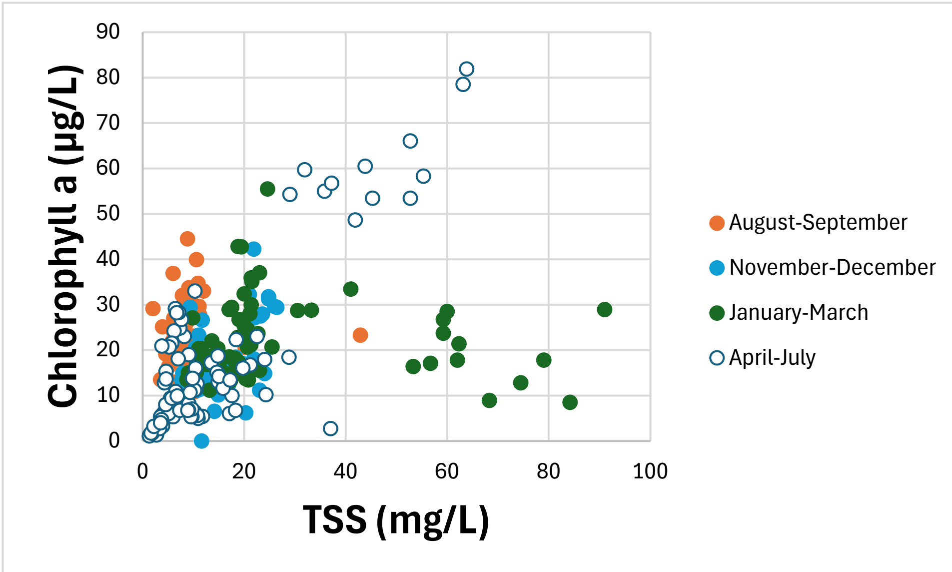


Figure 45. Relationship between total suspended solids (TSS) and Chl-a pigment in surface waters collected from both the North and South project areas over the monitoring period.

6.3.5 High-frequency Turbidity Measurements

High-frequency turbidity data was collected outside and inside the project area to record changes in turbidity as affected by the deployed controls. This information provided essential information during and immediately after storm events when turbidity levels can be much higher than during conditions characterized by traditional surface water sampling approaches. To present the information obtained during the monitoring period, the deployment schedule and data availability, and the review procedure to ensure data quality is first described. Next, a case study of data results during Hurricane Helene shows the pattern of turbidity response inside and outside the curtain installation. Turbidity lakeward of the installations was measured by adding sonde monitoring stations in deeper water, and this culminated in paired datasets that allowed reductions in turbidity to be assessed as a function of wind speed, wind direction, and lake stage.

6.3.5.1 Methods

6.3.5.1.1 Sonde Deployment Schedule and Data Availability

Sonde deployments began August 7, 2024 and continued through July 30, 2025, spanning the monitoring phase of the project and encompassing 34 individual events (Figure 46 and Table 2). Initially, locations inside and outside the curtain installation were compared by deploying sondes at similar positions relative to the edge of the littoral marsh and lake exposure (Figure 47, positions N-Sonde-In and N-Sonde-Out at the North Site, and S-Sonde-In and S-Sonde-Out at the South Site). Turbidity probes on EXO2 sondes (Xylem/YSI, Yellow Springs, OH) recorded readings at 5-minute intervals for periods of ~1 week before retrieving the data and being rotated out for final validation, cleaning and maintenance. Sonde deployments alternated weekly between the North Site and South Site (Table 2).

All sonde deployment locations were similarly devoid of vegetation (i.e., lacked dense patches of bulrush (*Schoeneoplectus californicus*, *Nymphaea* spp., *Paspalidium geminatum*) that were present at either site).

As part of the sonde QC protocol, final validations were performed using standard solutions of 0, 20, and 100 NTU and considered acceptable if within tolerances based on range (0 NTU: < 0.2 NTU; 0.1 – 10 NTU, ± 10%; 11-40 NTU, ±8%; 41-100 NTU ± 6.5 %; > 100 NTU, ± 5%).

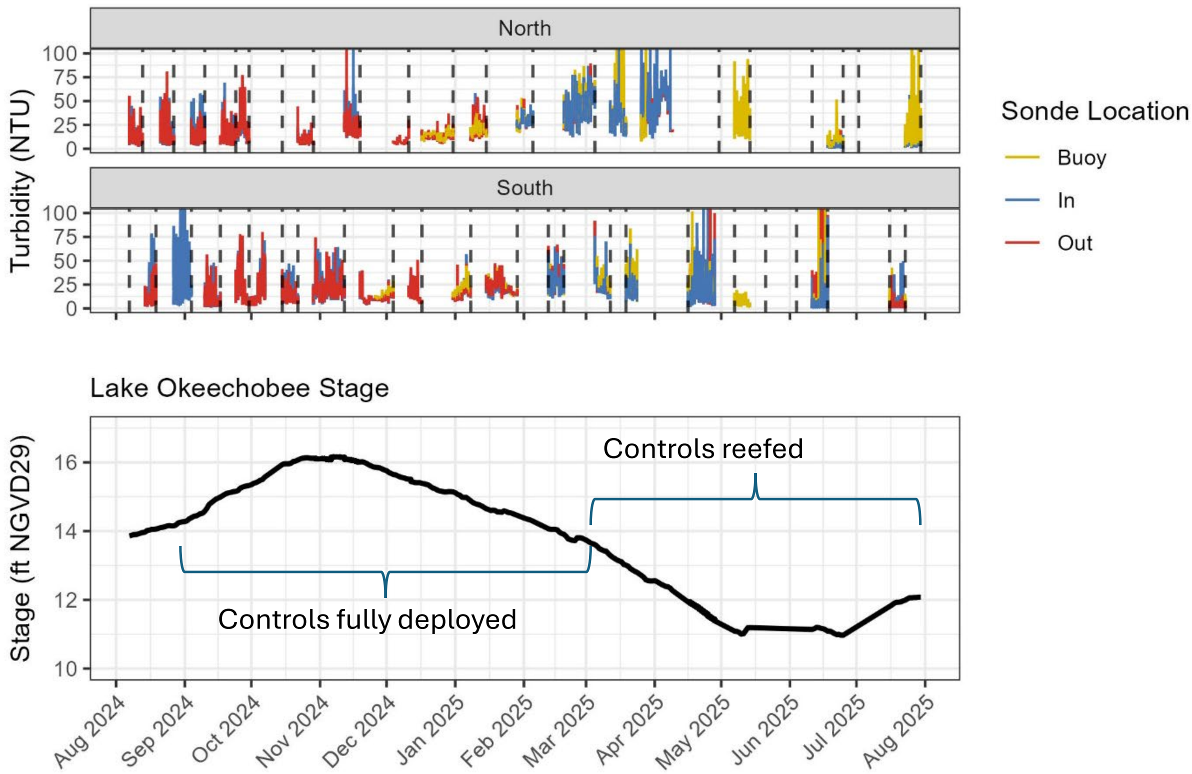


Figure 46. Data availability of high-frequency turbidity measurements recorded during the project period at the North Site and South Site, relative to water sampling events (vertical dashed lines, top panel) and lake stage (bottom panel).

Beginning January 29, 2025, four sondes were simultaneously deployed during most events to capture conditions in deeper water (the outer buoy location), locations inside and outside the controls, and an alternate location either inside or outside to examine the relative differences between specific locations. With the sonde equipment in a more continuous state of deployment, data was downloaded on the water, field validation were performed and then sondes were redeployed to continue data collection for up to 3 weeks before returning for final validation readings against turbidity standards. Field validations were performed by taking readings simultaneously using the deployed sonde and a second instrument calibrated that morning (either another EXO2 sonde or YSI ProDSS multiprobe). Readings were acceptable if the values agreed within 30%.

Table 2. Events when high-frequency data was collected by Exo2 data sondes deployed at the North Site or South Site during the project monitoring period 89 1-week datasets collected across 4 primary sites and 12 total sites.Green shade indicates sonde passed all QC (Turbidity within ±10% of standard at final validation). Grey boxes indicates field validation > 30% difference from calibration. Beige indicates data loss due to equipment failure.

Event_No	Event Period	N-In	N-In-2	N-Out	N-Out-2	N-Buoy-2	N-Bouy-3	S-In	S-In-2	S-Out	S-Out-2	S-Buoy-2	S-Bouy-3
1	Aug-7-24 to Aug-13-24												
2	Aug-14-24 to Aug-20-24												
3	Aug-21-24 to Aug-28-24												
4	Aug-27-24 to Sep-4-24												
5	Sep-4-24 to Sep-11-24												
6	Sep-11-24 to Sep-17-24												
7	Sep-17-24 to Sep-24-24												
8	Sep-24-24 to Sep-30-24												
9	Sep-30-24 to Oct-7-24												
10	Oct-14-24 to Oct-22-24												
11	Oct-22-24 to Oct-29-24												
12	Oct-29-24 to Nov-12-24												
13	Nov-12-24 to Nov-20-24												
14	Nov-19-24 to Nov-26-24												
15	Nov-26-24 to Dec-4-24												
16	Dec-4-24 to Dec-11-24												
17	Dec-11-24 to Dec-17-24												
18	Dec-17-24 to Dec-31-24												
19	Dec-31-24 to Jan-8-25												
20	Jan-8-25 to Jan-15-25												
21	Jan-15-25 to Jan-29-25												
22	Jan-29-25 to Feb-5-25												
23	Feb-12-25 to Feb 19-25												
24	Feb-19-25 to Mar-5-25												
25	Mar-5-25 to Mar-12-25												
26	Mar-12-25 to Mar-19-25												
27	Mar-19-25 to Mar-24-25												
28	Mar-26-25 to Apr-9-25												
29	Apr-16-25 to Apr-28-25												
30	May-7-25 to May-14-25											*	
31	Jun-11-25 to Jun-18-25								*				
32	Jun-18-25 to Jun-25-25												
33	Jul-16-25 to Jul-23-25										*		
34	Jul-23-25 to Jul-30-25												

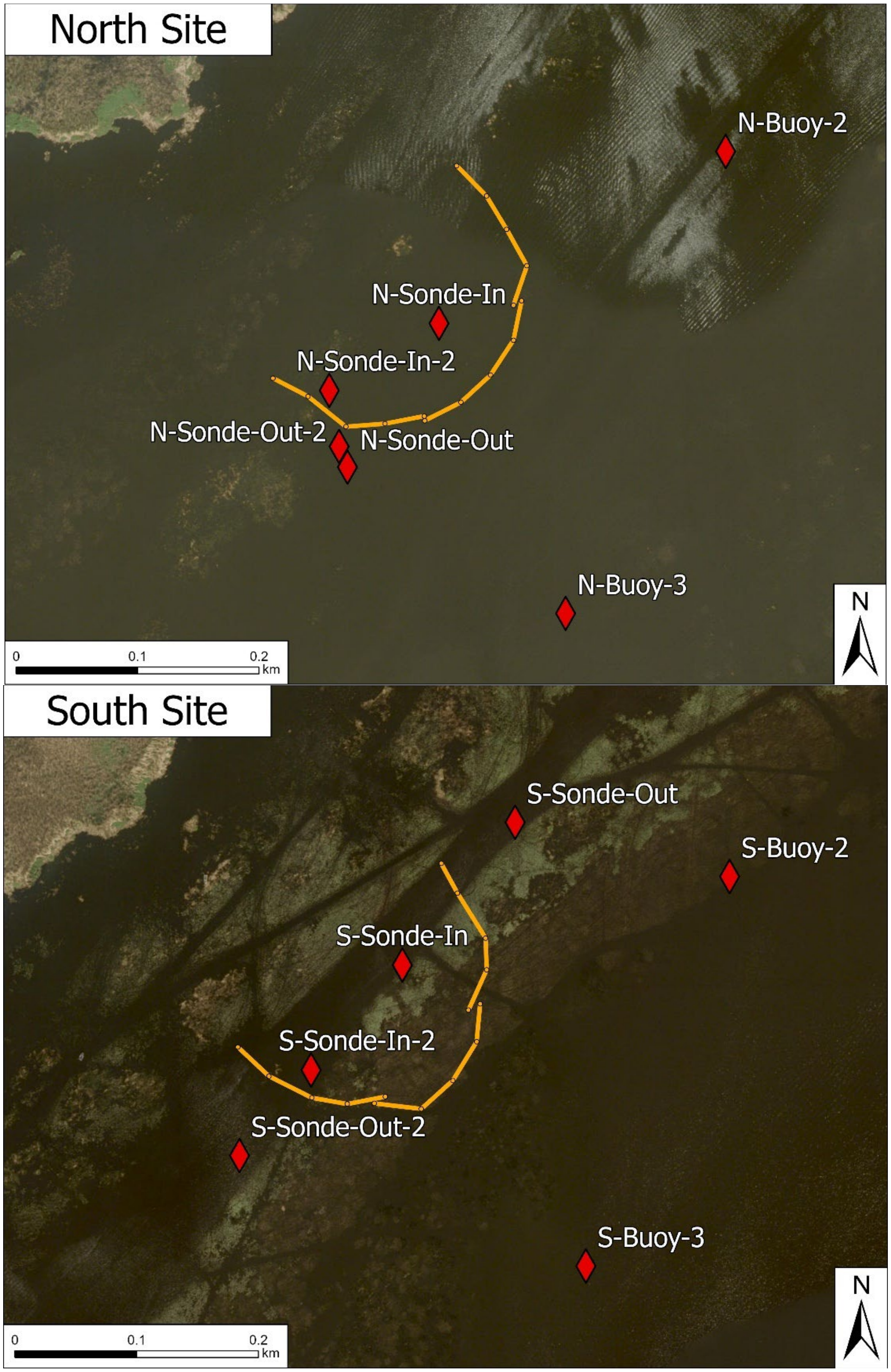


Figure 47. Upper panel: Locations of sonde deployment at the North Site. Lower panel: Locations of sonde deployment at the South Site. `In` and `Out` sondes were deployed within approximately the same transect to mitigate differences in water depth influencing comparisons. Sondes were not deployed at all locations at all times, they were rotated between sites and locations, utilizing the four sondes available.

6.3.5.2 Results

6.3.5.2.1 Turbidity during Helene - September 2024

During the 2024 hurricane season, three hurricane/tropical storm events occurred over the Florida peninsula, bringing high winds to the study area. On August 5, 2024, Hurricane Debby made landfall in the Big Bend area of Florida as a Category 1 storm. Sondes were not deployed during this time, and controls were installed but curtains remained reefed to the boom. Later from September 26-27, 2024, Hurricane Helene struck the Big Bend region, making landfall as a Category 4 storm. During this period, sonde devices were kept in place (sonde Event #8) and monitored changes in turbidity during the passing of this event with controls installed, curtains released and fully functional. On October 9, 2024, Hurricane Milton made landfall near Siesta Key and crossed the Florida peninsula through Central Florida. Curtains remained deployed through this storm, but sonde equipment was removed from the lake during the storm's approach due to concerns of potential loss of equipment during a potential direct hit. Since Hurricane Debby occurred prior to full curtain deployment, and Hurricane Milton occurred when sondes were not deployed, the data collected during Hurricane Helene provides valuable insight into curtain operation and turbidity conditions when both curtains and sondes were fully deployed.

During the approach of Hurricane Helene, wind speeds steadily picked up and turbidity at both sites and at both "In" and "Out" locations climbed (Figure 48). Turbidity reached its maximum at both sites several hours after wind speeds reached their peak of ~35 mph. Once the storm passed, turbidity rapidly dropped within a day back down to lower-level conditions. By the sampling event on September 30, 2024, wind speeds hovered around ~5 mph, and all turbidity readings were between 7-8 NTU at the North Site, and even lower between 3-6 NTU at the South Site (Figure 39).

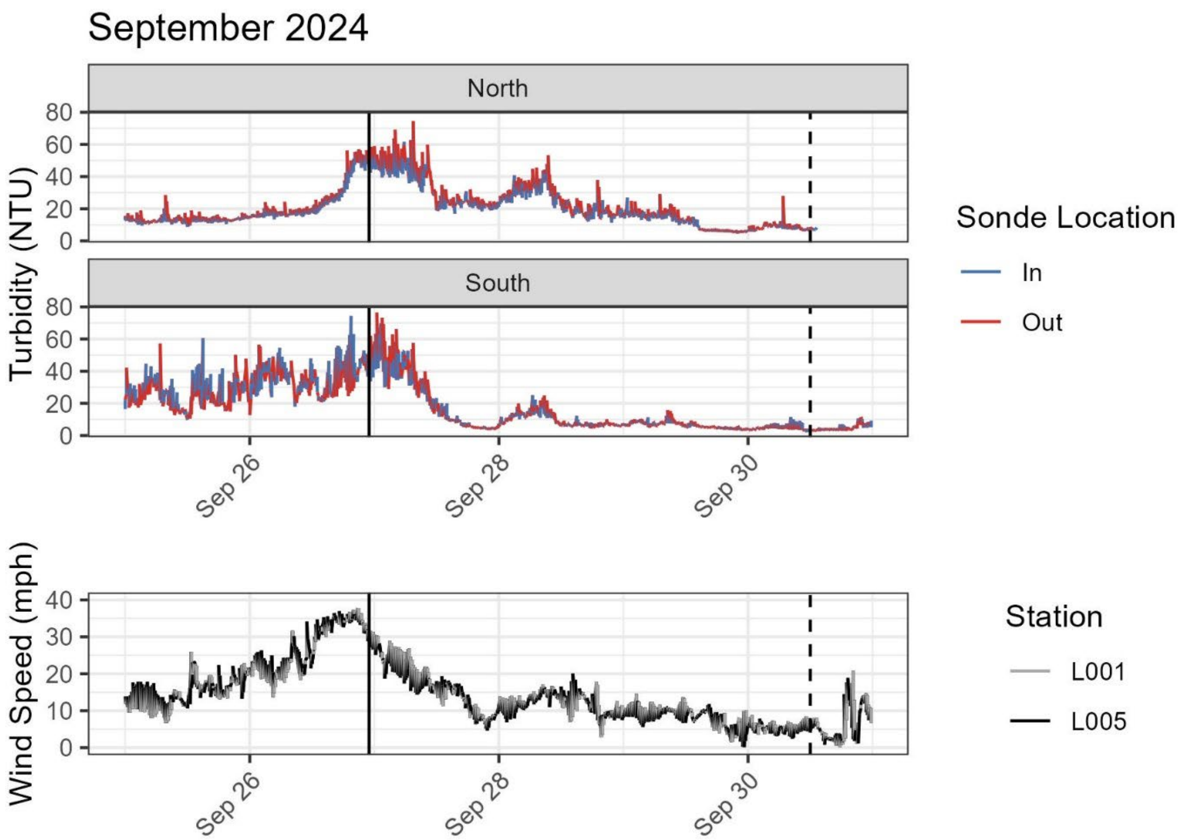


Figure 48. Turbidity, wind speeds, and stage when Hurricane Helene made landfall on 9/26/2024 at approximately 11:00 PM (vertical solid line). DBE staff returned to both sites for field measurements on 9/30/2024 (vertical dashed line).

Based on initial sonde results, beginning October 29, 2024 (Event #12), additional sonde deployment locations were included to evaluate whether the assessment was influenced by choice of location inside or outside the curtain. Two locations were added (S-Sonde In-2 and S-Sonde-Out-2). Where S-Sonde-Out was north of the curtain, S-Sonde-Out-2 was south of the curtain and could be differentially affected by wind waves approaching from the south or southeast. Under such conditions, the location north of the curtains would have been located on the leeward side of the curtains. These data were used to assess effects of wind direction, described in Section 6.4.

6.3.5.2.2 Turbidity Comparison to Outer Buoy – November 2024

Data collection further lakeward from the curtain began on November 26, 2024 (Event #15) at S-Buoy-3 (Figure 49). This “outer buoy” station was in slightly deeper (+ 0.5 m) waters and routinely showed higher turbidity conditions than the “In” and “Out” locations established closer to the curtains (e.g., Figure 50). On December 17, 2024 (Event #18), a sonde was similarly deployed at an outer buoy (N-Buoy 3). During subsequent events, the buoys were routinely included to contrast turbidity levels in water lakeward of the controls from that within and adjacent to the controls (Table 2 and Figure 46). The buoy locations represented the turbidity of pelagic water potentially moving into the nearshore environment.

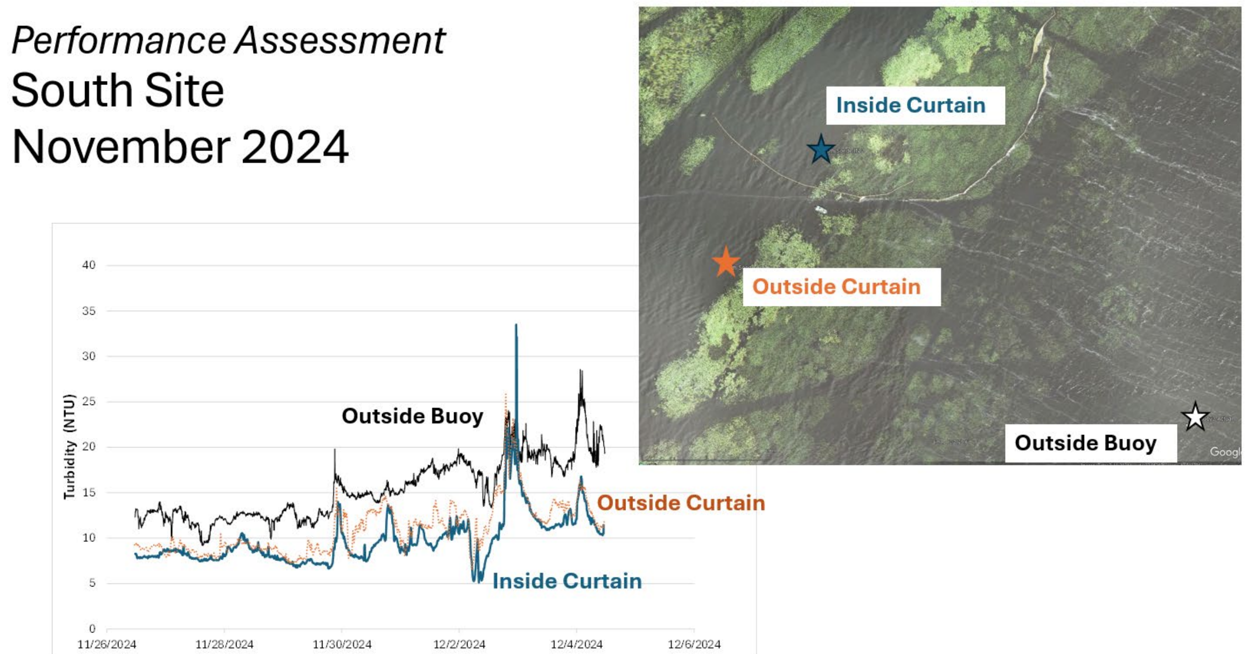


Figure 49. Turbidity measured simultaneously at three locations at the South Site during Event #15, from November 26 to December 4, 2024.

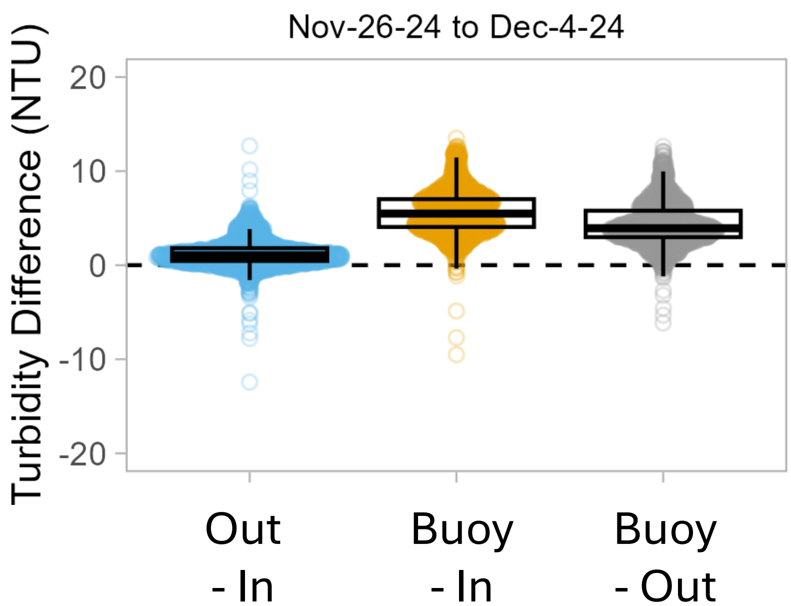


Figure 50. Comparison of turbidity values simultaneously recorded at locations inside and outside the installed controls and equipped with data sondes for high-frequency measurements during the period between November 26, 2024 and December 4, 2024. The box plot shows median differences between locations, and the dashed line indicates no difference.

6.3.5.2.3 Turbidity during March 2025 – Windy Conditions at Low Lake Stage

As was noted earlier during Hurricane Helene, a close association between turbidity and wind speed was often observed in the data, especially when winds were strong and consistent. Wind conditions leading up to the March 5, 2025, sampling event at the North Site hovered around 20 mph and turbidity was maintained at ~60 NTU (Figure 51). Lake stage was ~14 ft and water depths were declining to approach the limit where curtains could remain vertically suspended above the lake sediment and still maintain a 1 ft gap below the bottom edge. No difference in turbidity was apparent between locations inside and outside the controls, or between the outer buoy location and the monitoring location inside of the curtain. High turbidity at the North Site was also evident at the primary monitoring stations visited on March 5, 2025 (Figure 41).

Turbidity curtain controls had been fully deployed (i.e., curtains "unreefed" or hanging vertically downward from the floating boom) from September 2024 through March 2025, when Lake Okeechobee stage was above 14 ft. As water levels dropped in late spring, between 14 and 12 ft lake stage, a partial reefing strategy was implemented so that the curtain was suspended 18" from the boom, rather than the full 3' length. Below lake stage of 12 ft, it was necessary that the curtains were fully reefed to the boom, in order to maintain clearance below the bottom of the curtain and avoid contact between the curtain and the lake sediment (Figure 46). The shallow water conditions also limited the ability to deploy sondes without risk of exposure of the sensors. On April 28, 2025 (end of Event #29), water levels were < 1 ft and too shallow for continued deployment. Sondes were retrieved from the lake. For Event #30, May 7 – 14, 2025, sondes were deployed only from buoys in deeper water, two buoy locations each at the North and South project sites. Lake stage reached the seasonal minimum on May 24, 2025 (10.90 ft) before slowly increasing. Sonde deployments resumed June 11, 2025 with Event #31. The final events of the project captured turbidity in the lake's nearshore environment under low lake stage conditions that persisted through the end of the monitoring period.

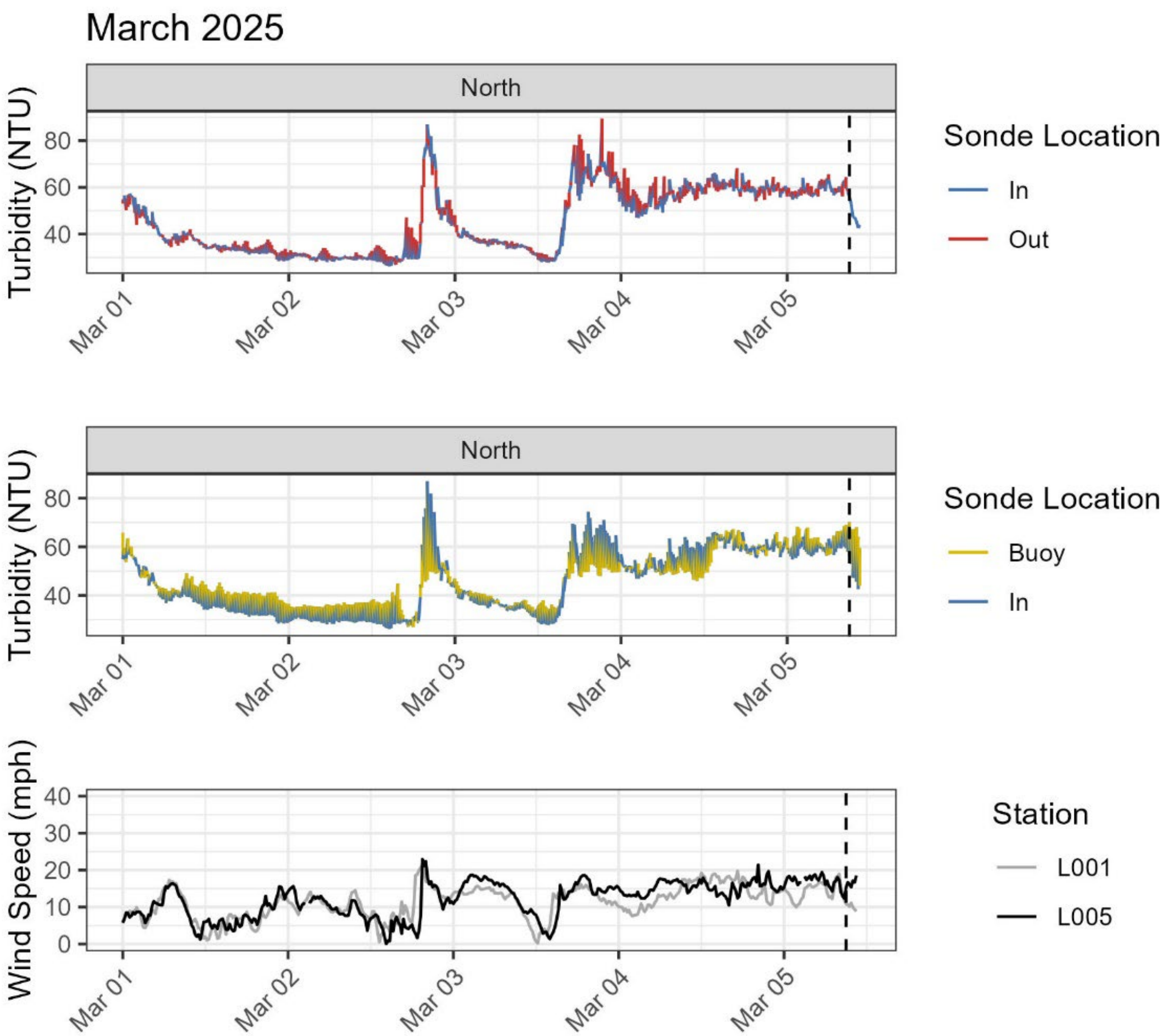


Figure 51. Turbidity, wind speeds, and stage in March 2025 at the North Site. Field measurements were performed on 3/5/2025 (vertical dashed line) at the North Site.

6.4 Influence of Wind Speed, Direction and Lake Stage on Turbidity Reduction

6.4.1 Methods

To more closely examine the effect of wind speed, direction and lake stage on turbidity reductions by the installed controls, sonde data was compiled from all deployment periods and qualified data not meeting the above QC criteria was excluded from analysis. Sonde data was only assessed when curtains were fully installed at both sites (data originated after September 5, 2024).

Wind speed and direction data from L001 (DBKEY: IX847 and KV264) and L005 (DBKEY: IX866 and KV266) were compiled from DBHYDRO during the project period of record and aligned with sonde data using R coding language. Where wind and sonde data are concurrently assessed, the data frequency has been reduced to 15-minute intervals, while sonde data assessed without companion wind data included the full dataset (5-minute interval).

For assessment, the following metrics were calculated at each timepoint:

- Out sonde – In sonde = diff (Out-In)
    - Note these sondes are inside the littoral vegetation, so the difference is likely to be smaller and relevant specifically to the turbidity control
- Buoy sonde – In sonde = diff (Buoy-In)
    - Represents combined littoral and turbidity controls effect
- Buoy sonde – Out sonde = diff (Buoy-Out)
    - Represents littoral effect without controls

Positive differences for diff (Out-In) indicate that turbidity was greater on the outside of the curtain relative to the inside, or a turbidity reduction.

When applying nonparametric analysis using Wilcoxon signed rank tests, most comparisons were significantly different than a mu = 0; however, mu = 1 NTU was applied to help differentiate wind effects and is measurable with some confidence when typical turbidity values are ~ 10 NTU. The percent of measurements showing a net positive turbidity reduction was also calculated.

For wind speed and lake stage analysis, all sonde results that passed QC were included. Curtain performance at different wind speeds was assessed by assigning readings to incremental bins at 5 mph intervals; lake stage was assessed by incremental bins at 1 ft intervals. For wind direction analysis, the dataset used wind speeds > 10 mph when wind direction would be more likely to influence turbidity. The sonde deployments at the South Site from September 5 – October 22, 2024 was also excluded when the "Outside" sonde was located north of the curtain enclosure, and included the events where the "Outside" was represented by the location south of the curtains (S-Sonde Out-2, in Table 2 and Figure 47).

6.4.2 Results

6.4.2.1 Wind Speed

During the project period, recorded wind speeds at L001 and L005 ranged from 0-51 mph, with median wind speed at station L001 of 9.78 mph and L005 of 9.92 mph. As seen in the case study events, <10 mph wind speeds often resulted in <10 NTU turbidity concentrations. At these low wind speeds, the turbidity difference between the "In" and "Out" locations were much less pronounced, and the median difference was less than 1 NTU, and thus not significant (Table 3, Figure 52).

Table 3. Median diff (Out-In) at the North Site and South Site during wind conditions of varying wind speeds.

	0-5 mph	5-10 mph	10-15 mph	15-20 mph	20+ mph
North	0.23	0.23	0.49	-0.14	2.26
South	0.66	0.78	0.88	1.50	1.44

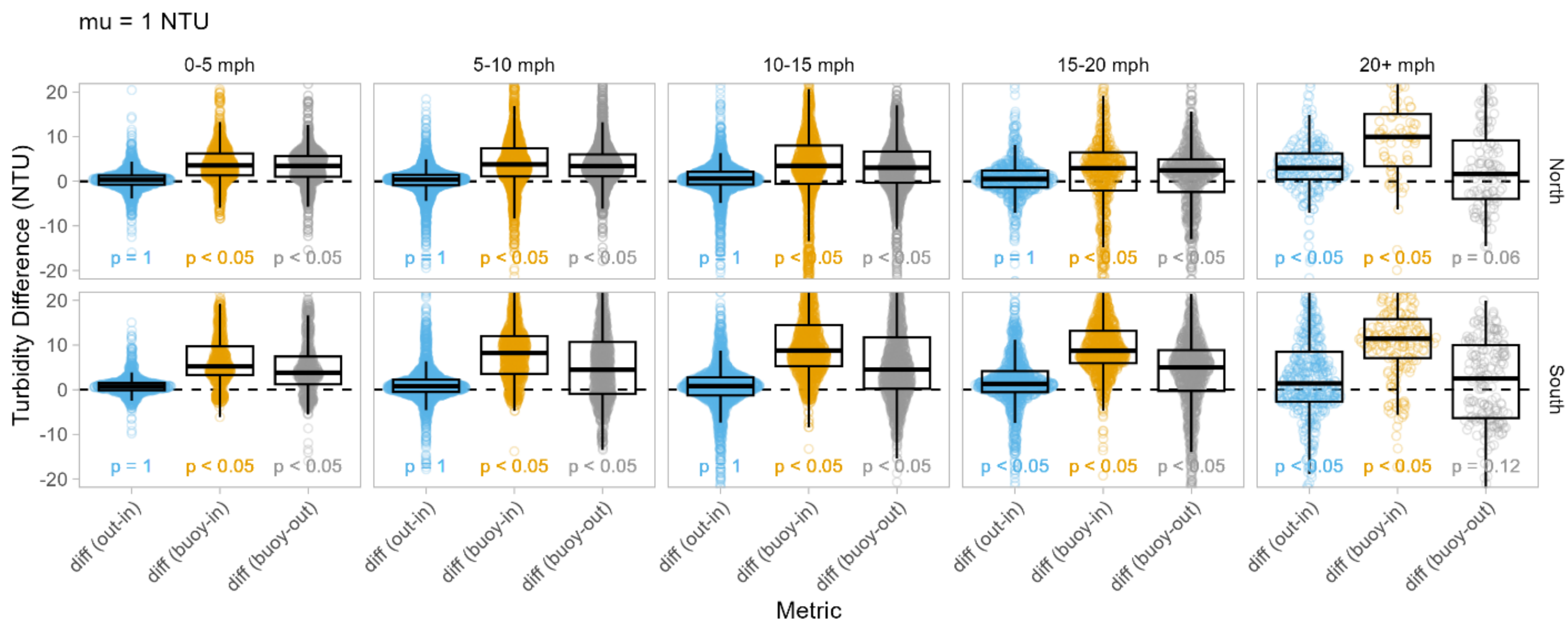


Figure 52. Boxplots of calculated turbidity differences between sonde positions: “Out” – “In” (blue), “Buoy” – “In” (orange), and “Buoy” – “Out” (gray). Orange represents a combined vegetation and turbidity control effect, while Gray represents a littoral effect. Data was binned by wind speeds averaged from monitoring stations L001 and L005. Statistics represent results of Wilcoxon signed-rank tests where if the median difference between sondes is greater than 1 NTU (mu = 1).

Turbidity curtains only demonstrated a significant reduction between “Out” and “In” sondes greater than 1 NTU at higher wind speeds (Figure 52). This effect was only observed at the North Site when wind speeds exceeded 20 mph, while the effect was observed starting at 15 mph for South Site. Median diff (Buoy-In) was significantly greater than 1 NTU for all wind speed conditions at both sites, while diff (Buoy-Out) was significantly greater than 1 NTU for all wind speeds less than 20 mph (i.e. lost at higher wind speeds). Median diff (Buoy-In) remaining significant at 20+ mph suggests that the curtains may have provided some benefit during storms beyond what could be attributed to the position and water depth factors alone (Buoy-Out). Although median turbidity reduction remained low, the difference between “Out” and “In” did increase with increasing wind speeds (Table 3), demonstrating curtains were more effective at turbidity increase mitigation during windier conditions. At times, the reduction was substantially greater than the median, and in terms of frequency a net turbidity reduction was observed diff (Buoy-In) 85% of the time when winds were 5-10 mph and 88% of the time when winds were > 10 mph while sondes were deployed at the South Site (Figure 53). A net reduction was observed less often between the buoy and Outside locations diff (Buoy-Out) at the South Site, supporting the hypothesis that the curtains contributed to more frequent turbidity reductions. At the North Site, the effect of the controls installation on frequency of a net turbidity reduction was most evident at >20 mph wind speeds.

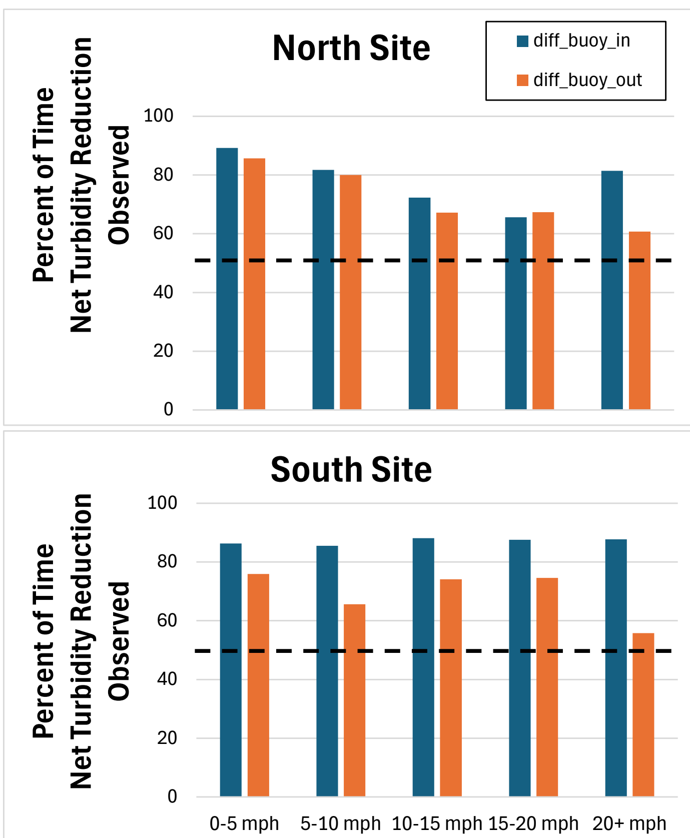


Figure 53. Percent of time when a net reduction in turbidity was observed between the sonde readings at the buoy and at the locations inside or outside the curtains, as a function of wind speed. The dashed line at 50% represents equal proportion of measurements showing increase and decrease in turbdity.

6.4.2.2 Wind Direction

During the project period (between 9/5/2024 and 7/31/2025), wind primarily came from the South (37% of the time) and East (34%), with North (17%) and West (11%) winds less common. Turbidity differences between the "In" and "Out" locations were not very pronounced at the North Site, with the median difference less than 1 NTU, regardless of wind direction. At the South Site median reduction was always significantly greater than 1 NTU and greatest when winds were from the South and West (Table 4, Figure 54). Median diff (Buoy-In) and diff (Buoy-Out) were all significantly greater than 1 NTU, regardless of the wind direction, with the exception of East winds at the North Site. When this condition occurred, the median difference was not significantly greater than 1 NTU between the Buoy and inside or outside the curtain.

Table 4. Median diff (Out-In) of turbidity (NTU) at the North Site and South Site during wind conditions coming from different directions.

	North (315-45°)	East (45-135°)	South (135-225°)	West (225-315°)
North	0.17	0.27	0.31	0.16
South	1.87	1.36	2.48	3.51

6.4.2.3 Lake Stage

Lateral transport of suspended sediment from the center of the Lake to the near-shore western regions occurs when lake stage is high, but is prevented to a degree by vegetation at lower lake stages (Phlips et al. 1993). As one would expect, all diff (Buoy-In) were significant and most diff (Buoy-Out) were significant, showing that turbidity difference between the two sondes was significantly greater than 1 NTU, reflecting high turbidity in deeper waters at the buoy sondes relative to the "In" and "Out" sondes nearer the control curtains (Figure 55). While diff (Out-In) did significantly exceed 1 NTU for several lake stage bins, median differences were still quite small (Table 5). For diff (Out-In), no significant reduction was attained at the North Site, and significance ($p<0.05$) was only attained at the South Site when lake stage was between 11.5 ft to 14.5 ft NGVD29, with the greatest median difference of only 2.23 NTU at the South Site when water levels were 12.5-13.5 ft NGVD29 (when waters were shallow and when curtains were reefed).

Table 5. Median difference (Out-In) of turbidity (NTU) at the North Site and South Site at different Lake Okeechobee stage levels (ft NGVD29).

	10.5-11.5ft	11.5-12.5ft	12.5-13.5ft	13.5-14.5ft	14.5-15.5ft	15.5-16.5ft
North	0.70	-1.25	-0.88	0.29	0.71	0.07
South	0.78	1.02	2.23	1.05	0.72	0.67

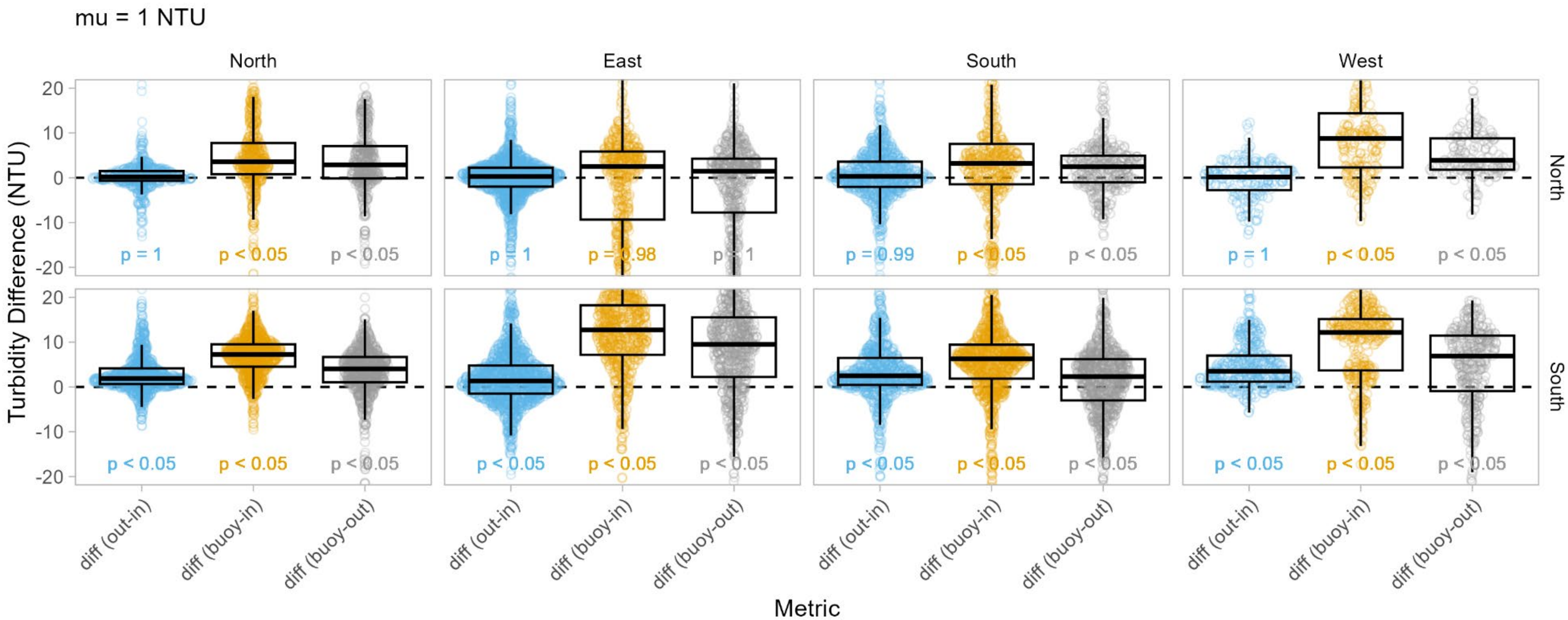


Figure 54. Boxplots of calculated turbidity differences between sonde positions: “Out” – “In” (blue), “Buoy” – “In” (orange), and “Buoy” – “Out” (gray). Orange represents a combined vegetation and turbidity control effect, while Gray represents a littoral effect. Data was binned by wind directions averaged from monitoring station L001 and L005, and converted to cardinal directions. Statistics represent results of Wilcoxon signed-rank tests where if the median difference between sondes is greater than 1 NTU (mu = 1).

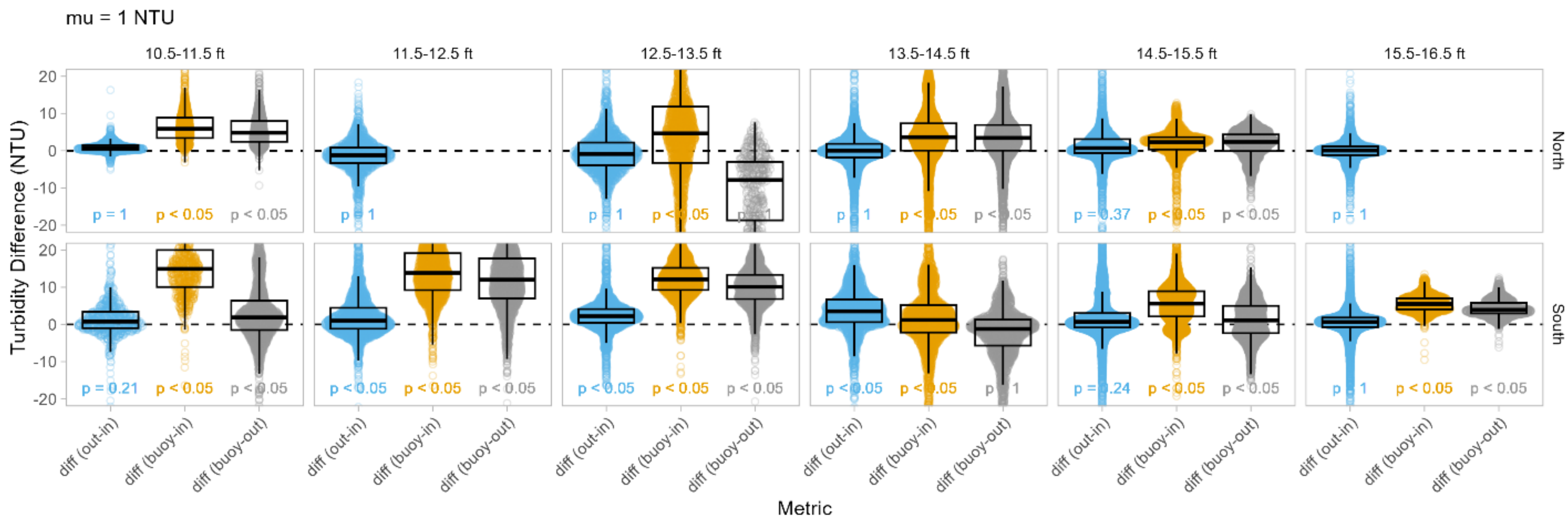


Figure 55. Boxplots of calculated turbidity differences between sonde positions: “Out” – “In” (blue), “Buoy” – “In” (orange), and “Buoy” – “Out” (gray). Orange represents a combined vegetation and turbidity control effect, while Gray represents a littoral effect. Data was binned by corresponding Lake Okeechobee stage (ft NGVD29) ranges. Statistics represent results of Wilcoxon signed-rank tests where if the median difference between sondes is greater than 1 NTU (mu = 1). Missing boxplots indicative of instances when either a sonde pair did not exist or a sonde pair was not present when Lake Okeechobee stage was within the stage level bin.

6.5 PAR Penetration to Lake Bed

The controls were designed to reduce turbidity, improve clarity, and increase light available to SAV. Light levels equivalent to average daily values of 29 µmol photons/m^2/sec were a threshold for no net growth by *Vallisneria americana* in Lake Okeechobee (Grimshaw et al. 2002). As described above, turbidity reductions were achieved, yet the target turbidity for adequate light was not well defined. To address this data gap and support further data analysis of the turbidity measurements made in situ by the ProDSS multimeter during daytime site visits and high-frequency records of turbidity at select locations, direct measurements of bottom PAR were made throughout the project monitoring period, and Secchi depths were recorded.

Secchi depth is a standard, direct approach to assessing water clarity, and where Secchi depth exceeds half the total water depth, light may be expected to reach the bottom in shallow lakes such as Lake Okeechobee. This assumes the Secchi depth is the approximate midpoint of the photic zone and that the distribution of light attenuating particles suspended in the water column is homogenous (Havens and James 1999). Within the dataset across all stations and events during the current project, Secchi/Total depth > 0.5 when turbidity was less than 15 NTU (Figure 56).

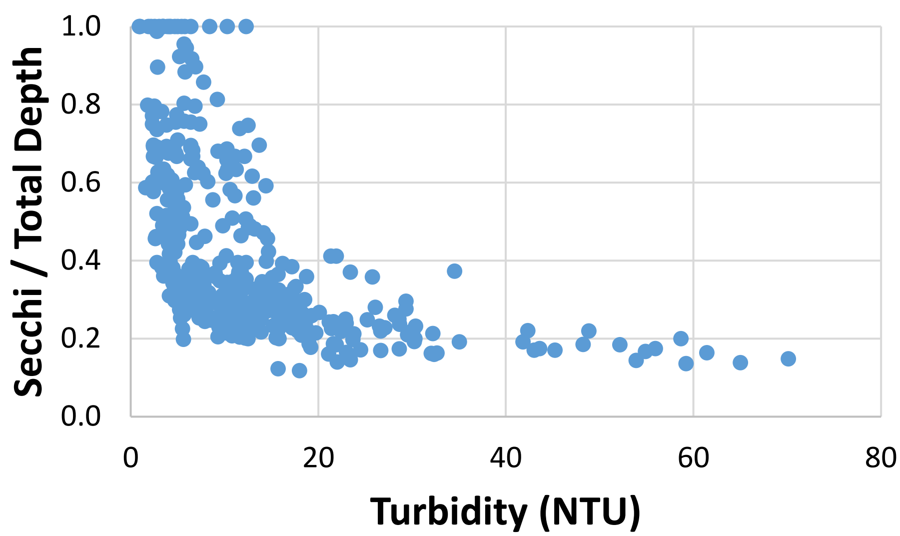


Figure 56. Relationship between turbidity and the ratio of Secchi depth to total water depth across observations throughout the two project sites and monitoring period, for when both metrics were available and water depth was greater than 60 cm (August 2024 – July 2025, N = 444).

Bottom PAR increased as a function of both turbidity and water depth in predictable pattern. For the period through February 2025, bottom PAR values did not exceed 100 µmol photons/m^2/s when turbidity exceeded 7 NTU (Figure 57). Continued monitoring captured a wider range of turbidity during the project monitoring period (high values in March 2025), and also captured increased bottom PAR at low turbidity during shallow conditions late in the study (Figure 58).

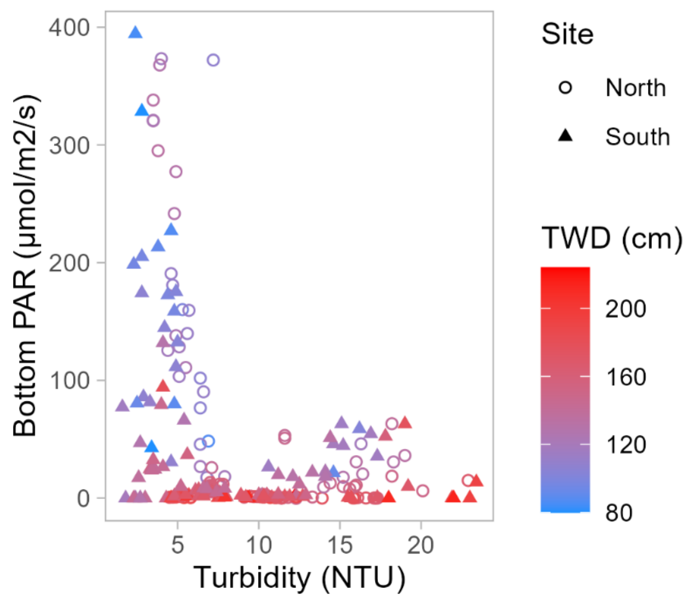


Figure 57. Relationship between bottom PAR and turbidity as determined at locations within the North and South project areas for the montioring period through February 28, 2025. The total water depth (TWD) for each measurement event and location is indicated by color.

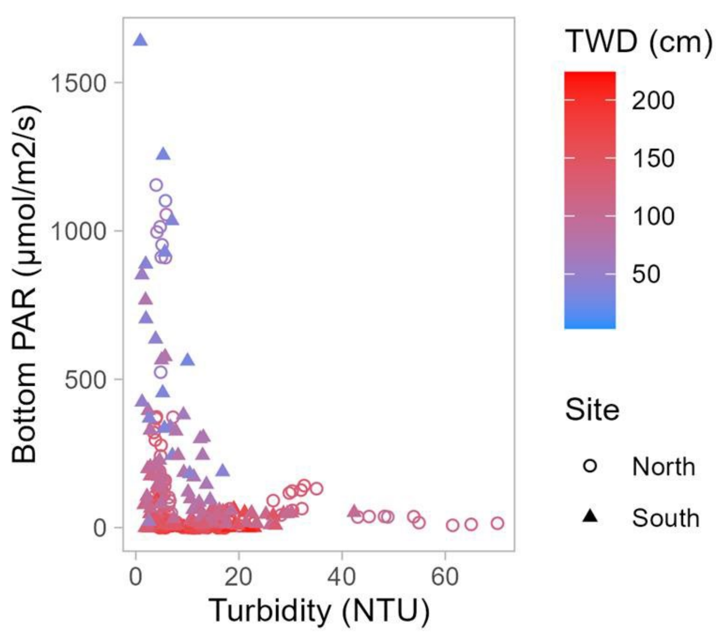
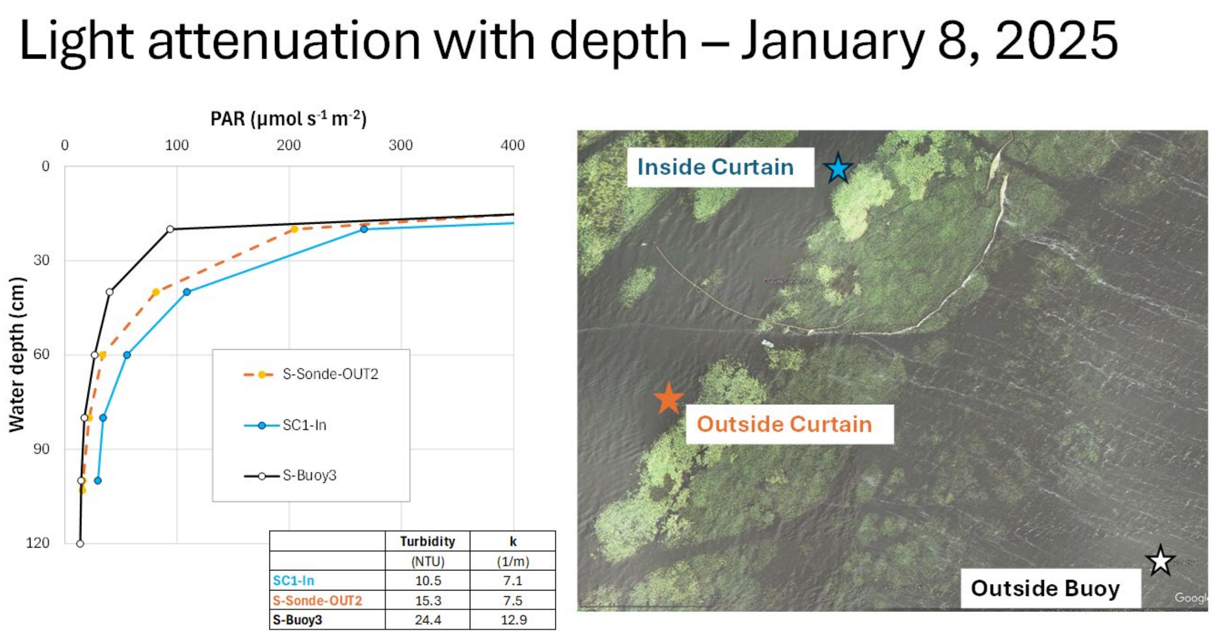


Figure 58. Relationship between bottom PAR and turbidity as determined at locations within the North Site and South Site for the montioring period through July 30, 2025. The total water depth (TWD) for each measurement event and location is indicated by color.

In this study, PAR measured in a vertical profile at 20 cm depth increments was used to calculate the light attenuation coefficient, k. An example of light attenuation with depth at the South Site from January 8, 2025 indicated higher turbidity and greater light attenuation lakeward of the controls installation and the outer buoy location, and lower k and turbidity inside the curtains

(Figure 59). The effect of k on PAR available at depth is shown in Figure 60a for depths up to 2 m and theoretical k values of 2, 5 and 10 m^{-1}. Using the same relationships, the depth at which 1% of the PAR remains can be described as a function of k (Figure 60b). To convert this relationship to a turbidity target, vertical profile measurements were performed 49 times throughout the study with concurrent turbidity readings to establish a relationship between k and turbidity (Figure 60c). Within that dataset, turbidity ranged from 2.7 – 59 NTU, and k from 2.1 – 17.7 m^{-1}. Each k was determined using the Solver routine in Microsoft Excel to fit the light attenuation equation (See Section 6.3.4) to measured PAR values as a percent of ambient light levels over the depth profile, by adjusting k to minimize the sum of squared error between the modeled and observed data. At a water depth of 1 m (~3 ft), approximately 1% of ambient light would remain when turbidity is 5 NTU (Figure 60d). This was considered a reasonable turbidity target threshold for providing sufficient light to SAV growing in Lake Okeechobee nearshore conditions, if water depths were also favorable (< 3 ft). Between August 7, 2024, and July 30, 2025, turbidity at primary stations during routine, daytime monitoring events (N=380) was 5 NTU or less for 29% of measurements inside the curtains, and 24% for measurements outside the curtains.



	Turbidity	k
	(NTU)	(1/m)
SC1-In	10.5	7.1
S-Sonde-OUT2	15.3	7.5
S-Buoy3	24.4	12.9

Figure 59. Relationship between water depth and PAR as measured along with turbdity on January 8, 2025 at three stations within and around the South Site.

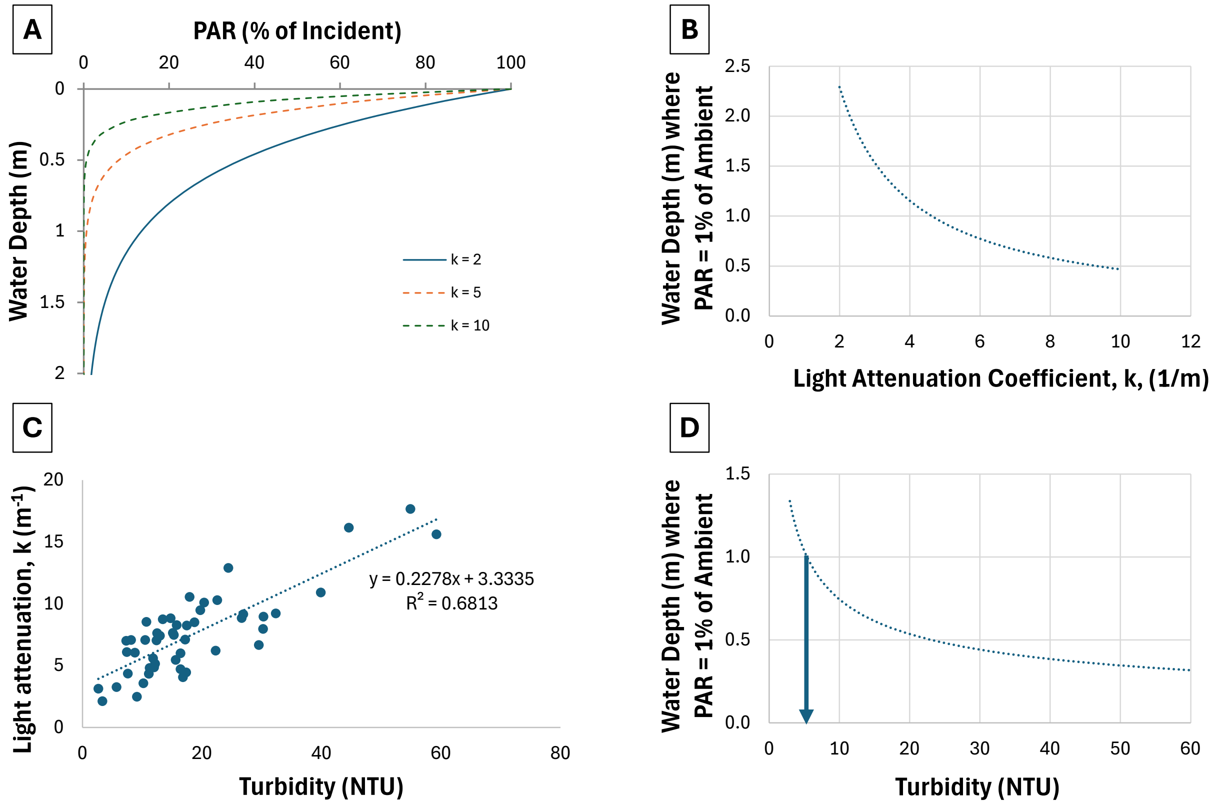


Figure 60. A: Relationships between PAR and water depth as a function of light attenuation coefficient, k; B: the relationship between depth at which 1% of ambient light remains as a function of k; C: linear relationship between turbidity and k in Lake Okeechobee (from N=49 vertical profiles of measured PAR); D: water depth at which 1% remains as a function of turbidity, used to set a turbidity target of 5 NTU for 1 m depth.

6.6 How Typical Was the Project Period of Record?

As a pilot project to inform potential applications of the turbidity controls in the future, it is important to note whether the water quality conditions during the study period were typical for the lake, or may differ from other lakes. For the past ten year period, two nearshore stations in the SFWMD monitoring network that are nearest to the current project (POLESOUT and TIN16100, Figure 61) have had lower turbidity and TSS concentrations than the two closest pelagic stations (L001 and L005), and encompass the range of values observed in the present study (Figure 62). Among those two SFWMD nearshore stations, POLESOUT was consistently the more turbid location; it also had higher Chl-a concentrations than TIN16100 and often higher than the two pelagic stations, with annual peaks > 60 µg/L (Figure 63).

Peak Chl-a concentration among primary stations in the current study was 78.5 µg/L at the North Site (N-C5-Out) in April 2025. Prior to curtain establishment and the initiation of routine monitoring, preliminary sampling in July 2024 measured 114 µg/L Chl-a at the South Site, and District monitoring at POLESOUT the same month reported concentrations exceeding 180 µg/L, a severe algal bloom condition (Figure 64). Thus, the monitoring period captured peak events yet remained within the recent historic range for this region of the lake, and was considered a representative period for evaluation.

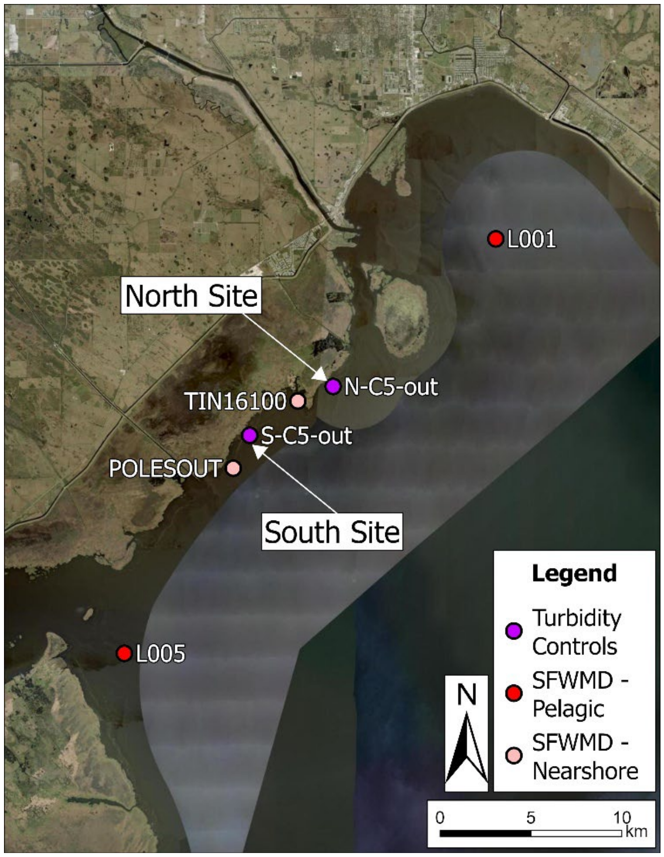


Figure 61. Location of pelagic and nearshore stations monitored by SFWMD with data available through DBHydro, which were compared to water quality at the turbidity controls locations of the current project.

Turbidity measurements in our study peaked in March 2025 at the North Site, reaching levels that were routinely recorded at nearby pelagic stations in the SFWMD monitoring network over the past ten years (Figure 62). Turbidity in Lake Okeechobee is often highest in the winter, moderate in the spring and fall, and lowest in the summer (Wang et al. 2012). This seasonal variation is the result of seasonal wind variation which strongly influences sediment resuspension throughout Lake Okeechobee because of its shallow depths and large fetch (Havens et al. 2007).

Peak TSS concentrations in the present study also occurred in winter. In March 2025, TSS exceeded 80 mg/L at the North Site N-C5-Out which was very high but within the range observed at pelagic stations L001 and L005 since 2015 (Figure 62). POLESOUT exceeded 80 mg/L only once since 2015, but showed elevated TSS (> 60 mg/L) in March 2025 at the same time as the peak observed at the North Site (Figure 64). Havens (2003) summarized water quality for Lake Okeechobee's nearshore environment from sampling conducted in 1999-2002, and the maximal TSS concentration at which SAV was observed was approximately 50 mg/L (Havens 2003). For that earlier period, the range of values within nearshore stations also indicated high variability in water quality conditions: TSS ranged from 0 to 142 mg/L, NVSS from 0 to 86 mg/L, Chl-a from

0 to 96 µg/L, and color from 8 to 536 PCU at stations where water depths ranged from 0.05 to 3.7 m, and Secchi depths ranged from 0.10 to 1.64 m (Havens 2003).

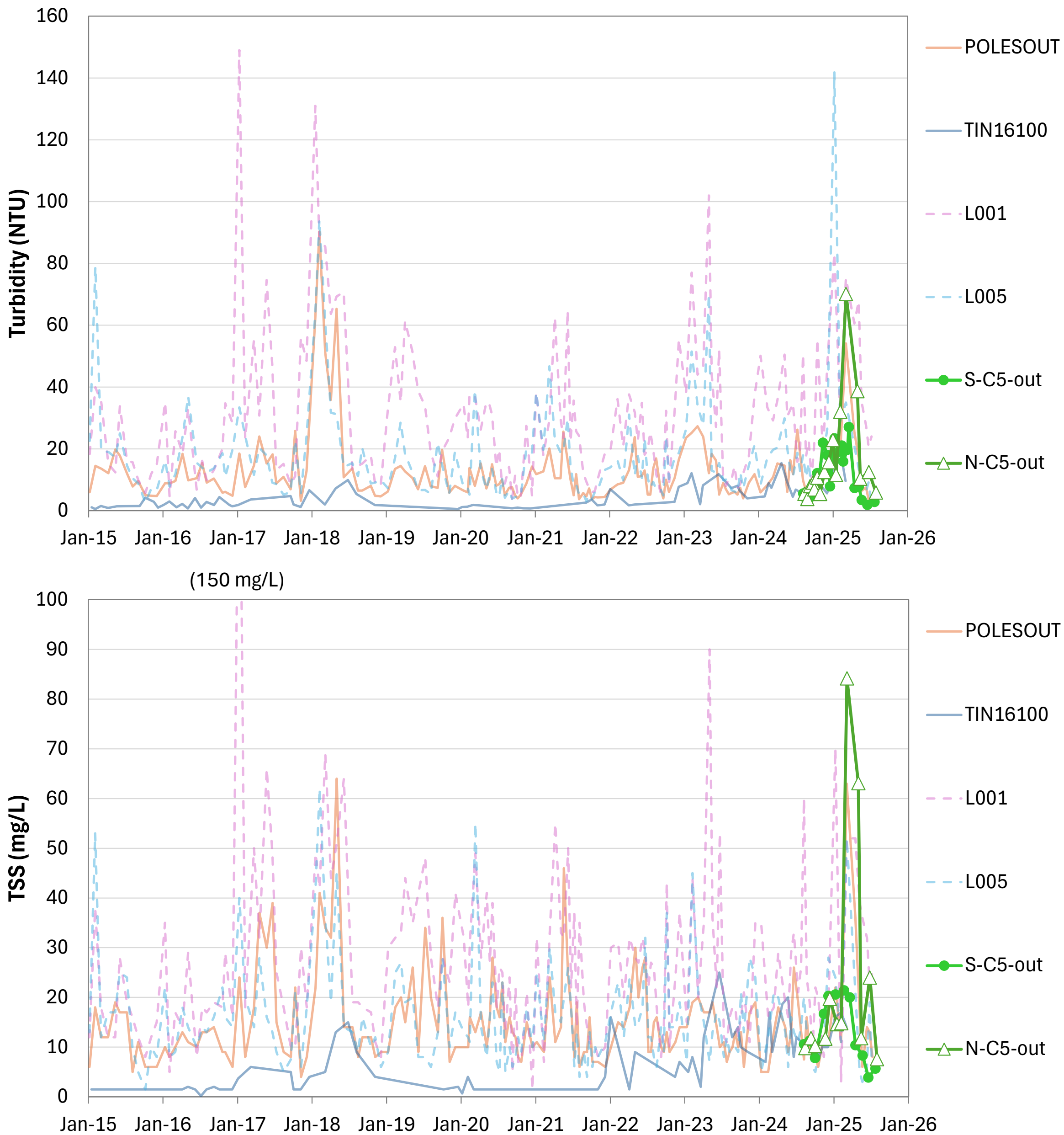


Figure 62. Comparison of turbidity and total suspended solids (TSS) concentrations at lakeward monitoring stations (S-C5-out and N-C5-out) during the current project period to a 10-year period of record using SFWMD monitoring data available in DBHydro, from nearshore stations (solid lines, POLESOUT and TIN16100) and pelagic stations (dashed lines, L001 and L005) near the project sites.

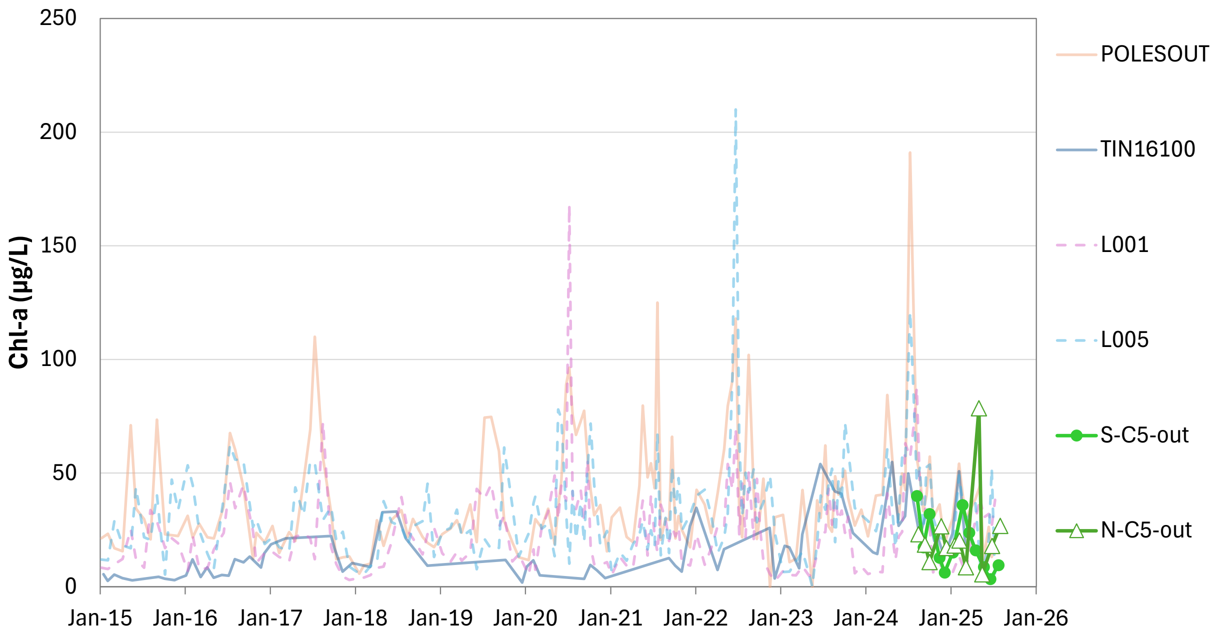


Figure 63. Comparison of Chl-a concentrations at lakeward monitoring stations (S-C5-out and N-C5-out) during the current project period to a 10-year period of record using SFWMD monitoring data available in DBHydro, from nearshore stations (solid lines, POLESOUT and TIN16100) and pelagic stations (dashed lines, L001 and L005) near the project sites.

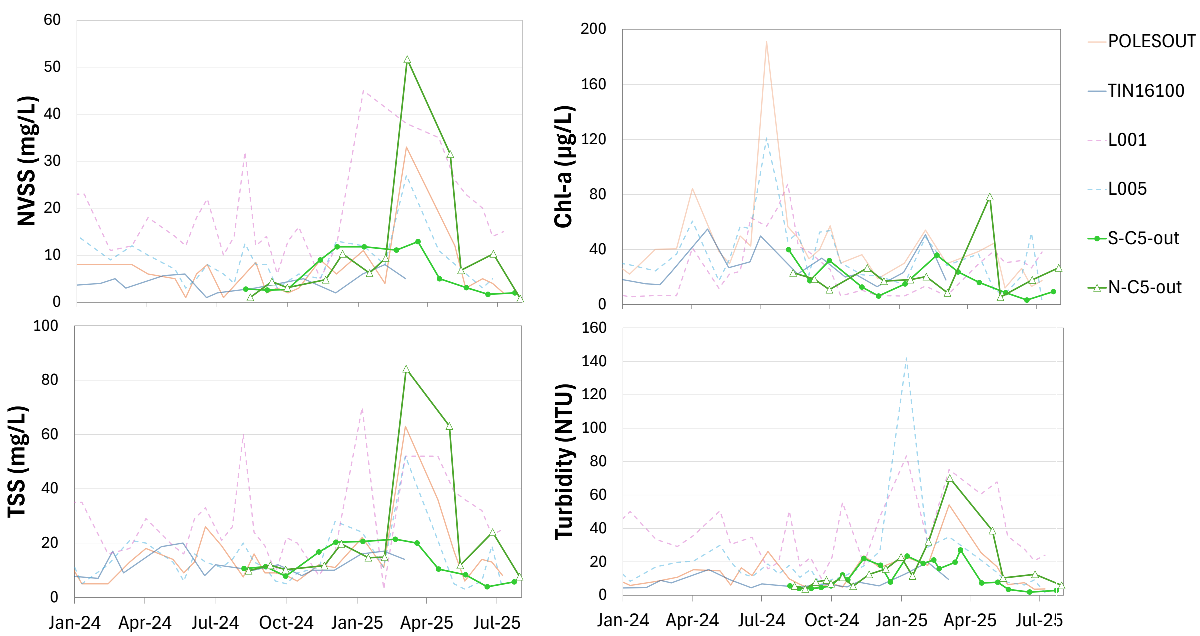


Figure 64. Comparison of turbidity, TSS, non-volatile suspended solids (NVSS) and Chl-a concentrations at lakeward monitoring stations (S-C5-out and N-C5-out) during the current project period to SFWMD monitoring data available in DBHydro, from nearshore stations (solid lines, POLESOUT and TIN16100) and pelagic stations (dashed lines, L001 and L005) near the project sites.

When the ratio of Secchi depth to total depth is > 0.5, Havens and James (1999) suggested light may reach the lake bottom in the shallow waters of the Lake Okeechobee nearshore. In that study

(1988-1998), Secchi depths ranged from ~0.2-1.5 m in the northwestern near-shore region of the lake. Secchi depths up to 95 cm were observed in the present study, and the ratio of Secchi depth to total water depth was a function of turbidity (Figure 56). Above turbidity of 15 NTU, the ratio never exceeded 0.5 among measurements where total water depths were at least 60 cm. In waters shallower than 60 cm, the Secchi disk was most often visible on the bottom in the project areas (94% of the time).

6.7 Limitations to Approach

To apply temporary turbidity controls in the future, additional curtain configurations could be explored. The shape and orientation of the curtains was found to be reasonable, given the multiple directions from which wind and wave energy approaches the nearshore environment. Exposure to prevailing winds and waves would have to be carefully considered during the planning of any future deployment of similar controls. Additional layers of curtains deployed into deeper water may provide additional protection and turbidity reduction, and pre-installation of grommets for adjusting the curtain length would allow flexibility under a range of water depths. Caution is advised, however, that the partially reefed curtains may function differently from the fully unreefed curtain under severe weather. Curtains are designed to reorient and partially release the forces applied to the curtain and tension cables between anchor points when energy from water flows or waves is too high. The pockets caused by partial reefing will put strain into the curtain fabric at the grommet locations.

The anchoring approach used here worked well and was specific to the lake sediment composition in the project area. Regions with shallow or exposed rock substrate, or deep mud may require a different anchoring approach. Future applications would need to consider the substrate in the project area and modify the anchoring system accordingly.

The installation benefited from careful, thorough and routine maintenance to quickly repair and replace components that showed wear. While the physical dimensions of the installation are scalable, the level of effort required for maintenance to ensure properly functioning controls and safe conditions would also increase.

7 Conclusions and Recommendations

Turbidity controls were successfully designed, deployed and maintained in the Lake Okeechobee nearshore environment. The turbidity reductions observed were modest relative to the level of reduction required for light penetration to the lake bed when water depths exceed 3 ft. Performance was site-dependent, and influenced by wind speed and direction, as well as lake stage. The controls achieved fairly consistent but minor reductions, punctuated by periods of more substantial turbidity reductions during strong winds, but at times were also ineffective. These periods of ineffective performance could have been caused by changes in the composition of light attenuating particles (e.g., phytoplankton, dissolved organic matter, or volatile suspended solids vs. suspended mineral sediments), lake circulation patterns, or mass flow of water that were beyond the scope of this project to characterize.

The controls were effective at reducing turbidity when wind speeds exceeded 15 mph, and the installation proved capable of withstanding tropical storm conditions and winds exceeding 50 mph with rapid recovery after storms passed. The controls required regular maintenance and some components were strained by the conditions at the pilot study locations, requiring minor repairs.

Regrowth of *Vallisneria* was observed in early March 2025 at one of the two project areas before recovery of the SAV community was observed across a wider area along the nearshore region of the lake. The exclusion cages had a positive effect on leaf length, number of leaves per ramet, and dry weight biomass of *Vallisneria* at the end of 72 days during the growing season, supporting the hypothesis that herbivory pressure may limit recovery efforts that center around small-scale planting initiatives. These results suggest medium- to large-scale exclosures that can withstand conditions in the lake could be developed and deployed to protect SAV during recovery, particularly when total lake coverage is minimal. Multiple sites with turbidity control and herbivore protection would provide important refugia and increase natural recruitment potential within the lake in subsequent years.

While this project was designed to improve water clarity and not to protect SAV from physical disturbance (e.g., wave energy), there was some evidence in the southern site that the curtains may have sheltered a patch of SAV over the winter and through extreme weather events, as it was one of the only known patches remaining on the lake in spring 2025. While it was located just within and north of the project area, there would have been some leeward protection from south and southeastern winds that occurred during Hurricane Milton. Physical structure may provide critical protection to SAV beds, even if ineffective at reducing turbidity. Strategic deployments of more robust barriers in different parts of the lake may help to retain SAV for seed dispersal to other areas after hurricanes, and create at least some resilient communities to reduce herbivore impacts as the habitats in the lake recover. Additionally, if feasible, turbidity curtains could be co-deployed with more substantial physical barriers, which would likely reduce maintenance costs and improve their performance and longevity, providing improvements to water clarity *and* robust protection from storms. Coupled with vegetation plantings or other experimental clarification products (e.g., flocculants), curtain deployments may be useful in future projects on the lake and were shown to be feasible in this study.

However, by themselves, these turbidity curtains are likely to be inefficient, with too minimal a benefit to justify the cost of their deployment and maintenance. Granted, low water levels and hurricanes complicated the implementation and results of this study, but unpredictable conditions are a staple of this system, and any future project is likely to face similar or even greater risks. A large-scale solution is important for SAV recovery in this large lake ecosystem, and the scale of this pilot project offers valuable insights to lake managers for future decision making. These results should be considered when designing and deploying future projects that restore or protect critical SAV communities in the lake.

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Appendix

Installation Details and Records of Site Visits for Maintenance/repair Activities during Project Period

A.1 Design Features of the Turbidity Controls

The turbidity controls were designed to reduce turbidity and improve light penetration in the primary SAV growth zone. The controls consisted primarily of turbidity curtains suspended from the water surface via floatation and extending toward the lake bed by weighted ballast chain. The curtains partially redirect mass flow of water that might otherwise transport turbid water into the project area. The boom provides an obstruction for surface films of algae and other floating organic material (plant detritus) drifting into the project area. A gap between the lower edge of the curtain and the lake bed provides protection against entrapment of animals by the curtain, and burial of the curtain material by sediment which can compromise the integrity of the control system. Barriers were 100-ft in length, coupled into 400-ft sections. Gaps in the length of these coupled curtains were included every 400 ft, with overlap to minimize the ingress of water moving along the outside edge of the curtain.

In front of these gaps, a “silt fence” was deployed to provide additional mitigation of movement of sediment material along the lake bed toward these gaps, and provide an area of minimal buildup of material that might contribute to localized resuspension and turbidity. Silt fences, described further below, extend upward from the lake bed toward the water surface, but do not come all the way to the water surface. Both curtains and silt fences are designed to be flexible and will partially give way under sustained high forces to avoid compromising the integrity of the installation under severe storm conditions.

The controls are designed for the Lake Okeechobee nearshore environment, and to endure the winds and waves associated with a 20-mile fetch. To protect the installed control system, the holding power of various anchors was evaluated and a fail-point coupling at turbidity control curtain anchor attachments was incorporated into the design so that curtains break loose during a major event, rather than compromising the anchors or destroying the material associated with the turbidity controls. After the storm energy subsides, the curtains can be reattached to the anchors with replacement couplings.

A.2 Custom Curtains

Custom-made for this study, turbidity curtains were deployed with a 3-ft curtain hanging vertically in the water column, weighted by a standard 5/16” galvanized chain and suspended by 5/16” stainless steel tension cable (9,000 lb breaking strength) that was incorporated into the 22-oz vinyl below the floatation (Figure 1). These curtains were anchored at either end and every 50 ft to toggle anchors deployed to maintain position and adjust tension (Figure 65).

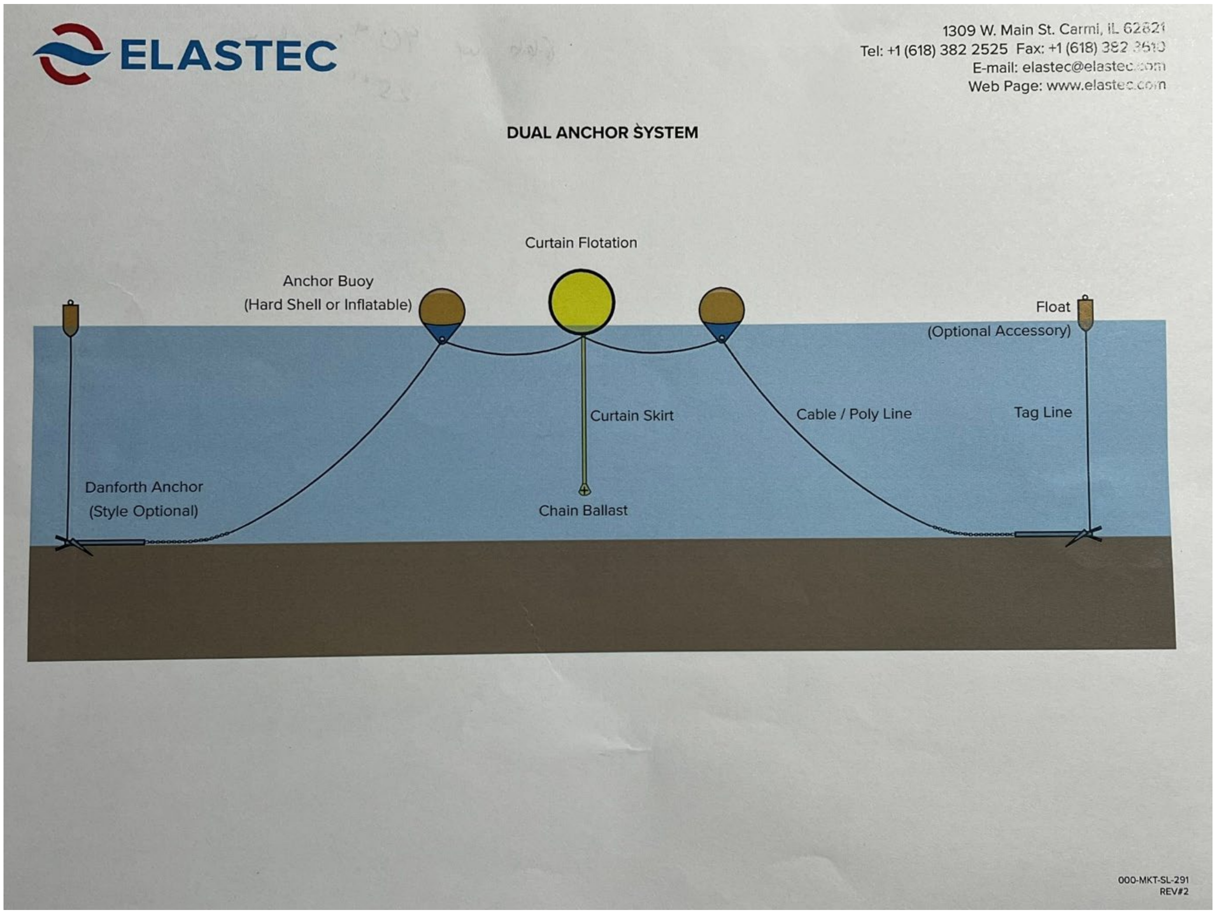


Figure 65. Schematics of curtain, float, anchor and ballast chain configuration for deployment of turbidity control. Note that duckbill toggle anchors were used in place of the Danforth anchors depicted here.

A.3 Silt Fence (Submersible Curtain)

Silt fences were deployed to reduce the movement of material laterally along the lake bed. These devices were constructed from similar materials to the boom and barrier systems, with smaller floatation and increased-weight ballast chain (5/8" galvanized steel) to position the vinyl material vertically within the water column, extending from the lake bed toward the surface (Figure 66). Tension cable anchored at either end is used to maintain position and the system is deployed with some allowance for movement to release pressure against the vinyl in the event of a strong storm event. These submersible curtains were installed in front (lakeward) of the gaps between 400' curtain sections, two at each project site (Figure 67).

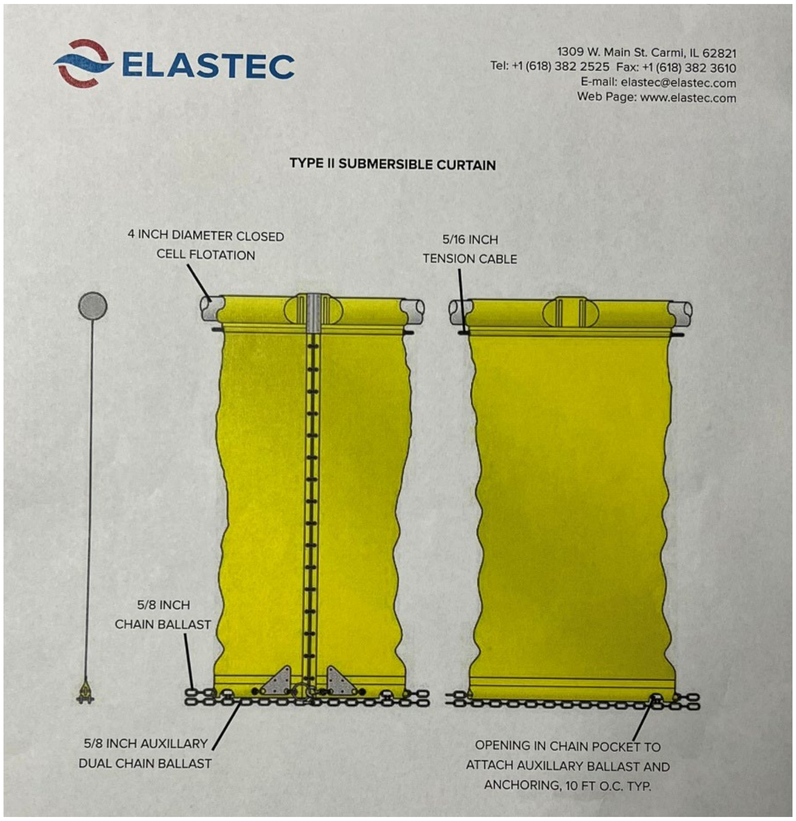


Figure 66. Schematic of submersible curtain ("Silt Fence") barrier, ballast chain and floatation that extends from lake bed upward toward the water surface.

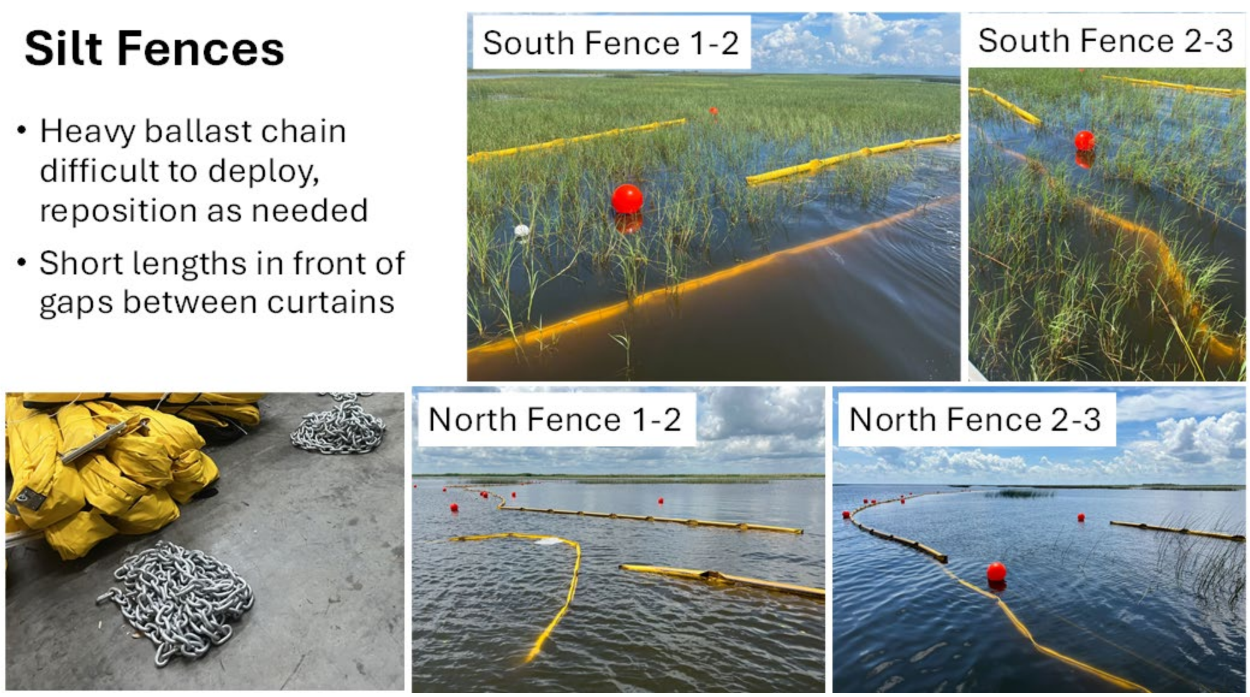


Figure 67. Installed silt fences at South and North project locations, and the heavy 5/8" ballast chains.

A.4 Anchors

Toggle anchors (duckbill earth anchors) were driven into the lake bed to provide a fixed anchor point with a nominal holding capacity of 3000 lb (Figure 68). Holding power is affected not only by the size of the toggle, but also by installation depth and the composition of the substrate (Figure 69). Duckbill 88 anchors were used in the compact sand and cemented shellrock in Lake Okeechobee to provide stability, and were attached to a 1/4" galvanized aircraft cable (breaking strength 7,000 lb) and lower rode (3/8" galvanized steel chain, breaking strength 7,800 lb), then to a 40' length of 5/8" yellow twisted polypropylene anchor rode (breaking strength 5,600 lb), 15" inflatable buoy, 6' length of 5/8" yellow twisted polypropylene painter rope, attached to the boom and barrier (curtain) with stainless steel shackles and soft shackle with breakaway link.

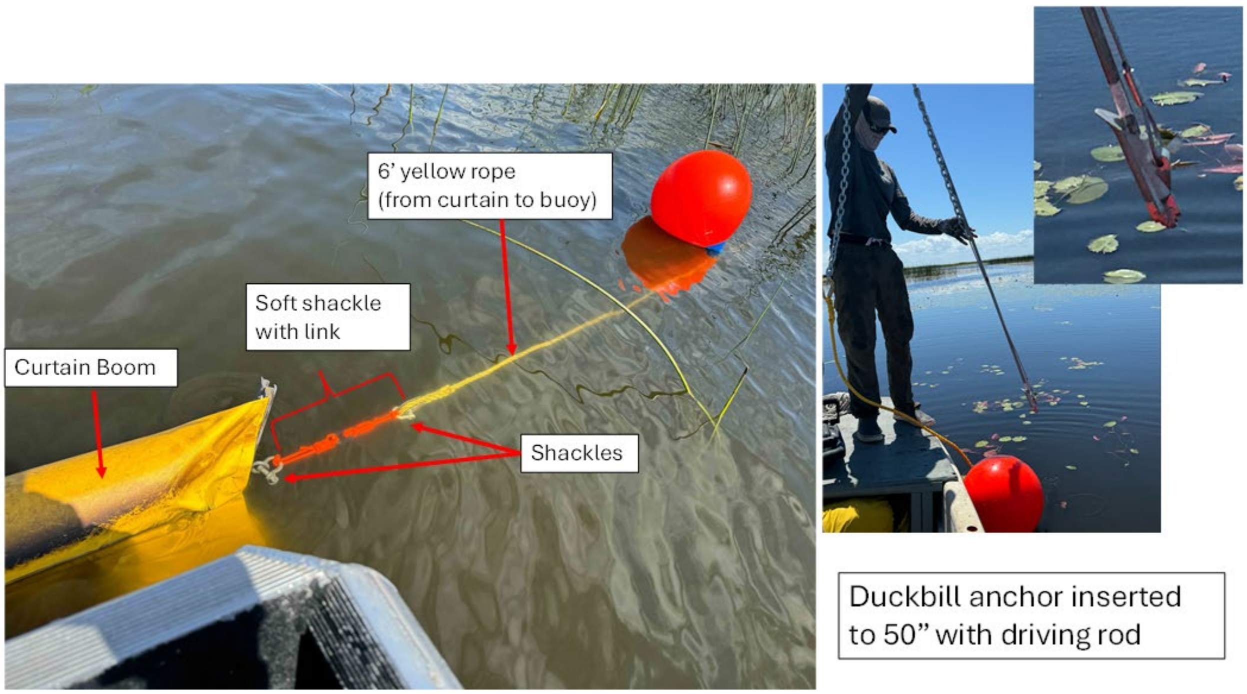
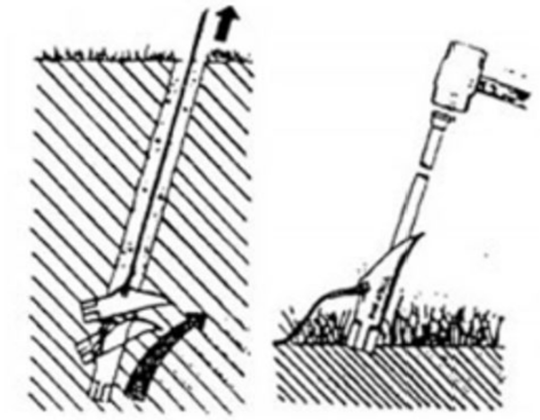


Figure 68. Anchor installation and rode components to secure boom and turbidity barrier system.



Duckbill Earth Anchors

Holding Capacity

Duckbill Model	Ultimate Capacity	Normal Soil*	Normal Installation Depth
40	580 lbs (261 kg)	300 lbs (135 kg)	20 inches (.5m)
68	2,045 lbs (920 kg)	1,100 lbs (495 kg)	30 inches (.75m)
88	6,180 lbs (2,781 kg)	3,000 lbs (1,350 kg)	42 inches (1.05m)
138	10,670 lbs (4,802 kg)	5,000 lbs (2,250 kg)	60 inches (1.5 m)

- Typical Blow Count Per ASTM-D1586. Normal Soil Blow Count Range 24-40.
- Common Soil Type – Dense Fine Sand; Very Hard Silts and Clays; Dense Clays; Sands; and Gravel; Hard Silts and Clays.

DUCKBILL® EARTH ANCHORS

Figure 69. Duckbill anchor ratings vary by size, soil type and depth of installation.

A.5 Soft Shackles and Breakaway Links

Breakaway links provided a planned fail point for releasing tension from the curtain before catastrophic failure. In several cases, this proved an essential design component, including intense storm energy associated with the nearby passing of Hurricane Milton (the storm did not pass directly over Lake Okeechobee) but also what were suspected to be boat strikes to the anchor lines and/or curtain booms. Repeated cuts in the anchor lines along the outer edge of the curtains, together with high-speed boat traffic passing the installations captured on cameras deployed at either site, suggest the damaged anchor lines and booms resulted from boats running through the project. In most cases, the break-away links had become stretched and gave way, and the anchor lines were quickly reattached during the next scheduled maintenance visit. The soft shackles were made from double braided polyester winch cord 1/4” with a nominal break strength of 2000 lb, and the plastic links had a nominal breaking strength of 1500 lb, which was the lowest of any component of the anchoring system (Figure 70). Testing confirmed link holding power of at least 1200 lb.

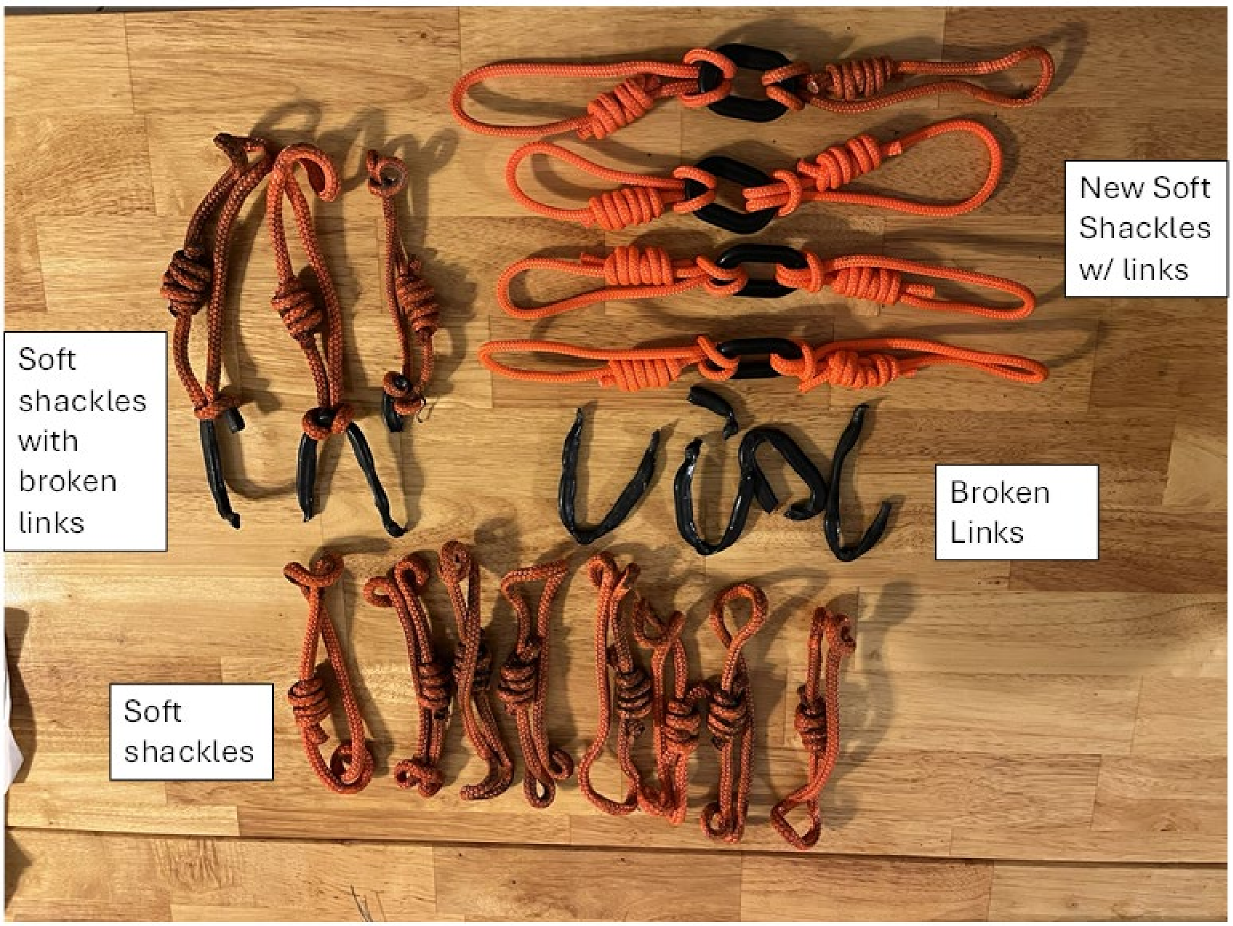


Figure 70. Soft shackles and breakaway links used to attach the curtain booms to anchor points.

A.6 Adapting Controls to Shallow Water – Grommet Install under Task 4a

Under Task 4a, turbidity curtain modifications were initiated at the beginning of March 2025 and completed on April 29, 2025.

Modifications were completed by a combination of work on and off the water. Initial grommet installation occurred at (and in consultation with) the curtain manufacturing facility to review the equipment and design (Figure 71). Several curtains were in need of minor repairs to the hardware (metal end plates) or vinyl curtain, and these repairs were completed before grommets were installed every 3-4 ft along the barrier, 18” from the bottom edge (Figure 72). This position allows the curtain to be rolled tight from the bottom edge to shorten the length of curtain to 18” down from the water line and float, rather than full depth curtains at 3’ length. The “partially reefed” curtains can operate in water as shallow as 2 ft and maintain 6” clearance below the bottom of the curtain. As lake levels increase to water depths > 4 ft, the curtain can be released to a full depth of 3 ft to provide turbidity reduction, while maintaining 1 ft clearance below the curtain. This design modification was implemented with on-water installation to expedite delivery (Figure 73) and provide operational flexibility in the lake across a range of water depths. Modifications were completed for all 24 curtains (12 at each of two project locations).

Figure 71. Grommet installation tools at manufacturing facility.

Figure 72. Preparation and deployment of modified controls.

Figure 73. On-water installation of the modifications to expedite delivery of results.

A.7 Maintenance and Visit Task Log

Anchor point maintenance checklists (Figure 74) and field sheets for monitoring activities (Figure 75) proved useful for keeping track of the details during each site visit. The record of activities includes recon trips during project design, installation, maintenance, monitoring and removal (Table 6).

Date: 1/8/2025 South Site

Personnel: DM RU

Position	Connection	Condition
Boom 4.000	Soft shackle	Replaced anchor rope w/ 50' and new Soft Shackle
Boom 4.050	Soft shackle	Replaced two zipties w/wire
Boom 4.100	Triple anchor	Replaced five zipties w/wire
Boom 4.150	Soft shackle	Replaced one ziptie w/wire
Boom 4.200	Soft shackle	Replaced ziptie w/wire
Boom 4.250	Soft shackle	Cut line needs replaced
Boom 4.300	Triple anchor	(One line cut) Need replacing; Replaced four zipties w/wire
Boom 4.350	Soft shackle	Replaced two zip ties w/wire
Boom 4.400	Soft shackle	Replaced one ziptie w/wire
Boom 5.000	Soft shackle	✓
Boom 5.050	Soft shackle	✓
Boom 5.100	Triple anchor	✓
Boom 5.150	Soft shackle	Replaced one ziptie w/wire
Boom 5.200	Soft shackle	Replaced three zip ties w/wire
Boom 5.250	Soft shackle	Replaced two zipties w/wire
Boom 5.300	Triple anchor	✓
Boom 5.350	Soft shackle	Replaced 3 zip ties w/ wire
Boom 5.400	Soft shackle	Replaced 1 zip tie w/ wire
Boom 6.000	Soft shackle	Removed a double shackle and two zipties w/ wire
Boom 6.050	Soft shackle	Replaced two zip ties w/wire
Boom 6.100	Triple anchor	✓
Boom 6.150	Soft shackle	✓
Boom 6.200	Soft shackle	✓
Boom 6.250	Soft shackle	✓
Boom 6.300	Triple anchor	✓
Boom 6.350	Soft shackle	Replaced zip ties with wire at all shackles.
Boom 6.400	Soft shackle	Replaced w/ 50 ft rope, added 2 hard shell buoys 15 ft apart.

Figure 74. Example maintenance field sheet for checking the integrity of installation components.

Date 12/17/2024 Lake O Turbidity Initials BL DM

North Site - Weekly maintenance event		
Lake Stage: 15.41'	Arrival Time: 1410	Departure Time: 1530
Ambient Conditions (wx, wind, waves):	Sunny, 76°F light winds 10mph NNE, 1-1.5ft secs. winds building to 10+ mph as day progressed.	
Activities	**NOTES:**	
Inspection of boom and anchor lines	all seem to be in place & secured	
Inspection of curtains	Good	
Inspection of navigation aids	Present & in proper location	
Inspection of exclosures/plots	Crew did not inspect or find any	
Inspection of silt fences and other equipment	In Position, boom 2.0 out of position due to wave and is in front of silt curtain	
Overall Site photo numbers		
Repairs	Changed batteries in Game Camera	
Sonde stands	Missing PVC marker Pole @ N. outside.	
Weather Station	N/A	
Observations	**Inside**	**Outside**
Water observations (color/clarity):	Brownish, tannic less turbid than normal	Brownish, Tannic less turbid
Vegetation	Good	Good
Wildlife Present "*" if TRAPPED AND RELEASED	none	none
Sonde DEPLOYED / RETRIEVED (circle one)	Sonde ID: 4422 Time: 1450 Depth to bottom: 150 Depth to Sonde: 98 Probe orientation: N S (E) W	Sonde ID: 4420 Time: 1507 Depth to bottom: 154 Depth to Sonde: 104 Probe orientation: N (S) E W
Photo numbers		

Sonde: 1787
Deployed: 1515
Depth: 162
> Buoy #3

Lake O Turbidity (FB)
5 of 10

Figure 75. Example field record of monitoring and maintenance activities.

Table 6. Activity log for reconnaisence, design, testing and installation, routine maintenance and field monitoring (FM), and water quality (WQ) sampling. Grey-shaded areas denote planning, installation, and removal, while green shading indicates the period when turbidity controls were installed, maintained, and efficacy was monitored.

Date	Event	Maintenance	FM North	FM South	WQ North	WQ South
4/4/2024	Recon Trip 1					
4/8/2024	Recon Trip 2					
4/15/2024	Recon Trip 3					
4/30/2024	Sub-bottom Profile Day 1					
5/1/2024	Sub-bottom Profile Day 2					
5/21/2024	Anchor Testing at Lox					
5/23/2024	Anchor Testing in Lake Day 1					
5/30/2024	Anchor Testing in Lake Day 2					
6/4/2024	Anchor Testing at Lox					
6/5/2024	Drone and Buoy anchors					
6/6/2024	Duckbill install					
7/9/2024	Preliminary WQ sampling					
7/10/2024	Anchor Install Day 1					
7/11/2024	Anchor Install Day 2; Vallisneria Inoculation					
7/17/2024	Anchor Install Day 3; Sign install Lock 7 S127 ramps					
7/22/2024	Anchor Install Day 4					
7/24/2024	Anchor Install Day 5					
7/29/2024	Anchor Install Day 6					
7/30/2024	Anchor Install Day 7					
7/31/2024	Anchor Install Day 8					
8/1/2024	Installation Inspection					
8/4/2024	Tropical Storm Debby					
8/7/2024	Maintenance + South WQ	X		X		X
8/12/2024	Maintenance					
8/13/2024	Maintenance + North WQ	X	X		X	
8/14/2024	Buoy check + cage install south site	X				
8/19/2024	Silt Fence Install Day 1 and South FM	X		X		
8/21/2024	Silt Fence Install Day 2	X				
8/26/2024	Silt Fence Install Day 3	X				
8/27/2024	Maintenance + North Field Measurements	X	X			
9/4/2024	Maintenance + South WQ	X		X		X
9/10/2024	Maintenance + North WQ	X	X		X	
9/11/2024	Navigation Buoy Labeling	X				
9/17/2024	Planting, Field Maintenance, South FM	X		X		
9/24/2024	Maintenance + North FM	X	X			
9/25/2024	Vallisneria Sampling					
9/26/2024	Hurricane Helene					
9/30/2024	Maintenance + North & South WQ	X	X	X	X	X
10/1/2024	Maintenance	X				
10/7/2024	Maintenance	X				
10/9/2024	Hurricane Milton					
10/15/2024	Repair after Milton + North and South FM	X	X	X		
10/16/2024	Repair Day 2	X				
10/22/2024	South Site FM + Mx	X		X		
10/23/2024	Curtain Repair	X				

Table 6 (continued).

Date	Event	Maintenance	FM North	FM South	WQ North	WQ South
10/29/2024	North FM + Maintenance	X	X			
11/12/2024	Maintenance + South WQ	X		X		X
11/14/2024	Second drone flight - mid project	X				
11/19/2024	Maintenance + North WQ	X	X		X	
11/26/2024	Maintenance	X				
12/4/2024	Maintenance + South WQ	X		X		X
12/11/2024	Maintenance + North WQ	X	X		X	
12/17/2024	Maintenance + South Site FM	X		X		
12/31/2024	Maintenance + North Site FM	X	X			
1/8/2025	Maintenance + South WQ	X		X		X
1/15/2025	Maintenance + North WQ	X	X		X	
1/22/2025	Maintenance	X				
1/29/2025	Maintenance + South Site FM	X		X		
2/5/2025	Maintenance + North WQ	X	X		X	
2/12/2025	Maintenance + South Site FM	X		X		
2/19/2025	Maintenance + South WQ	X		X		X
2/26/2025	Partial Reef Boom Swap	X				
3/5/2025	Maintenance + North WQ	X	X		X	
3/12/2025	Maintenance + South Site FM	X		X		
3/19/2025	Maintenance + South WQ + grommets	X		X		X
3/24/2025	Maintenance + grommets	X				
3/26/2025	Maintenance + grommets	X				
4/2/2025	Maintenance + grommets + curtain repairs	X				
4/9/2025	Maintenance + grommets	X				
4/10/2025	Maintenance + grommets	X				
4/16/2025	Maintenance + South WQ	X		X		X
4/21/2025	Vallisneria prep for lake					
4/23/2025	boat trouble, blown spark plug, day aborted					
4/28/2025	Val exclosures, grommets	X				
4/29/2025	Third drone flight - final aerials					
4/30/2025	Maintenance + North WQ + Val plants South	X	X		X	
5/7/2025	Maintenance + South Site FM	X		X		
5/14/2025	Maintenance + North WQ	X	X		X	
5/21/2025	Maintenance + South WQ	X		X		X
5/28/2025	Maintenance	X				
6/4/2025	Maintenance + South Site FM	X		X		
6/11/2025	Field Measurements + Maintenance	X	X			
6/18/2025	Maintenance + South WQ	X		X		X
6/25/2025	Maintenance + North WQ	X	X		X	
7/2/2025	Maintenance + North Site FM	X	X			
7/9/2025	Vallisneria Sampling; anchor removal trial	X				
7/10/2025	Vallisneria Sample Processing					
7/16/2025	Maintenance + South Site FM	X		X		
7/23/2025	Maintenance + South WQ	X		X		X
7/30/2025	Maintenance + North WQ	X	X		X	
8/6/2025	Curtain removal					
8/7/2025	Anchor removal					
8/13/2025	Curtain removal					
8/27/2025	Curtain removal					
9/3/2025	Final curtain removal					