

100-acre Marsh Restoration at Parker River NWR

Monitoring Report, updated April 2023

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Background and Purpose

From 2014 to 2020, Parker River NWR staff and partners tested various restoration techniques to address specific issues or symptoms of salt marsh degradation, such as excessive standing water and vegetation dieback. The purpose of each pilot study was to understand the underlying cause of each issue or symptom and test innovative, low-cost, low-impact techniques to restore marsh surface hydrology. Techniques include runneling, ditch plug removal, OMWM modification, creation of microtopography islands, and ditch remediation.

Through these pilot projects, we have gained a deeper understanding of marsh restoration techniques and their interactions with natural processes. From 2021 to 2022, we combined all we have learned about marsh response to the previous pilot studies and used these techniques to comprehensively restore marsh surface flood-ebb hydrology on 100 acres of marsh within Parker River NWR. We chose specific restoration techniques to reestablish proper expression of ecosystem processes, boost resilience to increased flooding, and establish a marsh-sustaining trajectory.

The project site spans approximately 100 acres of salt marsh located between Plum Island Sound and the Refuge Road (see maps in Appendix A). The proposed restoration site is easily accessible and highly visible to visitors. This portion of the marsh is heavily impacted by anthropogenic alterations, including extensive mosquito control ditches, ditch plugs, and OMWM plugs, radial ditches, and pools. OMWM infrastructure is particularly extensive, and these infrastructures exacerbate other legacy impacts. As a result, much of the area is highly saturated, and pools are expanding and merging. The Refuge already addressed all but two ditch plugs that previously impounded water in this area (2019), and we piloted lowering OMWM plugs in a pilot in 2020. Response to the 2019 ditch plug removal and preliminary results of OMWM plug pilot are promising. This project addresses the remainder of the legacy alterations, including the extensive pools and highly saturated areas, particularly near the upland edge.

Description of Restoration Work

The restoration work done in 2021 and 2022 is as described in the ACOE permit with exception to 31 features where adjustments were made in the field. As-built maps and an explanation of these changes can be found in Appendix A. Below is a summary of each restoration feature.

Table 1. Summary of restoration work completed.

Restoration Feature	Number completed	Timeline
Runnels	23 (64 segments)	September 7 - October 7, 2021
Microtopography Islands	60	September 7 - October 7, 2021
Ditch Remediation	30	September 16 - October 5, 2022

Runnels

Purpose: The purpose of runneling is to remove excessive standing water and/or to lower the groundwater zone of saturation to a depth suitable for vigorous plant growth (20 to 30 cm below marsh surface). This

technique can address pools that are enlarging unnaturally or inundated marsh platforms where the water is not ebbing on its own, particularly where the vegetation may be converting to *Spartina alterniflora* or showing signs of dieback. Often, these inundated areas are associated with legacy embankments or high-density ditches left from the salt marsh haying era (Adamowicz et al., 2020). As runnels are shallow, they will not drain all pools and are not used to drain naturally occurring pools.

Work Completed: From September 7th to October 7th, 2021, we created 23 runnels, or shallow channels, to treat areas exhibiting excessive saturation and/or standing water. Some of these runnels were split into segments if the entire length did not need to be opened. This resulted in 64 individual runnel segments.

Metrics of success: Hydroperiod in both the ditches, pools, and adjacent marsh areas will be assessed to determine if hydrological restoration goals are met. Ditches and pools should ebb and flood with minimal tidal lag or restriction. Ditch geomorphology may change to accommodate new tidal volume and should not clog. Inundated marsh surface in area drained by the runnel should have lowered ground water levels (ideally 15-25 cm below surface) at all but the highest lunar tides. Increase in percent cover of high marsh plant species, however, colonization by marsh elder may be a sign of excessive drainage.

Adaptive Management: If monitoring data and reconnaissance surveys indicate that the above metrics are not met, adaptive management will be implemented. This includes adjusting the dimensions of the runnels and creating secondary runnels. Restoration design is purposely conservative to avoid excessive drainage.

Ditch plug removal and OMWM modification

Purpose and Work Completed: We employed ditch plug removal or OMWM modification where OMWM infrastructure (ditch plugs or OMWM plugs) were impounding water on a marsh and creating conditions that degrade marsh integrity. Some of these areas are visible in the field to a trained eye. We also use historical aerial maps and design overlays to identify most of these features. As previously mentioned, these ditch plug removals in this area were completed as part of pilot projects in 2010 and 2020.

Metrics of Success and adaptive management: Techniques same as those for runnels.

Microtopography islands

Purpose: We used sediment removed from runnels, ditch plug removal, and OMWM modification to create microtopography islands to support marsh accretion processes in the face of rising sea levels. The goal was to create islands big enough to support breeding salt marsh sparrows. Past pilot experiments indicated that we can successfully create suitable nesting habitat (thick *Spartina patens/alterniflora* mix with thatch at higher elevations). In this phase, we sought to increase the island size to increase the likelihood of nesting by sparrows while minimizing negative impacts of scaling up, such as predation and biochemical impacts of sediment addition. We did not specifically identify the size and location of microtopography islands during the project's design phase, as the exact location and dimensions were based on the amount of material removed during runneling.

Work Completed: From September 7th to October 7th, 2021, we created 60 microtopography islands using soils from the creation of runnels.

Metrics of Success: Microtopography islands should be 90-100% vegetated with native salt marsh plants, with >60% thatch layer by second growing season. No invasive or upland species should grow on these islands.

Adaptive Management: If invasive or upland species present on islands, elevation will be lowered to provided proper flooding.

Ditch Remediation

Purpose: Ditch remediation adds hay to select ditches to trap sediment and facilitate vegetation growth and peat development. By healing some ditches, we direct tidal flow into a smaller number of primary channels, restoring tidal flow closer to creek hydrology. Having the ebb tide flow through a smaller number of ditches will also help remaining ditches to remain open without maintenance.

Work Completed: We implemented ditch remediation on 30 ditch segments between September 16th and October 5th, 2022. This work was timed to avoid impacts to nesting saltmarsh sparrows and to avoid the highest tides of the month. Salt marsh vegetation was mowed adjacent to each target ditch using a low psi walk behind mower. Equipment was selected to avoid compaction and rutting of the marsh. The cut vegetation is then raked into the ditch by hand or by using a walk behind tractor-mounted hay rake. We added hay to the bottom of each ditch, compacted it manually, and secured it with twine and wooden stakes. Use of on-site hay avoids the introduction of invasive species and limits impacts from transporting material across the marsh.

Metrics of Success: The treated ditches will be vegetated with *Spartina patens* or *alterniflora*; with no impounding of water in portions of the ditches. Elevation of a remediated ditch will be at or slightly below (<15 cm) the marsh surface. There should be no sign of water impounding in the marsh panels in between remediated ditches. On a landscape scale, the remaining open ditches should be self-sustaining and at equilibrium with the tide shed.

Adaptive Management: Restoration is designed to avoid the potential issues identified above. If there's impounding of water in the marsh panels, micro-runnels can be used to direct water to the open ditches and accelerate evolution to single channel hydrology. We expect to return in spring 2023 for additional ditch remediation.

Monitoring

The monitoring protocol for this project is based on lessons learned from 18 years of salt marsh monitoring on the Refuge. For the initial pilot projects, monitoring was more extensive to increase our understanding of short-term marsh response to various restoration techniques. As we scale up restoration, we will continue monitoring at a subset of sites pre- and post-restoration to evaluate restoration efficacy and long-term marsh response.

In this integrated monitoring plan, the objectives of monitoring are as follows:

- Confirm the effectiveness of combined restoration techniques in restoring hydrology and high marsh vegetation.
- Understand any synergetic effects of combining multiple restoration techniques, particularly in achieving the goal of restoring flood and ebb hydrology on a tideshed scale.
- Continue to monitor subset of pilot projects to understand long term marsh response.

To achieve this, we are using a combination of qualitative and quantitative monitoring metrics. The qualitative (or reconnaissance) data are used directly to assess whether restoration objectives are met and to implement adaptive management, if needed. This includes adding additional treatments, such as additional runnels and ditch remediation. We will summarize the quantitative data (vegetation, water levels, marsh elevation, and availability of suitable sparrow habitat) and correlate them to each other to better understand the mechanisms driving improvements to marsh resiliency or sparrow habitat, and to inform

future projects. A compilation of the monitoring protocols used on this project can be found on [ServCat](#). Locations of completed monitoring and examples are shown in the maps included in Appendix B.

Qualitative Monitoring

We will use qualitative methods to assess whether target conditions are achieved at each restoration site. Qualitative monitoring includes:

Restoration Feature Measurement

In 2021, we took initial measurements of width, depth, and length of created runnels (Figure 1) and the length and width of microtopography islands (Figures 2 and 3). In 2022, we took initial measurements of the width, depth, length, and depth of treatment of remediated ditches (Figure 4). In addition, data was collected on vegetation and signs of inundation within and adjacent to the restoration features at the time the work was completed. Measurements for a subset of these restoration features will be taken again to assess any changes in dimensions, vegetation cover, and inundation for two years after work is completed.

Completed Monitoring:

- **2021:** The runnel segments were measured upon completion (Figure 1). The average width of the runnel segments was 53 cm (range 29 to 78 cm), and the average depth was 27 cm (range 16 to 44 cm). The microtopography islands were measured upon completion (Figures 2 and 3). The average length was 2.8 m (range 0.9 to 7.1 m), the average width was 1.8 m (range 0.4 to 4.8 m), and the average area was 5.7 m² (range 0.45 to 25.9 m²).

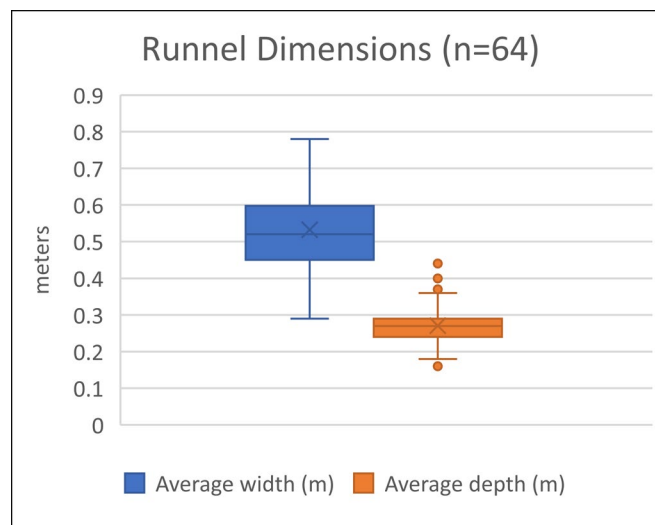


Figure 1. Dimensions of completed runnels.

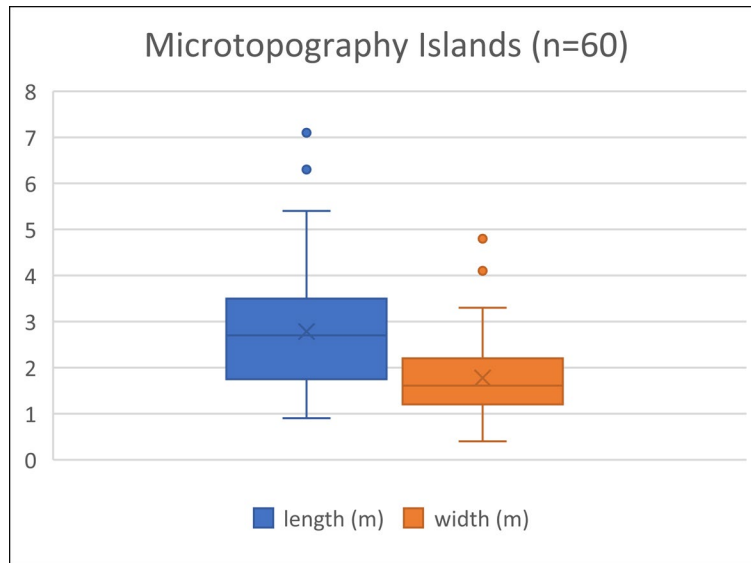


Figure 2. Dimensions of completed microtopography islands.

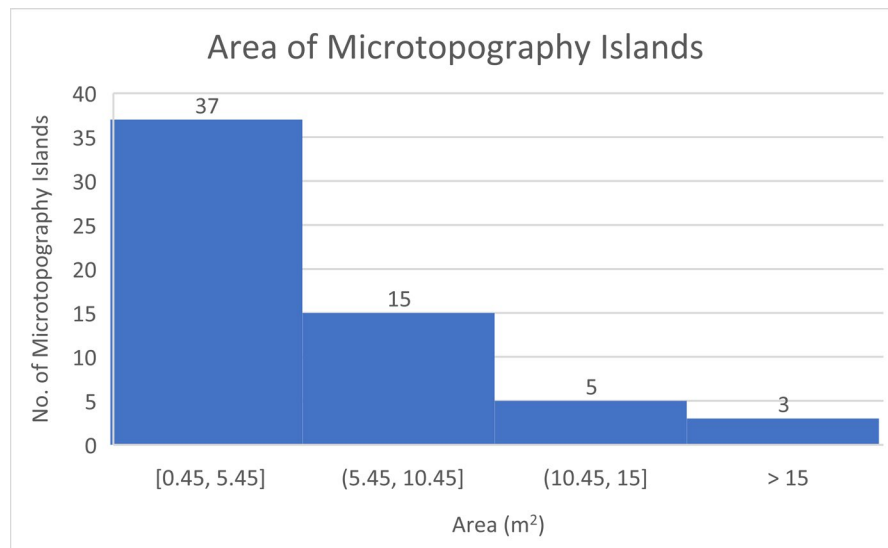


Figure 3. Area of completed microtopography islands.

- 2022:** Vegetation and soil saturation data were collected for a subset of 14 microtopography islands. Ditches were measured before and immediately after remediation. The average width of the ditches was 0.74 m (range 0.3 to 1.8 m), the average depth of the ditches before treatment was 0.39 m (range 0.1 to 0.78 m), and the average depth of the treatment was 0.28 m (range 0.08 to 0.58 m).

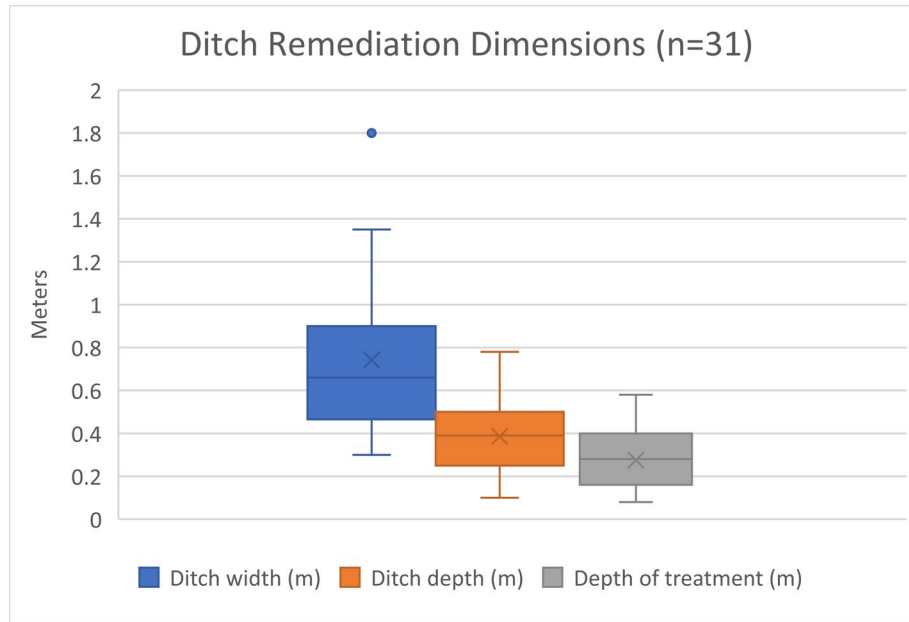


Figure 4. Dimensions of remediated ditches.

Results to Date:

We currently only have the initial measurements for the completed restoration features. A subset of these features will be re-measured starting in 2023. Once follow-up measurements of the restoration features are taken, we will assess any changes in dimensions, vegetation cover, and inundation.

The vegetation data taken for a subset of microtopography islands in 2022, after one growing season, showed that they are approximately 80 to 100% vegetated with native salt marsh plants (Table 2). Ten of the 14 sampled islands were dominated by vegetation typical of high marsh, such as *S. patens*, *Distichlis spicata*, and *Atriplex*. One island was primarily covered in wrack, leading to lower vegetation coverage. Thatch cover on the islands were either moderate (34-66%) or high (67-100%), except for the island that was dominated by wrack which had low thatch (1-33%). Additional species observed growing on the islands included *S. alterniflora*, *Salicornia* sp., *Lysimachia maritima*, *Suaeda* sp., *Agalinis maritima*, and *Symphyotrichum subulatum*. No invasive or upland species were observed growing on the microtopography islands. Based on this subset of data, it seems we are well on our way to meeting the metrics of success for microtopography islands; however, this will require another season of sampling to confirm.

Table 2. Dominant vegetation cover on microtopography islands.

Dominant Cover on Island	Number of Islands
<i>S. patens</i> / <i>Distichlis spicata</i> mix	4
<i>S. patens</i>	3
<i>D. spicata</i>	1
<i>Atriplex</i> species	2
<i>S. alterniflora</i> / <i>S. patens</i> mix	2
<i>S. alterniflora</i> (short form)	1
Wrack	1

Aerial Imagery Analysis

We will assess the extent of marsh surface flooding pre-restoration and post restoration, using aerial imagery (as hydrology and vegetation signatures can be more pronounced on aerial photos). This has not yet been completed as the most recent available aerial imagery of the site is for 2021, which would not show impacts from the restoration work that occurred in fall 2021 and 2022.

Results to Date:

Since the 100-acre marsh work was completed in 2021 and 2022 and latest aerial imagery available is from 2021, we will assess this once new imagery becomes available. However, we can show examples of aeriels from before and after restoration work from the 2017 and 2019 pilot projects. The exact dates and times that aerial photos were captured are not always available, therefore the exact tidal stages cannot be determined - a factor which needs to be taken into consideration while assessing changes.

- Example 1: Ditch plug removal was used to address two pools in an area south of the Salt Pannes. The top panel of Figure 5 (below) shows the area before restoration (April 2019), with two pools that are disconnected from tidal flow. Two ditch plugs were removed on May 22, 2019, as shown in the lower panel of Figure 5. This restoration allowed water to flow off the marsh surface, thereby draining the pools, with the tide cycle. A noticeable reduction in the size of the pools following the restoration can be seen in the lower panel of Figure 5, which uses aerial imagery from Spring 2021. Figure 6 shows the revegetation of the drained pools during the growing season (October 2021).
- Example 2: In May 2017, we removed two ditch plugs near the north end of the Salt Pannes Observation Area, a high visitor use area along the Refuge Road. The plugs were impounding water on the marsh surface, creating new pools and killing vegetation (Figure 7 - top panel, 2017). After removing ditch plugs, the pools drained almost immediately (Figure 7 - middle panel, 2018). Within two years, the pools and surrounding areas were densely vegetated with a combination low marsh and high marsh species (Figure 7 - bottom panel, 2021). The ditch plug removals resulted in approximately 12.4 cubic feet of impact to the marsh. This is a small price for the approximately 0.75 acres of marsh restored by this work.



Produced in the Parker River National Wildlife Refuge Complex Office
Newburyport, Massachusetts

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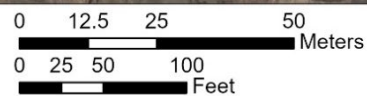
Basemap: 2019 and 2021 Aerial Imagery, MassGIS

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Source Data: Parker River NWR Management Units, USFWS, 2022

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Datum: D WGS 1984

Figure 5. Aerial photos from before and after 2019 ditch plug removal at two pools south of the Salt Pannes (Example 1).



Figure 6. Aerial imagery showing revegetation of the drained pools (Example 1) during the growing season. (Google Earth, October 2021)



Figure 7. Aerial imagery of the ditch plug removal site (Example 2) before and after restoration in May 2017. The locations of ditch plug removal are marked with red dots. (Google Earth 2017 & 2018; MassGIS 2021)

Visual Inspection

We will visually inspect all restored hydrology flows at least twice a year (spring and late summer) and adjust clogged areas and need for additional restoration follow-up.

Completed Monitoring:

- **2022:** We visually inspected the runnels completed in 2021 in 2022.

Results to Date:

No clogging was observed during the 2022 inspections. We plan to inspect restored hydrology flows again during 2023.

Photo stations

We will continue to monitor a subset of existing photo stations. In addition, we will establish new photo stations in areas expected to be affected by the proposed project, for easy comparison and visualization of change. Photo stations provide a powerful visual tool for communication and outreach. See the maps in Appendix A for locations of photo stations.

Completed Monitoring:

- **2021:** Eight photo stations were established to monitor microtopography islands in 2021. In addition, five existing ditch plug removal photo stations (established in 2019) south of the salt pannes were revisited.
- **2022:** In 2022, 22 existing photo stations were revisited to monitor impacts from previously completed runnel, ditch plug removal, and microtopography work. In addition, 11 new photo stations were established in areas where ditch remediation had recently occurred.

Results to Date:

- **Runnels:** Examples 2 and 3 below show the marsh's response to ditch plug removal and runneling. In general, photos show a reduction in marsh surface inundation and bare ground and an increase in vegetation cover after runnels are created or ditch plugs are removed.
 - Example 2 (continued): These on the ground photos correspond to the aerial imagery of Example 2 above. Two ditch plugs were removed in 2017 (see Figure 8).



Figure 8. Photo station imagery of the ditch plug removal site north of the Salt Pannes before and after restoration (Example 2).

- Example 3: Two ditch plugs were removed in 2019 and two runnels were created in 2021 (see Figure 9).



Figure 9. Photo station imagery of the ditch plug removal site before and after restoration (Example 3).

- **Ditch remediation:** We have not yet revisited ditch remediation photo stations since they were established in 2022 as the work was completed. Once additional photos are taken, we will be able to visually assess the marsh's response to this restoration. At this time, we can provide before and after photos from a 2015 ditch remediation pilot project (Example 5). Over the first three years following ditch remediation, treated ditches became shallower and more vegetated. *S. alterniflora* colonized ditches with the bottom above Mean Low Tide. Some ditches healed to 20 cm below marsh surface, while some healed to the marsh elevation. Detailed data is provided in Burdick et al. (2017). Figure 10 shows this progression from an open ditch in 2014 to revegetated peat in 2020, following the 2015 remediation.



Figure 10. A ditch before (left) and after (right) 2015 remediation. After remediation, peat developed within the ditch, and it thoroughly revegetated (Example 5).

- **Microtopography Islands:** In addition to collecting measurement, vegetation, and inundation data on a subset of microtopography islands, we will also document their progression with photos. Figure 11 below shows an island (ISL_SUOM_015) created in September 2021 (Example 4). In September 2021, the island was dominated by *S. alterniflora* with no thatch and some bare areas. In October 2022, while still dominated by *S. alterniflora*, the island is nearly completely covered in vegetation, including additional species such as *D. spicata*, *Suaeda* sp., *S. patens*, and *Salicornia*. In addition, the vegetation data reported moderate thatch cover for this island.



Figure 11. A microtopography island composed of removed ditch plug material immediately after creation (2021) and a year later (Example 4).

Quantitative Monitoring

In addition to the qualitative assessment, we will also collect quantitative data to measure response of vegetation, hydrology, elevation, and saltmarsh sparrows, as detailed below. See Appendix A for maps of monitoring locations and Appendix B for monitoring protocols.

Vegetation Transects

Vegetation transects have been established for each of the pilot innovative studies. We will continue to monitor a subset of these transects and add additional transects as needed. Transects typically run along salt marsh gradient (i.e., healthy high marsh to inundated areas targeted for restoration work, or upland to creek). Vegetation surveys are conducted in late summer or fall, and we collect point intercept and cover breaks data for all plant species, thatch, wrack, bare ground, and open water. We typically collect data for at least one year prior to restoration and multiple years after restoration. This monitoring technique allows us to assess local impacts of restoration actions on plant communities. While it is limited in spatial scope, this technique provides high quality quantitative data that can be readily interpreted in post-restoration analysis. Increases in total vegetation coverage indicate successful restoration at severely impacted sites. Transitions from *Spartina alterniflora* to high marsh communities with high thatch coverage indicate restored hydrology that supports high marsh and species like saltmarsh sparrows.

Completed monitoring:

- **2021:** Point intercept and cover break surveys were conducted on a subset of 14 vegetation transects between August 25th and November 9th, 2021.
- **2022:** One new vegetation transect was added and two transects were extended by adding additional plots. Point intercept and cover break surveys were conducted on a subset of 12 vegetation transects between September 6th and October 17th, 2022.

Results to Date:

We expect to see changes in vegetation within three to five years (McKown et al. 2023) and complete recovery of the vegetation communities may take at least a decade to occur (McKown et al. 2023). Therefore, we will continue to monitor vegetation and will analyze after at least another year's worth of data. While we don't yet have results from this project, data from previous pilot studies indicate hydrology and vegetation respond well to runneling. The following example is from a vegetation transect (VEG_SAPA_005) in the same location as Example 2 above.

Point-intercept data from 2017 and 2022 were converted to percent cover. Figures 12 and 13 show the average percent cover for each cover class in 2017 and 2022. Figure 14 shows the change in percent cover for each cover class between 2017 and 2022. Data show an increase in vegetation cover and reduction in bare ground from 2017 and 2022. However, it is important to keep in mind that in 2017 an inconsistent definition of the "bare ground" led to variability in surveyors' measurements of this cover class; this definition has since been defined more clearly. There was also an increase in species richness following restoration, with the establishment of seven new species by 2022. Most notable is the shift in dominance from *S. alterniflora* (low marsh species) in 2017 to *S. patens* (high marsh species) in 2022. In addition, the presence of other typical high marsh species, such as *D. spicata* and *Solidago sempervirens*, indicates that metrics of success are being met at this site.

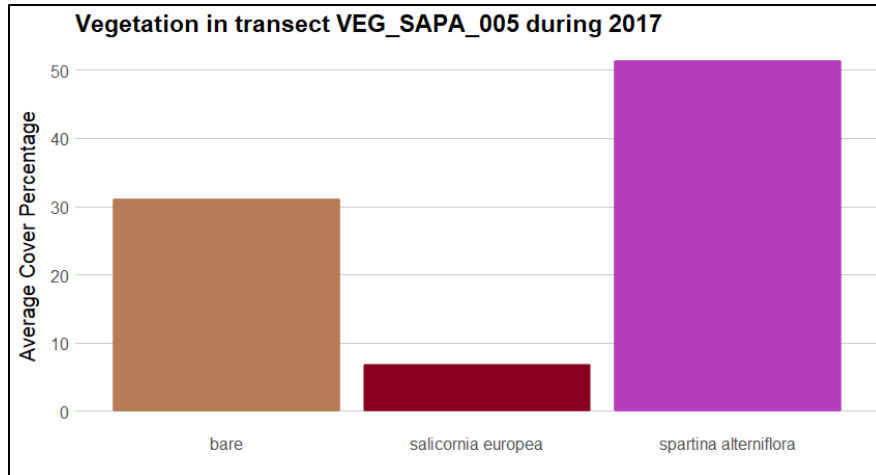


Figure 12. Average percent cover along transect VEG_SAPA_005 in 2017, prior to ditch plug removal (Example 2).

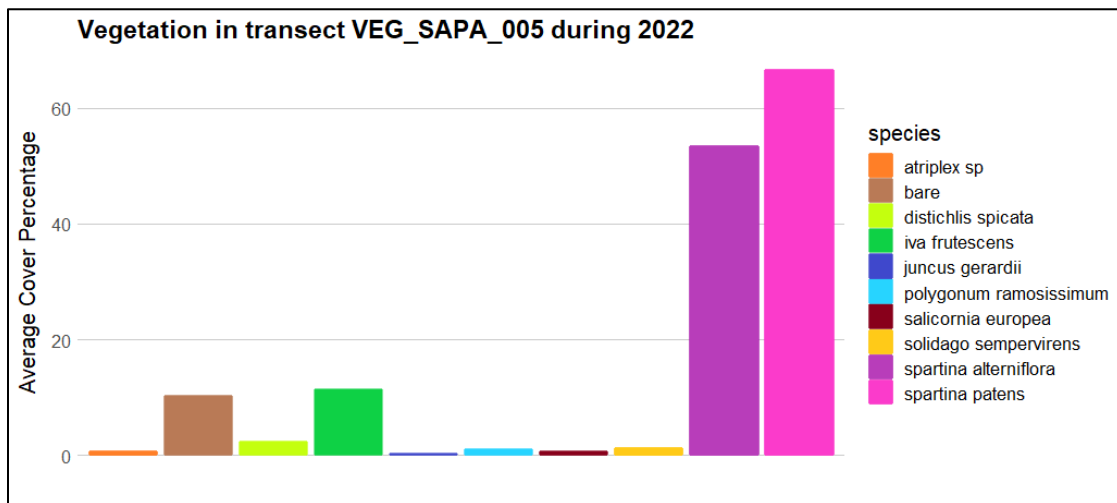


Figure 13. Average percent cover along transect VEG_SAPA_005 in 2022, after ditch plug removal (Example 2).

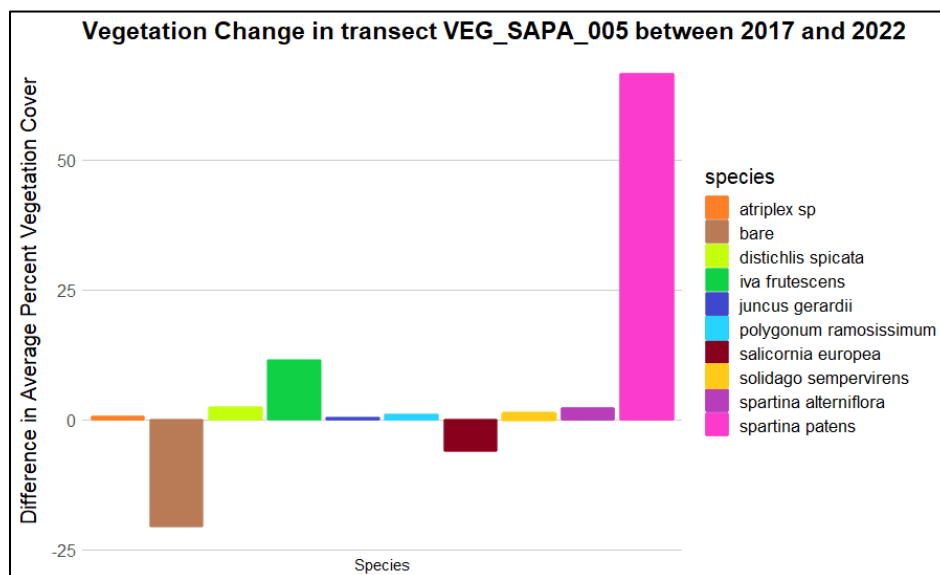


Figure 14. Difference in average percent cover along transect VEG_SAPA_005 between 2017 and 2022 (Example 2).

Water Level

We deploy water level loggers (WLL) in PVC wells driven roughly one meter into the marsh peat. We typically deploy loggers in replicate at both restoration sites and on healthy areas of the marsh (to serve as a control for comparison). These devices measure water depth within the well at 15-minute intervals throughout the entire spring, summer, and fall. We compare the hydroperiod (flood and ebb water levels through a monthly lunar cycle) to a control site to evaluate success of restoration. Other data, like tidal connectivity and the frequency of flooding can all further elucidate restoration success. Primary indicators of restoration success are lowered average water levels, reduced percentage of time the marsh surface is inundated, increased percentage of time under tidal influence, and decreased tidal lag.

Completed Monitoring:

- **2021:** Eight new water level monitoring wells were established. A total of 13 WLL were deployed between April 9th and November 16th, 2021.
- **2022:** A total of eight WLL were deployed between July 11th and November 18th, 2022. One WLL well (WLL_MP_SAPA_007) was lost during ditch remediation, therefore we only have data from deployed to the mid-season data download which occurred on August 30th.

Results to Date:

The following is a summary of the Refuge staff's 2021 analysis of water level data from ditch plug removal pilots that occurred north of and around the Salt Pannes from 2015 to 2020 (Stuntz 2021). Basic water level metrics and tidal connectivity data suggest that restoration of hydrology on the marsh platform was largely successful (Table 3, Figure 15). Following ditch plug removal, mean water level and the average percent of time the marsh surface was inundated declined. These conditions are only slightly wetter than those observed at the control sites. The percent of time during which water levels were tidally influenced increased and average tidal lag decreased at marsh platform and ditch sites following ditch plug removal. Data loggers deployed within pools did not show a change in tidal lag, however, following restoration, pool edges that were once inundated 100% of the time began to drain periodically. These results indicate that metrics of success were largely met for this pilot project.

Table 3. Water level and tidal connectivity data for marsh platform sites within the 2015-2020 ditch plug removal pilot project.

	Mean Depth (cm)	% Marsh Platform Inundated	% Tidally Influenced	Tidal Lag	Mean Depth (cm)	% Marsh Platform Inundated	% Tidally Influenced	Tidal Lag
<i>Logger ID</i>	<i>Before Treatment</i>				<i>After Treatment</i>			
WLL_MP_CONO_003	8.3	95.5	24.7	1 hr, 26 min	-4.2	13.2	51.2	1 hr, 15 min
WLL_MP_SAPA_001	7.1	87.7	24.7	1 hr, 38 min	-0.4	41.0	52.5	55 min
WLL_MP_SAPA_004	9.7	93.4	29.9	1 hr, 41 min	-15.5	4.6	65.0	1 hr, 13 min
<i>Control Sites</i>								
WLL_MP_CONO_002	-9.9	19.5	59.5	1 hr, 24 min				
WLL_MP_CONO_001	-4.2	38.5	35.8	1 hr, 14 min				

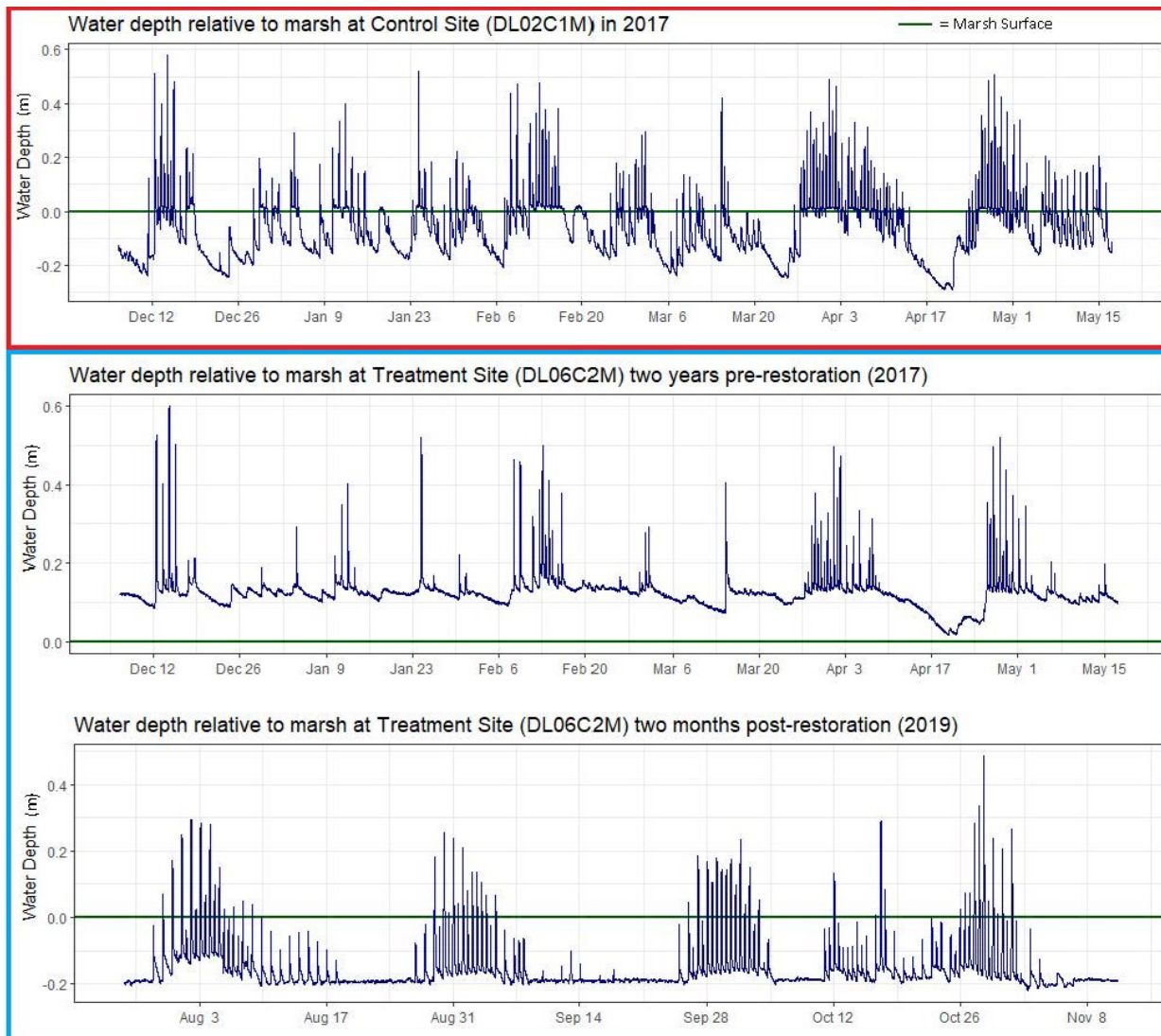


Figure 15. Hydrographs showing water depth (meters) relative to the marsh surface for a pilot runnel project at Parker River NWR. The top graph (bound in red) shows the water levels for a control site in 2017. The two lower graphs (bound in blue) show the water levels before (2017) and after (2019) ditch plug removal that was completed in May 2019. The mean water depth at the treatment site decreased to -0.15 m post restoration, which is close to the target of -0.20 m. In addition, the percentage of time that the marsh platform was inundated decreased from 93% (always inundated) to 5% (flooded only during the highest tides) at the treatment site following restoration.

Sufficient before and after water level data are not yet available for the entirety of the 100-acre Marsh Restoration Project, therefore a more comprehensive analysis will take place after at least another year of data collection. We can provide an example of a site that does currently have sufficient data for a preliminary assessment, WLL_MP_SUOM_005 (Example 6). The results are from water level data collected before (2020 and 2021) and after (2022) the completion of runnels on September 21, 2021 (Figure 16, Table 4). This water level logger was deployed in a well located on the marsh platform. Following restoration, mean water depth decreased from 0.51 cm to -9.6 cm (10 cm decrease) and the average percent of marsh platform inundated decreased from 45% to 17%. Tidal influence increased by about 6% and tidal lag increased by an hour. Aside from the increase in tidal lag, the other results are on target with the metrics of success. We will continue to monitor this and the other sites, so we have sufficient data for a more comprehensive analysis.

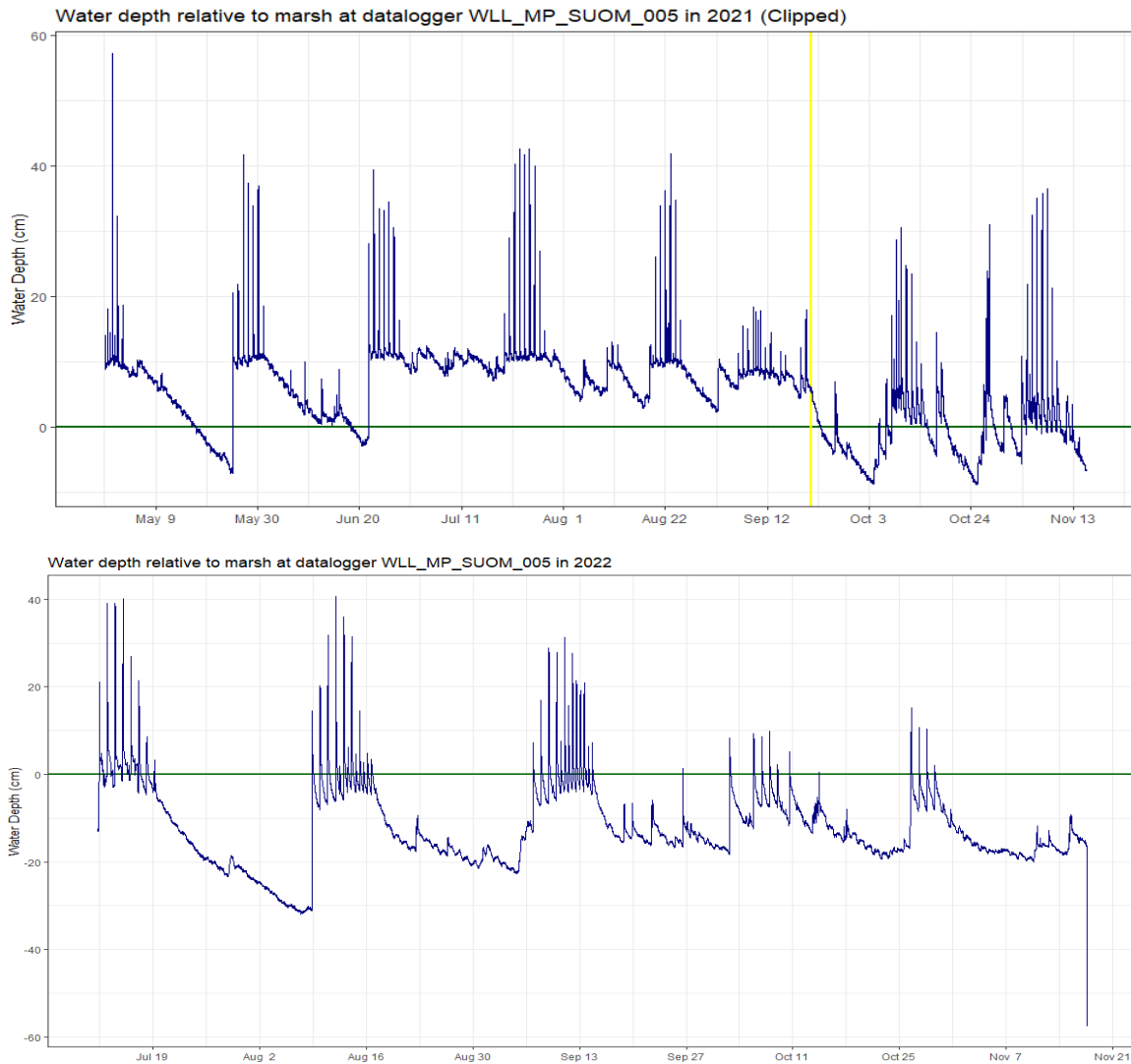


Figure 16. Example 6 hydrographs for 2021 to 2022. Green line = marsh surface, Yellow = restoration date.

Table 4. Water level and tidal connectivity data for Example 6 (Logger WLL_MP_SUOM_005. Runnels completed September 21, 2021. The table compares data from before the restoration (April - November 2020 and April - September 2021) and after restoration (September - November 2021 and July - November 2022)

Before Treatment				After Treatment			
Mean Depth (cm)	% Inundated	% Tidally Influenced	Tidal Lag	Mean Depth (cm)	% Inundated	% Tidally Influenced	Tidal Lag
0.51	44.6	35.5	56 min	-9.6	17.1	41.2	1 hr, 52 min

Elevation Monitoring

We use a combination of tools to measure changes in elevation in the restoration area: laser levels, feldspar marker horizons, and Sediment Elevation Tables (SETs). Protocol was changed slightly to use laser levels instead of Real-Time-Kinetic GPS (RTK-GPS) for elevation measurements. This new protocol is easier for new technicians to learn and has fewer technical difficulties than the RTK-GPS, while still offering a high

degree of accuracy (Stuntz 2021). Using a laser level, we measure elevation along a transect (typically along the staked vegetation transects). In addition, laser levels are used to measure the elevations of the microtopography islands. Five SETs were established in the restoration area, and these will be monitored as part of this project. Additional feldspar plots were established along inundation gradients in order to add additional resolution to the SET data. These monitoring techniques allow us to evaluate whether our interventions have resulted in positive or negative elevation trajectories.

Completed Monitoring:

- **2021:** Laser levels were used to take elevations at 59 microtopography islands. Eight of which were more intensively surveyed, with five elevation measurements taken on the islands and five taken on the adjacent marsh platform. The other 53 only received one elevation measurement per island. In addition, laser level elevations were taken along eight vegetation transects, six WLL wells, and at two established elevation control points. Readings were taken at 21 SETs.
- **2022:** Laser levels were used to take elevations at 11 microtopography islands. This subset was more intensively surveyed, with five elevation measurements taken on the islands and five taken on the adjacent marsh platform. Readings were taken at four SETs.

Results to Date:

- **Ditch Remediation:** Ditches generally occur at higher density than creeks, are deeper causing aeration of root zones, leading to loss of elevation through accelerated decomposition. The pattern of marsh elevation subsidence from aeration of root zones, due to oxidation of the peat when the sides of the ditches are exposed to air is referred to as the Oxidation Subsidence Trajectory. Wright (2012) found that ditched marshes are 20-25 cm lower in elevation compared to low density ditch areas. This finding is collaborated through monitoring of pilot studies (Burdick et al. 2017, Pau et al. 2022). See Figure 17 for an example of oxidation subsidence's effects on elevation in a ditched marsh. Through elevation monitoring along transects within ditch remediation areas, we hope to see increases in elevation within the treated ditches (target of at or <15 cm below marsh platform; see Example 5 above) and on the adjacent marsh platform. While we do not yet have sufficient data to see effects from the 2022 remediation, we will continue to monitor and perform an analysis of changes in the future.

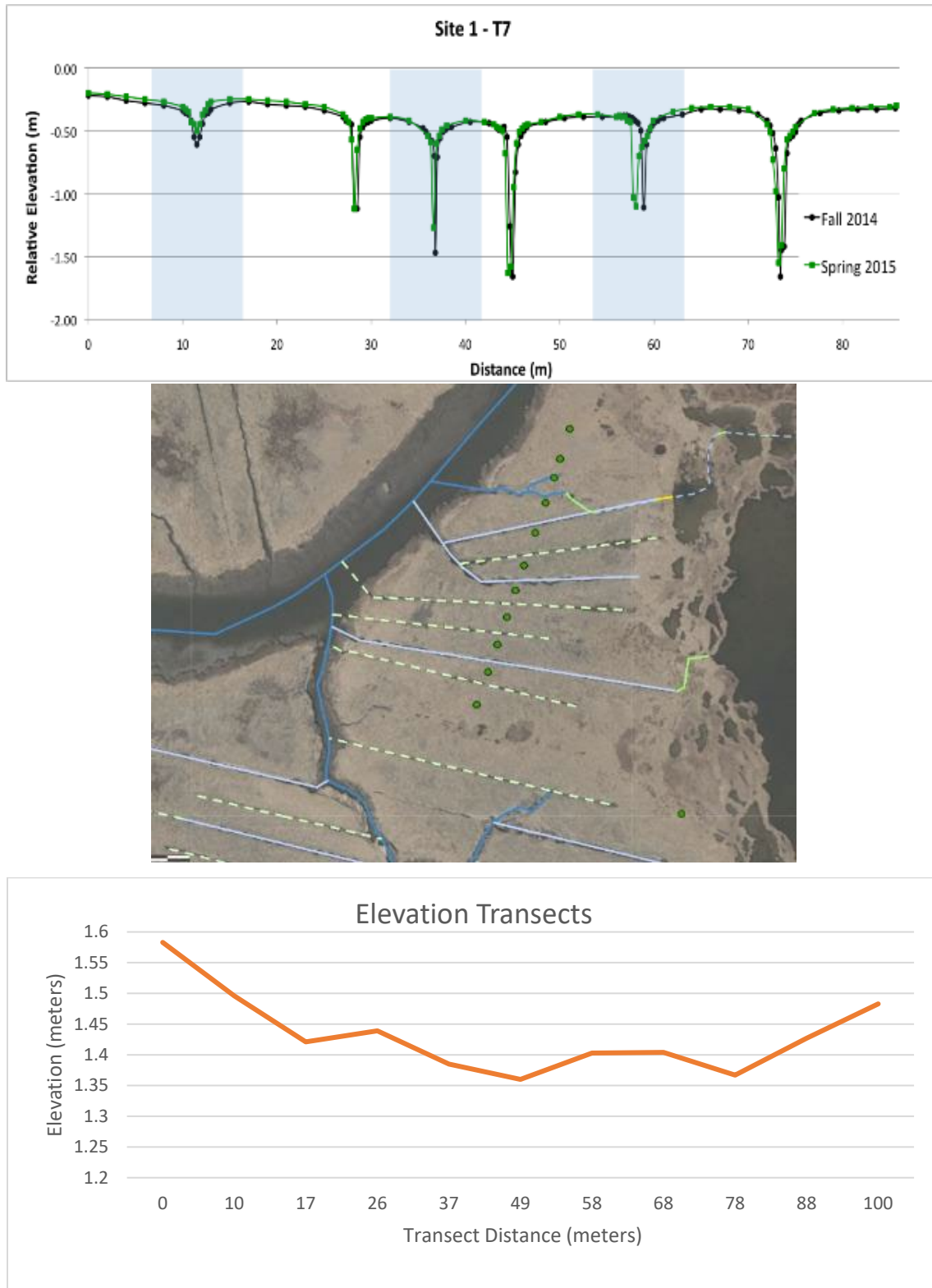


Figure 17. Example of oxidation subsidence's effects on elevation in a ditched marsh. The graphs show the elevation along transects that cross an area of high ditching in Pilot study and how it shallowed over time with treatment. The map shows the elevation transect as green dots and treatment ditches as the light green dashed lines in the 100-acre marsh. OST is indicated by the lower elevation of the marsh platform between ditches.

- **Microtopography islands:** We assessed the elevations of a subset of nine microtopography islands that were measured in both 2021 (year established) and 2022. In 2021, only three of this subset of islands were intensively surveyed and the rest only received one elevation measurement. All the islands surveyed in 2022 were measured using the intensive protocol. For islands that were measured using the intensive protocol, the average elevation on the islands and on the adjacent marsh platforms were used in this assessment.

Figure 18 compares the elevations (meters) of the subset of islands as measured in 2021 and 2022. The average elevation is similar between the years, with that of 2021 being slightly higher. The range of elevations for 2022 (1 to 2.3 m) was larger than that of 2021 (1.7 to 1.9 m). Lower elevation may be a result of weathering and settling. Higher elevations may be a result of the islands revegetating and collecting sediments.

Figure 19 compares the elevation on the microtopography islands to the elevation of the adjacent marsh platform in 2022. The average elevation for the islands (1.5 m) was just slightly higher than that of the marsh platform (1.3 m). The average difference between island and marsh platform elevations is 20 centimeters (range 10 to 40 cm). At this time, these elevations don't seem to be conducive to invasive or upland species establishment, therefore adaptive management is not currently being considered. Elevations will continue to be monitored to assess change over time.

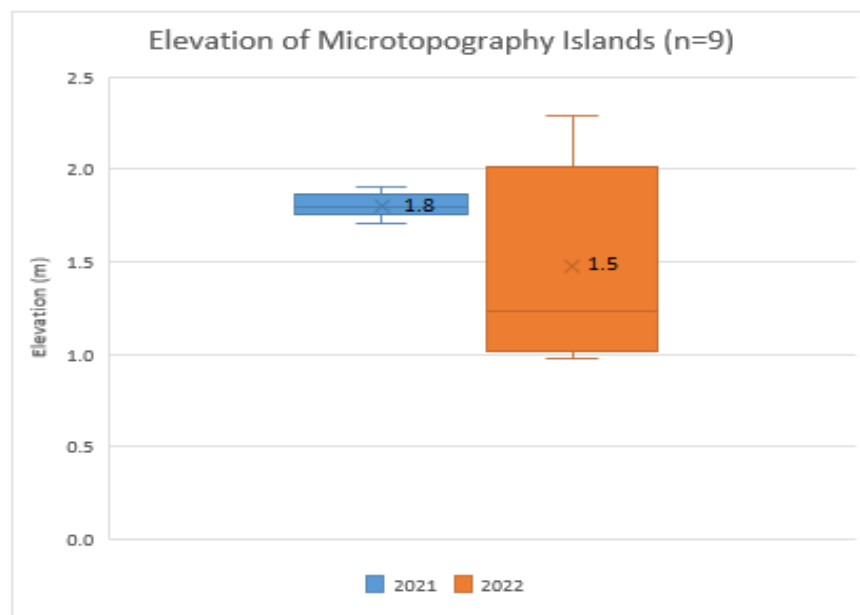


Figure 18. Comparison of microtopography island elevations from 2021 and 2022. In 2021, only three of the islands were intensively surveyed and the rest only received one elevation measurement. All the islands surveyed in 2022 were measured using the intensive protocol.

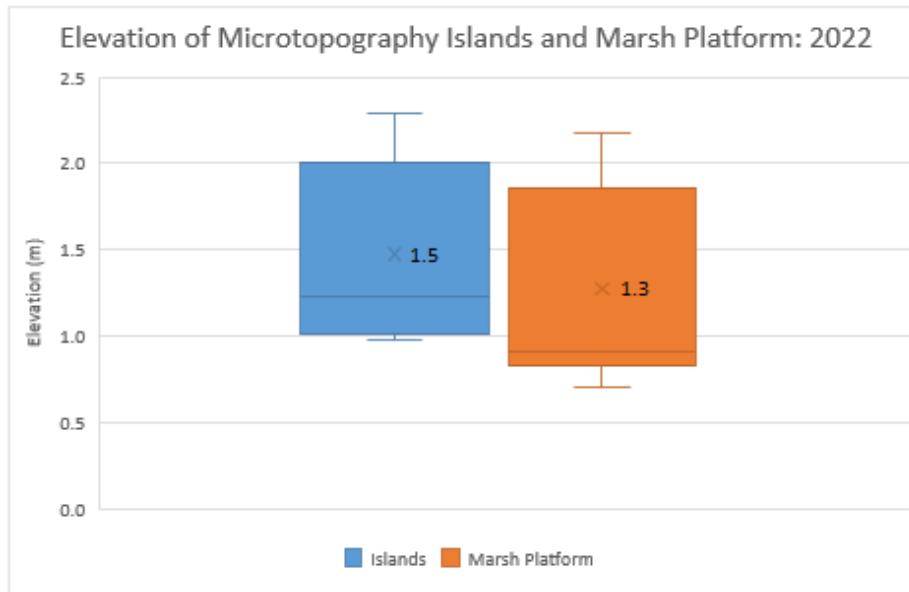


Figure 19. Comparison of microtopography island elevations with adjacent marsh platform in 2022.

Saltmarsh Sparrow Monitoring

We have monitored Saltmarsh Sparrows to estimate their abundance on the Refuge since the 1990s. Since 2013, we have conducted point counts at 30 established points throughout the salt marsh using protocols developed by the Saltmarsh Habitat & Avian Research Program (SHARP, 2015). To date, we have not detected a change in Saltmarsh Sparrow abundance at the Refuge. We will continue to monitor those same points at least every other year for the foreseeable future, a frequency deemed sufficient for trend analysis (Ladin et al., 2020). Annually, SHARP conducts additional point counts at randomly selected locations throughout the marsh as well.

We also began piloting rapid demographic surveys for Saltmarsh Sparrows in 2020. Rapid demographic surveys include conducting point counts and mark recapture surveys (via mist netting), nest searching and monitoring, and conducting vegetation surveys. These protocols are still being tested, but we hope that marsh restoration and improved nesting habitat will be reflected by increases in sparrow abundance and reproductive success. We also evaluate sparrow nesting habitat through other vegetation surveys described above. For example, sparrows require thatch to build nests, so we monitor thatch during vegetation transects and at microtopography islands and expect that it will increase following marsh restoration.

Completed Monitoring:

- **2021:** We conducted point counts according to SHARP protocols to monitor Saltmarsh Sparrows at 30 historic established points. We finished our first round of point counts prior to May 31st and completed the second round of point counts prior to June 30th. Standard SHARP vegetation surveys were completed at each point. These points are planned to be monitored again in 2023. We also continued our pilot of the rapid demographic surveys for Saltmarsh Sparrows in 2021. We trialed this protocol at three points; two in restored units and one in an unrestored unit.
- **2022:** We continued our pilot of the rapid demographic surveys for Saltmarsh Sparrows in 2022. We trialed this protocol at four points; two in restored units, one in a partially restored unit, and one in an unrestored unit.

Results to Date:

This project proposes to improve nesting habitat using ditch remediation and restoration of tidal hydrology to minimize marsh subsidence and the creation of microtopography to create new nesting habitat and to reduce nest flooding. We will use monitoring data to assess short and long-term effects of restoration work on the sparrows. Due to the variability of the year-to-year data, preliminary analysis of the data is scheduled for 2025.

Other funded monitoring

In addition to the effectiveness monitoring conducted by Refuge staff, other monitoring and research are ongoing on the Refuge. Results will indicate the effectiveness of this project and larger changes in marsh processes. We are collaborating with researchers on the following monitoring projects they are leading. Some metrics are still being finalized, but we have established joint protocols for vegetation, hydrology, elevation, and bird use so that data can be synthesized across projects.

- Monitoring of runnels, controls (no runnels), and naturally breached pools by Dr. Gregg Moore, UNH.
- Large-scale monitoring (23 projects from Maine to Rhode Island) of effectiveness of runneling to restore marsh resiliency and improve sparrow habitat (Dr. David Burdick, UNH, funded by NRCS). This includes two marsh sites within the proposed restoration project. Monitoring occurred in 2021 and 2022 for sites that range from one year to ten years post-restoration. These data were compared against those for reference and “No Action” control (NAC) marshes. In the 2022 Annual Report, Burdick et al. reported that NAC sites were flooded significantly more often than runneled and reference sites, which were similarly flooded, indicating that runnels were having the expected effects on hydrology. Although halophyte vegetation cover at runneled sites was not as high as at reference sites, it was significantly higher than NAC sites (Burdick et al. 2023). They also did an analysis on the impacts of runnels on unvegetated to vegetated ratio (UVVR) and percent vegetated cover. After restoration activities, the runnel treatment had a decline in UVVR score and an increase in vegetated cover (Burdick et al. 2023).
- In 2023, McKown et al. published “Runnels Reverse Mega-pool Expansion and Improve Marsh Resiliency in the Great Marsh, Massachusetts (USA)” which provides an analysis of seven seasons’ worth of monitoring data for a 2015 runnel pilot project that occurred in the Great Marsh. The runnels were constructed to drain two megapools. Pool drainage improved and salt marsh vegetation colonized the exposed pool bottoms after three years (McKown et al. 2023). In addition, the abundance of high marsh species such as *S. patens* and *D. spicata* increased in the surrounding marsh platform while *S. alterniflora* decreased (McKown et al. 2023).

Resources

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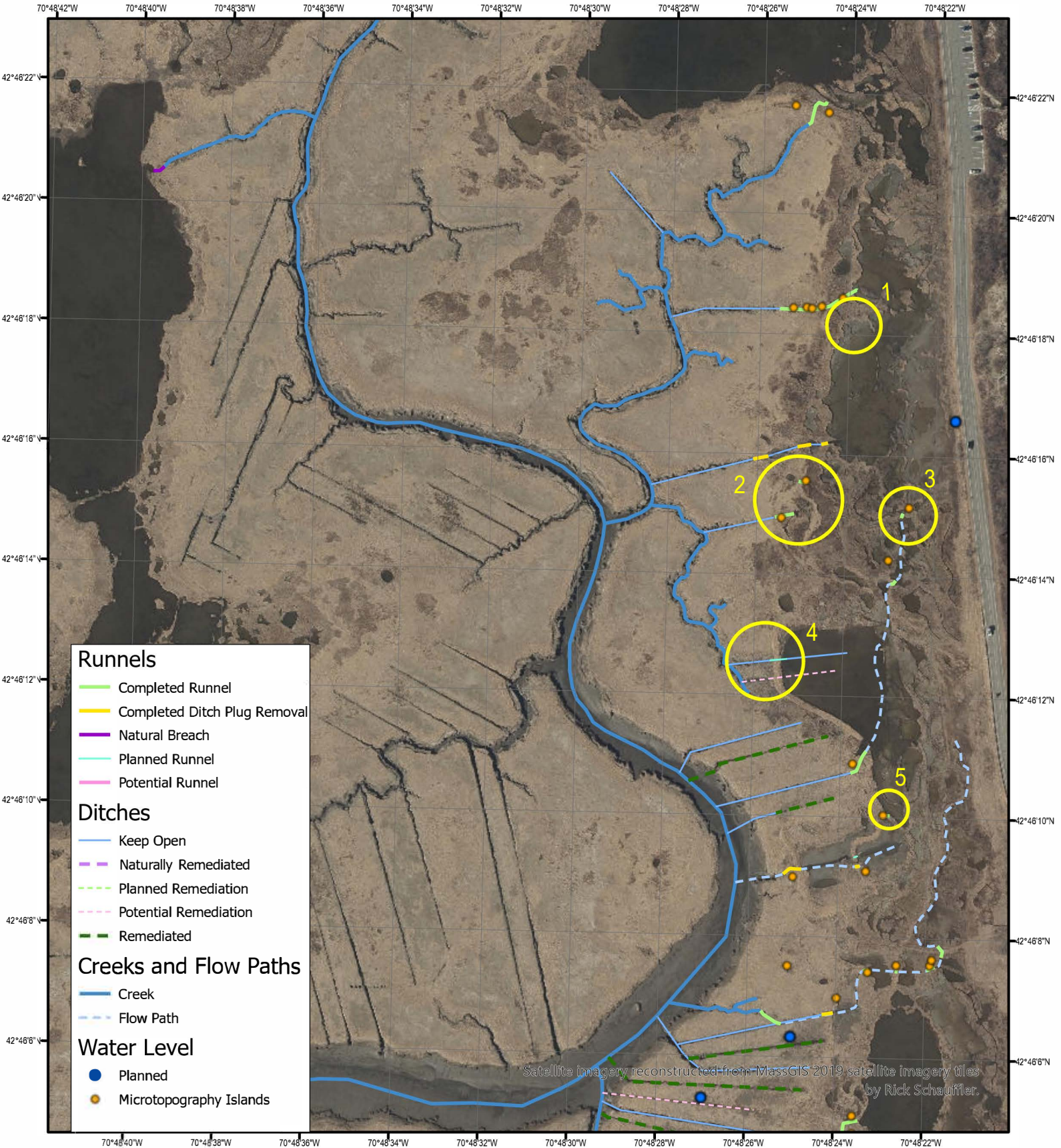
Appendix A: As Built Maps and Description



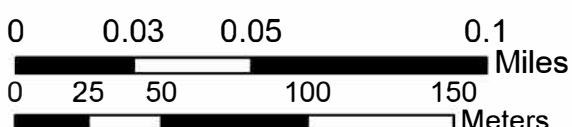
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Parker River NWR 100 Acre Marsh Restoration

Salt Pannes



Satellite imagery reconstructed from MassGIS 2019 satellite imagery tiles by Rick Schaffner.

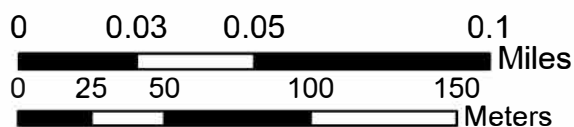
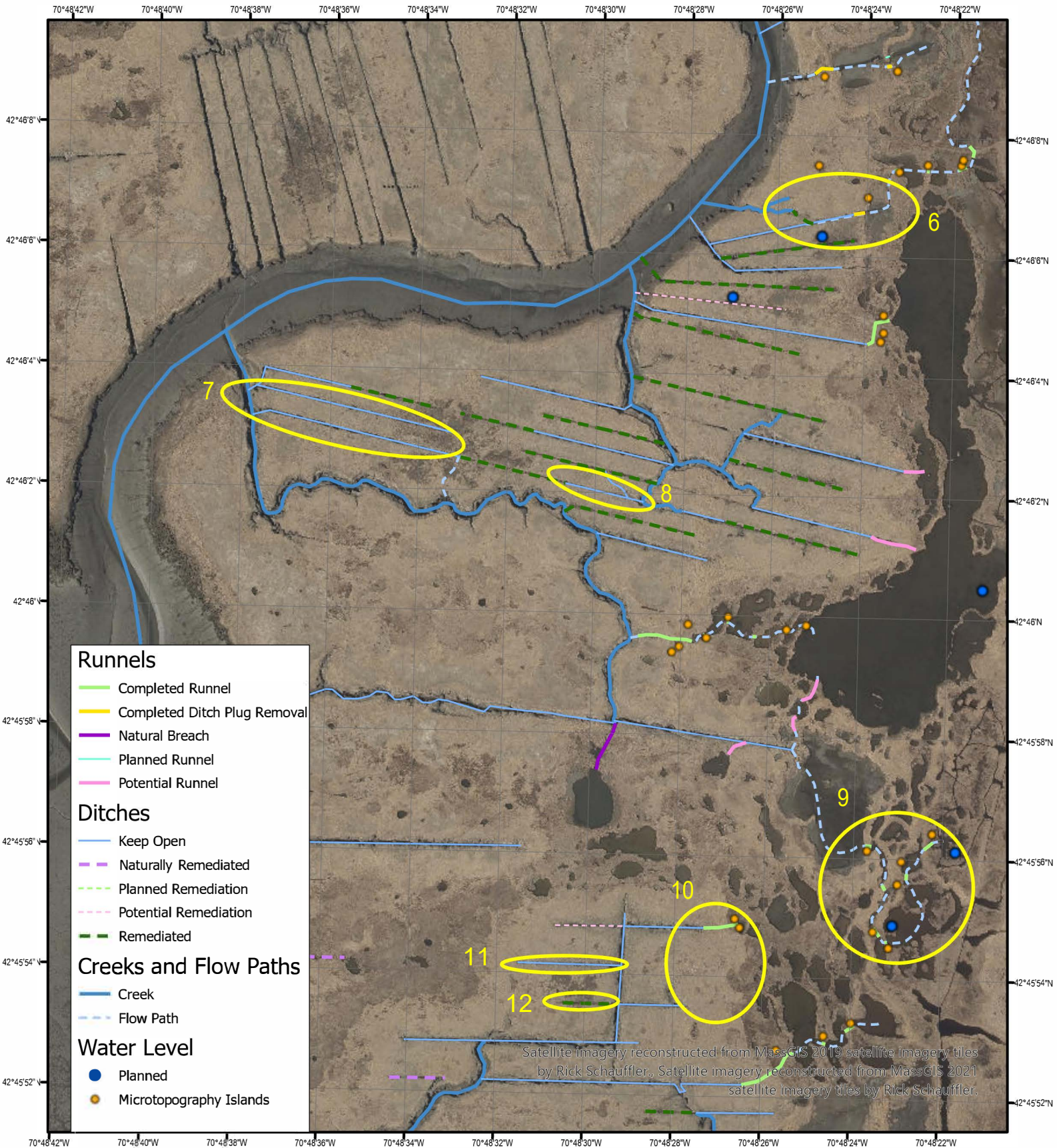




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Parker River NWR 100 Acre Marsh Restoration

Megapool Unit



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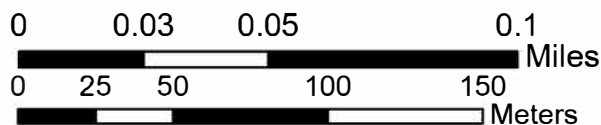
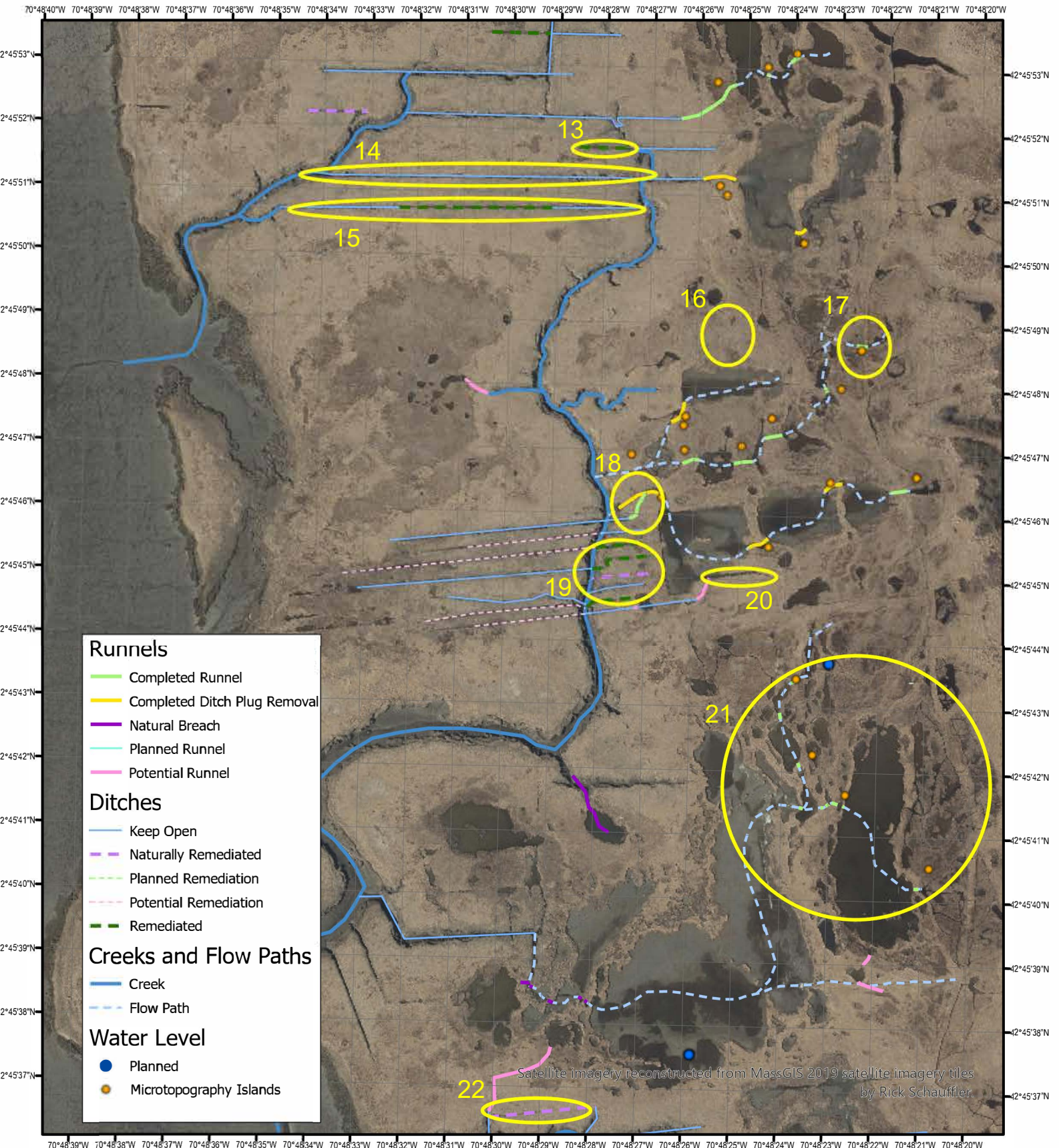
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Parker River NWR 100 Acre Marsh Restoration

OMWM Unit



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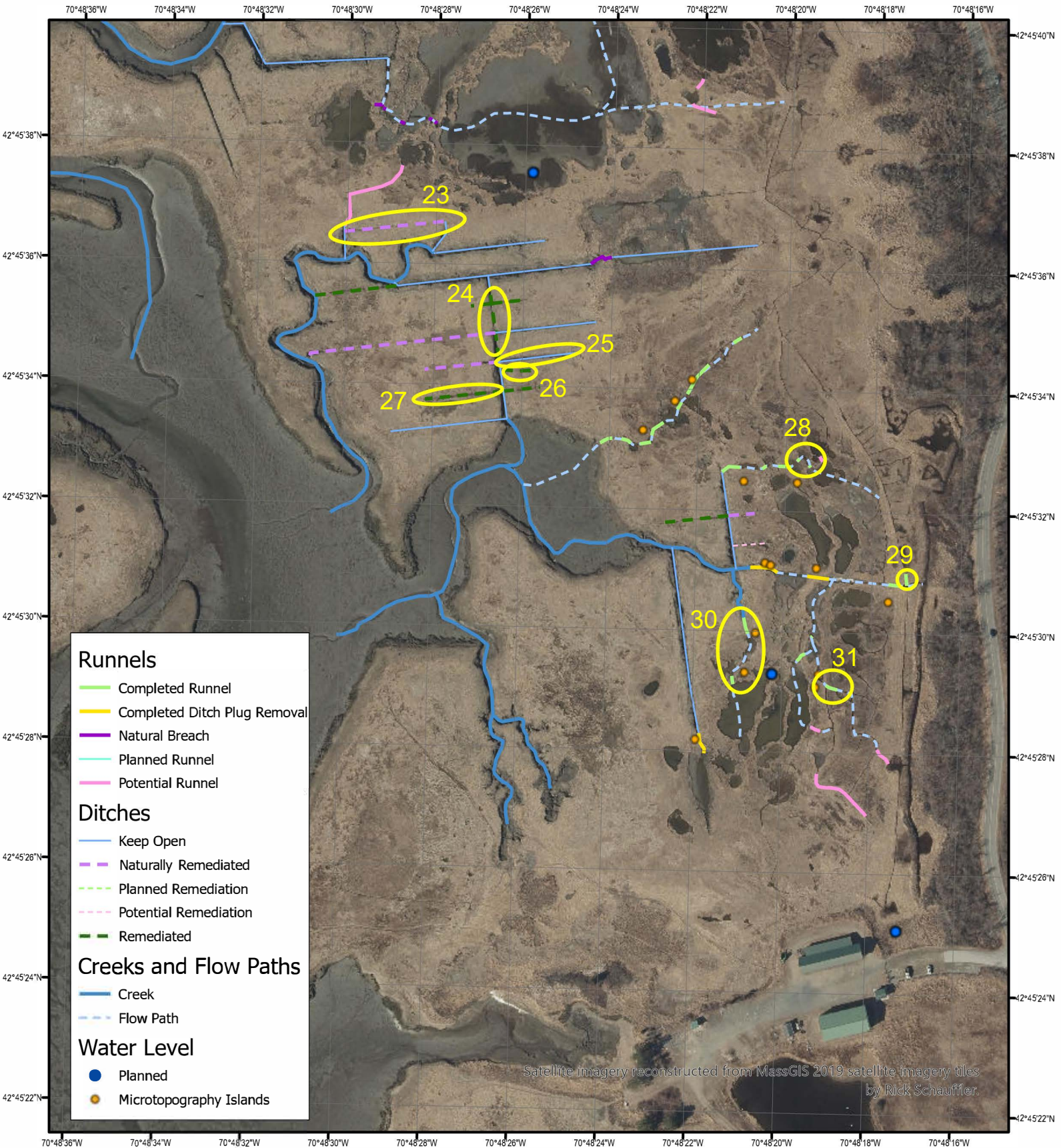
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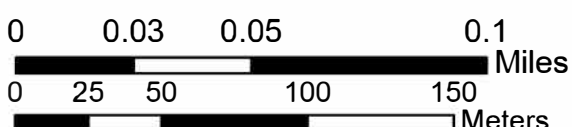
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Parker River NWR 100 Acre Marsh Restoration

Sub HQ Unit



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National Wildlife Refuge Complex Office
Newburyport, Massachusetts
Produced: 3/7/2023



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Overview of 100 Acre Marsh restoration plan changes

Reference	Change
1	Removed planned runnel
2	Added runnels
3	Added runnel
4	Removed planned ditch remediation, added runnel
5	Added runnel
6	Reduced runnel length, added ditch remediation
7	Removed planned ditch remediation
8	Removed planned ditch remediation
9	Adjusted runnel design
10	Adjusted runnel design
11	Removed planned ditch remediation
12	Added ditch remediation
13	Added ditch remediation
14	Removed planned ditch remediation
15	Reduced planned ditch remediation length
16	Removed planned runnel
17	Added runnel
18	Added runnel
19	Adjusted location of ditch remediation
20	Removed planned ditch remediation
21	Adjusted runnel design
22	Removed planned ditch remediation
23	Removed planned ditch remediation
24	Added ditch remediation
25	Removed planned ditch remediation
26	Added ditch remediation
27	Added ditch remediation
28	Adjusted runnel design
29	Added runnel
30	Added runnels
31	Added runnel

Explanation of changes

Changes 1-5: Adjusted runnel design based on site visit observations of marsh inundation and drainage points of megapools

Change 6: Shortened runnel length and remediated ditch to first creek based on hydrology flow path. Second creek naturally remediated.

Change 7-8: Removed planned remediation to leave ditches open to address site inundation

Change 9: Changed runnel design to work with naturally forming drainage

Change 10: Adjusted runnel design based on site visit, the existing creek had increased in the length making it more suitable to connect the runnel to

Changes 11-12: Switched which ditch to remediate versus keep open based to further spacing between open ditches

Changes 13-15: Adjusted ditch remediation based on site visit for ditch spacing and formation of a new ditch

Change 16: Removed planned runnel, connecting creek naturally remediated

Change 17: Adjusted runnel design based on site visit to address marsh inundation

Change 18: Added runnel where ditch plug removal was not successful

Change 19: Adjusted ditch remediation based on site visit and naturally remediated ditch

Change 20: Removed planned runnel for potential megapool breach

Change 21: Changed runnel design to work with naturally forming drainage

Change 22: Planned ditch remediation naturally remediated

Change 23: Planned ditch remediation naturally remediated

Change 24: Added ditch remediation to address new ditch forming

Change 25: Planned remediation left open for drainage

Change 26: Added ditch remediation to address ditch forming

Change 27: Switched which ditch to remediate versus keep open based to further spacing between open ditches

Change 28: Changed runnel design to work with naturally forming drainage

Change 29: Added runnel to drain OMWM ditch

Change 30: Changed runnel design to work with naturally forming drainage

Change 31: Added runnel to work with naturally forming drainage

Appendix B:

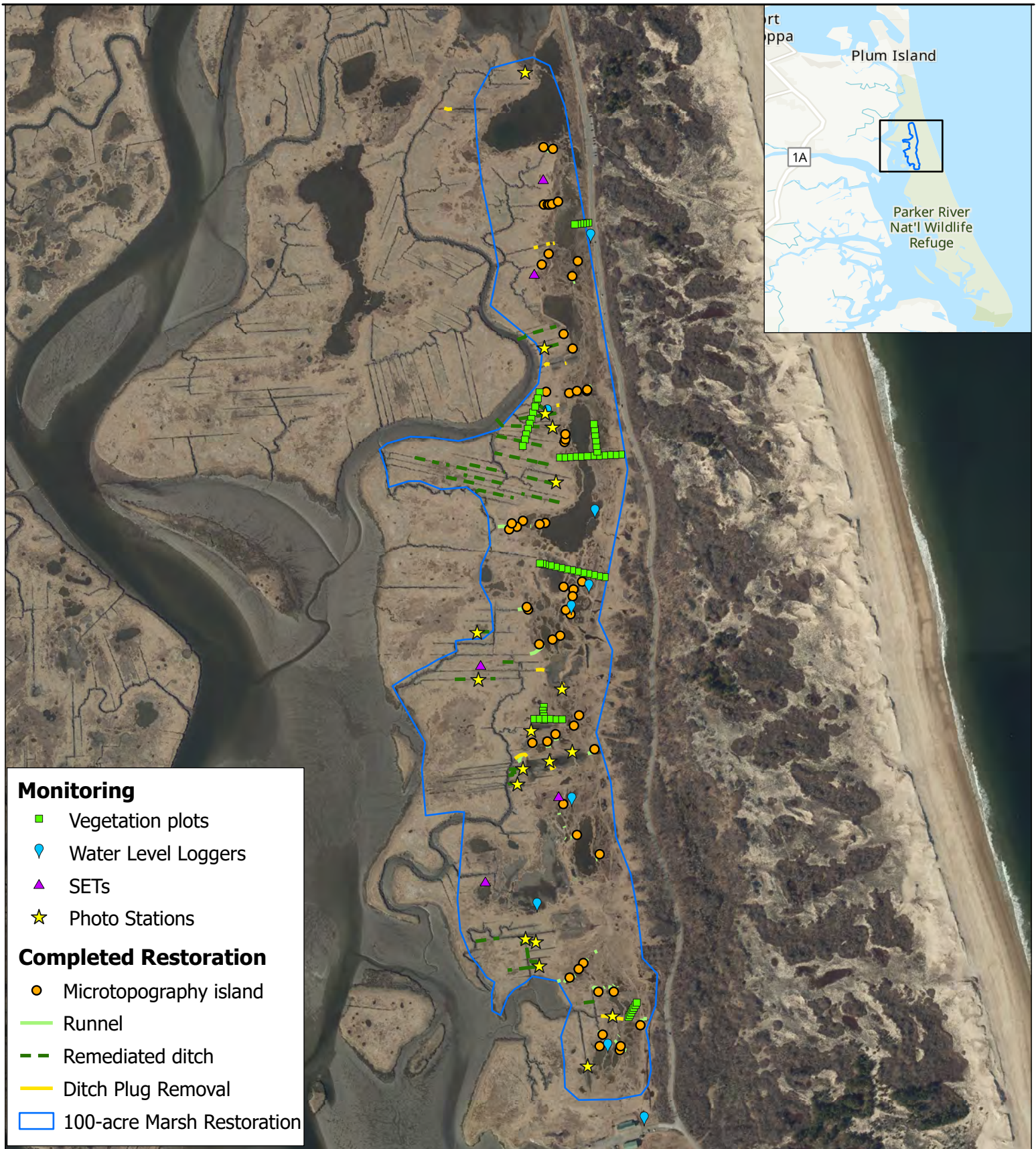
Monitoring

Maps



U.S. Fish & Wildlife Service

100-acre Marsh Restoration Monitoring: Overview



Produced in the Parker River National Wildlife Refuge Complex Office
Newburyport, Massachusetts

Produced: 4/19/2023

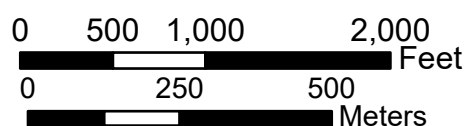
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Source Data: Parker River NWR Marsh Restoration and Monitoring Features, USFWS, 2023

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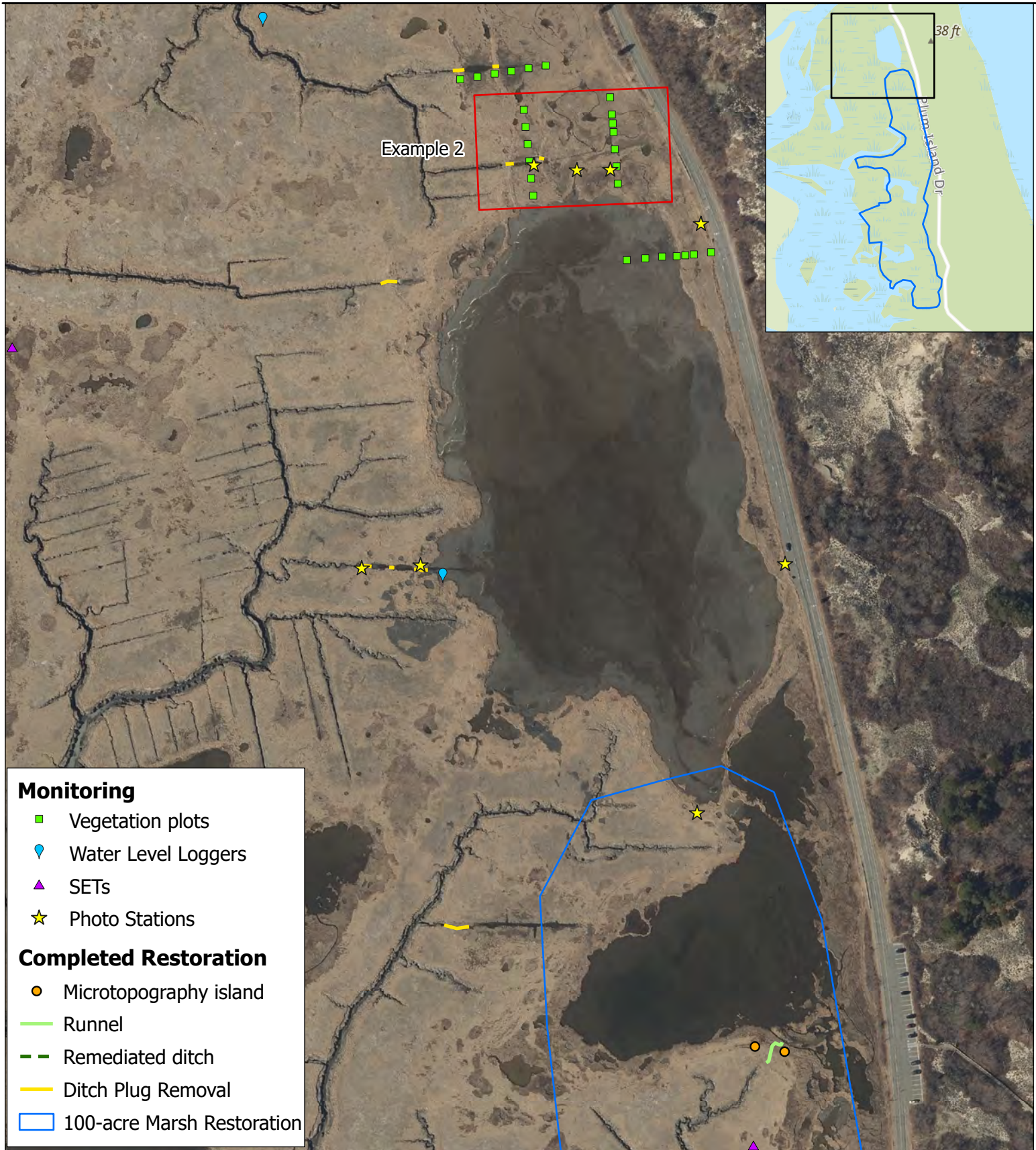
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100-acre Marsh Restoration Monitoring: Submap 1



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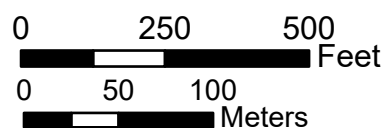
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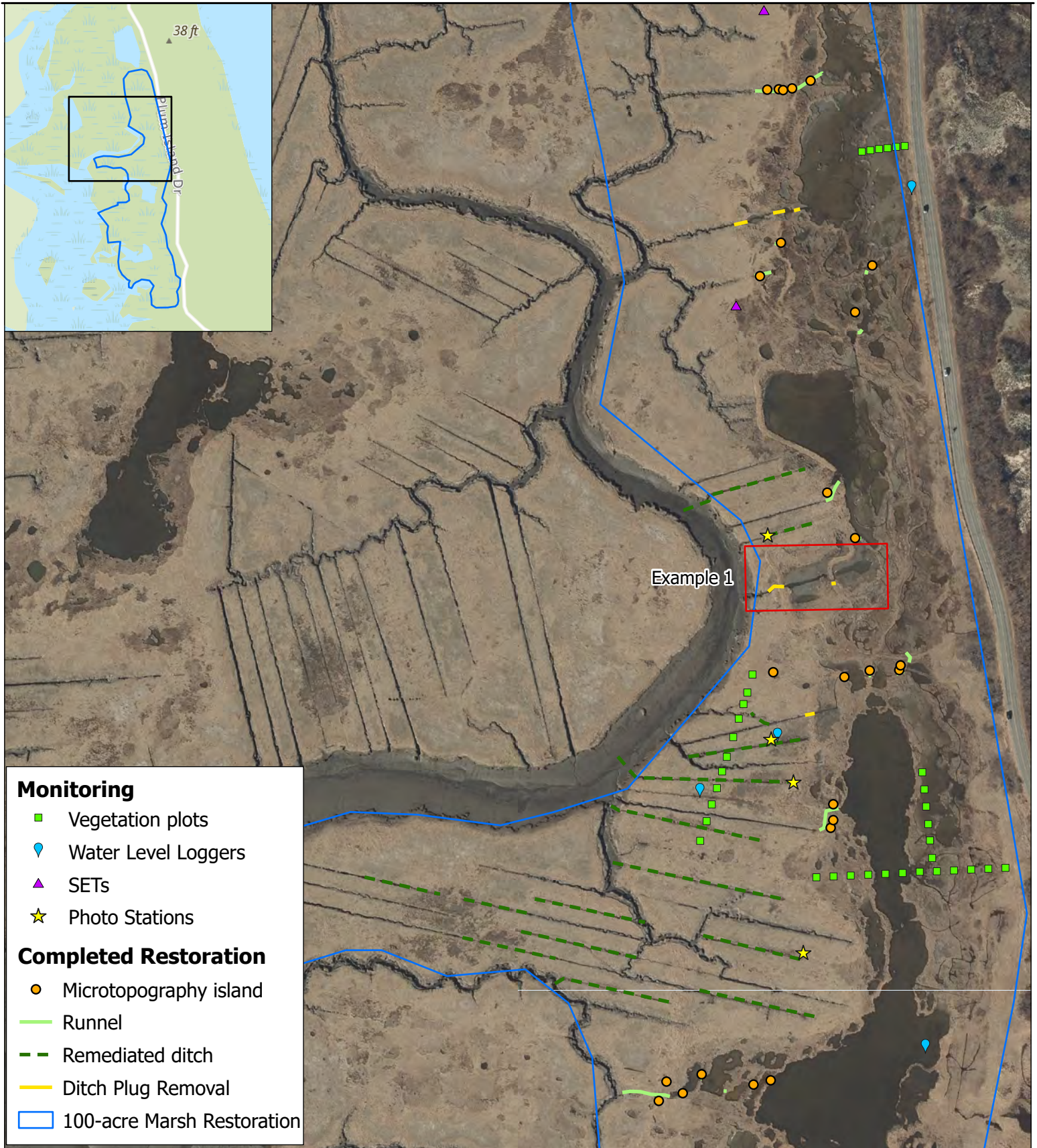
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100-acre Marsh Restoration Monitoring: Submap 2



Monitoring

- Vegetation plots
- Water Level Loggers
- ▲ SETs
- ★ Photo Stations

Completed Restoration

- Microtopography island
- Runnel
- - - Remediated ditch
- Ditch Plug Removal
- 100-acre Marsh Restoration

Produced in the Parker River National Wildlife Refuge Complex Office
Newburyport, Massachusetts

Produced: 4/19/2023

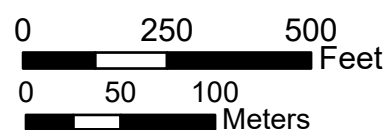
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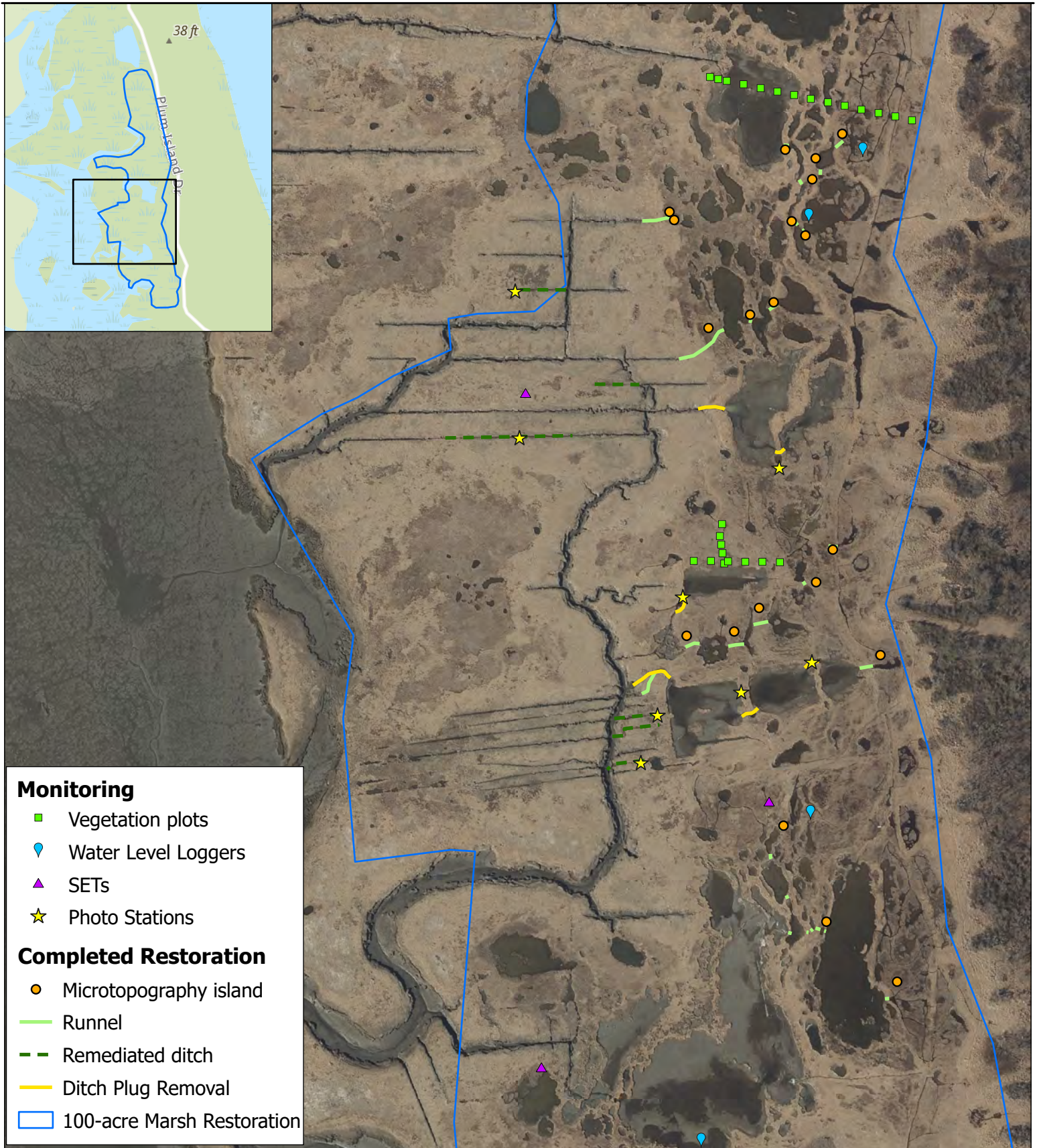
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100-acre Marsh Restoration Monitoring: Submap 3



Monitoring

- Vegetation plots
- ◆ Water Level Loggers
- ▲ SETs
- ★ Photo Stations

Completed Restoration

- Microtopography island
- Runnel
- - Remediated ditch
- Ditch Plug Removal
- 100-acre Marsh Restoration

Produced in the Parker River National Wildlife Refuge Complex Office
Newburyport, Massachusetts

Produced: 4/19/2023

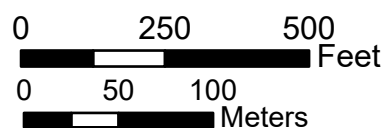
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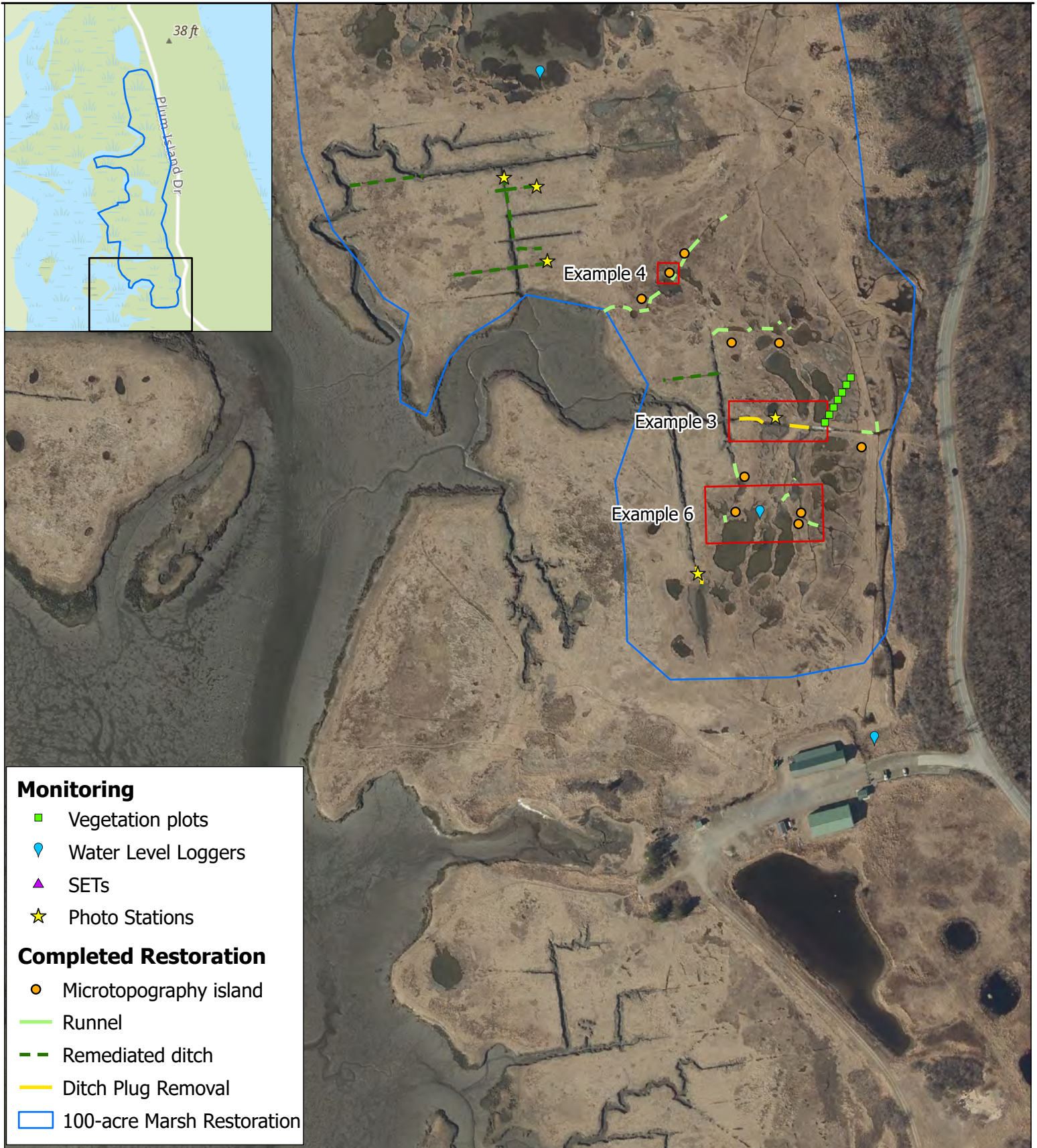
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100-acre Marsh Restoration Monitoring: Submap 4



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