South Shore Salt Marsh Restoration Prioritization

PREPARED BY:

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In Partnership with Umass Boston and Cohasett Center for Student Coastal Research

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EXECUTIVE SUMMARY

This report presents the results of a multi-partner assessment and prioritization strategy for salt marsh restoration potential across the South Shore of Massachusetts. Approximately 3,400 acres of saltmarsh across eight distinct areas in six towns were evaluated. The project, led by the North and South Rivers Watershed Association in partnership with Mass Audubon, UMass Amherst, UMass Boston, and the Massachusetts Bays National Estuary Partnership, was supported by the Massachusetts Office of Coastal Zone Management. The primary goal was to identify marsh vulnerability, evaluate restoration potential, and provide actionable recommendations to enhance marsh resilience in the face of accelerating sea level rise and anthropogenic pressures.

Eight key marsh complexes were assessed through a combination of field surveys, sediment monitoring, and GIS-based analysis. These sites span diverse geomorphological, hydrological, and land-use conditions, from the extensive Duxbury Bay marshes to smaller suburban marsh units like Green Harbor and Peggotty/Kent Street. Analytical methods included vegetation transects, sediment trap deployments, elevation and resilience modeling, unvegetated-to-vegetated ratios, and sea-level rise simulations to predict future marsh migration potential

Key findings include:

- **Marsh Loss**: Between 2011 and 2021, approximately 36 acres (1.2%) of salt marsh were lost across all study sites, with the South River experiencing the greatest relative and absolute loss (1.86%, 14.2 acres).

- **Resilience**: Duxbury Bay exhibited the highest percent of resilient marsh (89.6%), while the North River Mid-Upper Reaches showed the lowest (29.4%). Average resilience across all sites was 70.1%.

- **Sediment Dynamics**: Sediment deposition rates were adequate to support marsh accretion at most sites (median ~6.2 mm/yr). Marine-derived sediment is the primary source due to low fluvial sediment inputs.

- **Marsh Migration Potential**: The Gulf River and Peggotty marshes exhibited the greatest potential for marsh migration under projected sea level rise scenarios, with gains of up to 47% and 43% respectively by 2100. Migration potential varied between upland and vegetated wetland transitions depending on site topography and land use.

- **Vegetation Health**: Most field sites were dominated by traditional salt marsh species (e.g. *Spartina*, *Distichlis*, etc), although signs of stress such as panne formation, Phragmites invasion, and surface instability were observed at several locations, particularly at Green Harbor and Kingston Harbormaster.

Based on combined ecological, geomorphic, and land ownership factors, the report identifies and prioritizes restoration opportunities. Restoration opportunities are grouped into short-, medium-, and long-term needs. Short-term opportunities generally mean that marsh lifespan

categorization was determined as “Protect/Restore”; stressors and solutions are fairly obvious; access and parcel ownership is straightforward; and restoration approaches could advance in one to five years. Medium-term sites generally have less urgent needs or may have more challenging approaches in terms of access, ownership, size, or other factors. Restoration approaches at these sites are likely to take longer to develop and may be on a three to ten year timeline or more. Long-term sites generally have no immediate restoration needs. Actions at these sites may include land-protection, long-term monitoring, or larger scale protections.

1. **Short-term priority sites and actions**:
    - Scituate Conservation (North River Lower Reaches)
    - Green Harbor (Marshfield)
    - Kingston Harbormaster Site
2. **Medium-term priority sites**:
    - South River
    - North River Mid-Upper Reaches
    - Calista Property, Kingston
3. **Long-term**
    - Duxbury Bay Complex
    - Gulf River/Musquashcut Brook
    - Upper North River
    - Third Cliff
4. **Community Engagement Opportunities**:
    - Sites with strong educational or visibility benefits, such as Peggotty/Kent Street and Kingston Harbormaster, are suitable for pilot-scale restoration and public outreach.

The results of this study provide a foundation for strategic salt marsh conservation, restoration, and adaptation planning on Massachusetts’ South Shore. Recommendations include targeted pilot projects, enhanced monitoring of vegetation and sediment trends, and improved management of tidal restrictions and stormwater infrastructure. The findings are intended to inform both near-term restoration investments and long-term resilience planning under changing climatic and coastal conditions.

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Acknowledgement of Support

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1 INTRODUCTION

1.1 Project Background

Salt marshes are an iconic New England coastal habitat, providing essential ecological and aesthetic value to the region. On the South Shore of Massachusetts, there are approximately 7,000 acres of salt marsh in our bays, rivers, harbors, and coastline providing a transitional zone between land and sea. These ecosystems buffer nearby properties from the impacts of coastal storms, help filter out excess nutrients, capture atmospheric carbon, and sustain essential habitats for fish, shellfish, and birds. Salt marshes are constantly shaped by natural forces including tides, storm surges, sea level rise, and seasonal ice. For hundreds of years local marsh health has been impacted by ditching, filling, and other agricultural alterations. More recently sea level rise, increasing storm intensity, nutrient loading, and encroachment from development have added additional stressors to marsh health.

The North and South Rivers Watershed Association (NSRWA), in partnership with Mass Audubon, UMass Amherst, UMass Boston, and the Cohasset Center for Student Coastal Research (CSCR) with input from CZM, DER, and partner towns developed the following habitat analysis and restoration approach for the tidal marshes across the South Shore of Massachusetts. The goal is to identify stressors, current conditions, and potential for adaptation or restoration at a range of sites across the south shore.

The team assessed salt marsh units using several field methods including vegetation surveys and sediment monitoring as well as desktop methods such as the unvegetated to vegetated ratio (UVVR), elevation changes over time, tidal restrictions, marsh loss, and sediment availability.

Education and outreach opportunities about the importance of salt marsh restoration and protection were provided through collaboration with the Cohasset Center for Student Coastal Research, Scituate High School, the Duxbury Beach Reservation and local property owners.

1.2 Project Partners

The following organizations have partnered together to implement this project:

- North and South River Watershed Association (NSRWA)
- Massachusetts Bays National Estuary Partnership (MassBays)
- Mass Audubon
- UMass Amherst College of Natural Sciences
- Center for Student Coastal Research (CSCR)
- UMass Boston School for the Environment
- Towns of Scituate, Marshfield, Duxbury, and Kingston

2 PROJECT APPROACH AND METHODS

2.1 Site Selection

Site selection was based on a number of factors. Sites were selected to represent a range of representative marsh conditions. These included sites at the mouth of the estuary, mid estuary, and near the upstream extent of tidal intrusion. While all of the sites have seen some human alteration (ditching) the sites ranged from heavily altered (Scituate Conservation, Kingston Harbormaster) to relatively unaltered (Duxbury). Additionally, site selection was intended to be geographically diverse, spanning a range of South Shore towns and property ownership (Town, NGO, private). An overview of the study sites is shown in Figure 1.

Study areas were assessed at several different scales appropriate to the methods used. Large scale marsh complexes ranging from 82 to 1140 acres were analyzed by GIS for measures of resilience and migration potential. These large units were broken into smaller conceptual marsh units for the South Shore based on tide sheds to predict marsh lifespan as part of an ongoing analysis by Mass Audubon. In each of the large study sites, individual small parcels (1 – 12 acres) were identified for focused, on the ground field studies. Method selection and details are provided in sections 2.2 - 2.5.

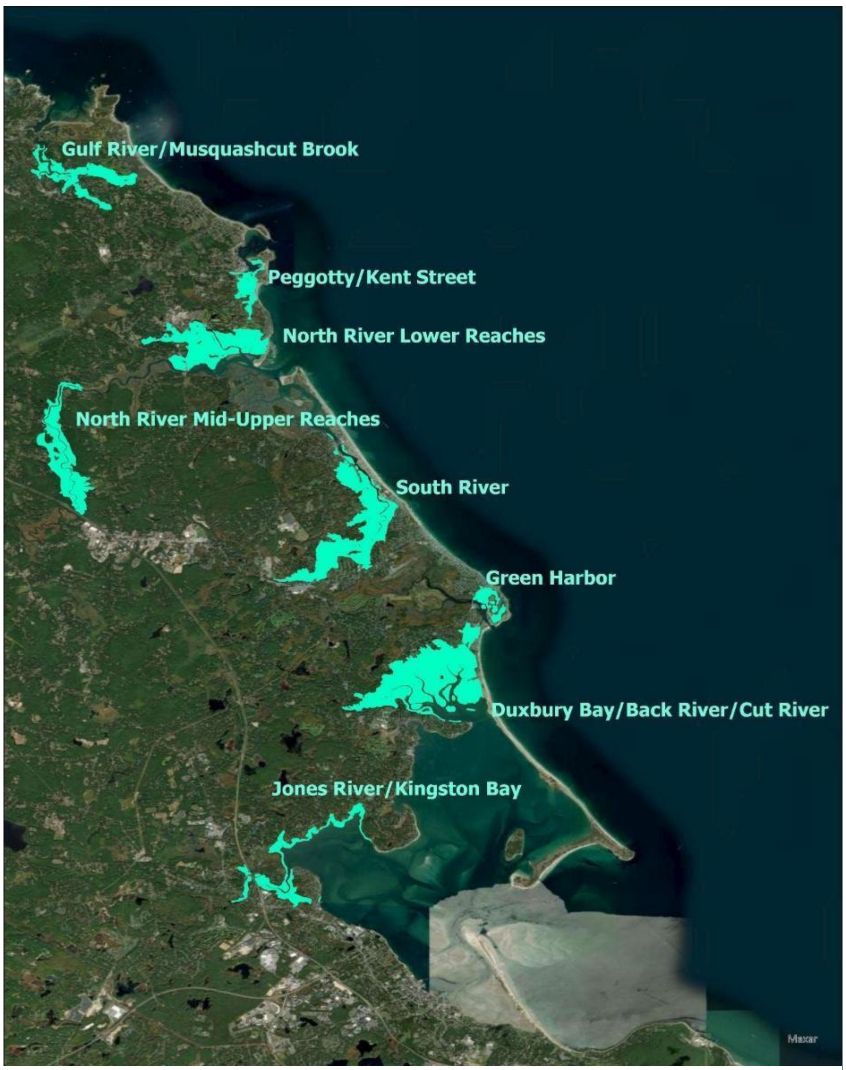

Figure 1. Map of Overall Study Area

Each of the study sites are described in detail from South to North in the following subsections.

2.1.1 Jones River/Kingston Bay

The Jones River marsh units cover 256 acres extending along the western shore of Kingston Bay, into Island Creek, and up the Jones River to the head of tide at the former Elm Street Dam (removed 2020) (Figure 2). Tributaries include Smelt Brook, Stony Brook, Tussock Brook, and Stony Brook. The marsh unit has a relatively high number of tidal restrictions. It also includes a variety of surrounding infrastructure including a state highway (Rte. 3), active and inactive railbeds, and a marina. Portions of this study area overlap with areas evaluated in the 'Assessment of Restoration Opportunities for the Jones River Estuary' (Beals & Thomas 2023).

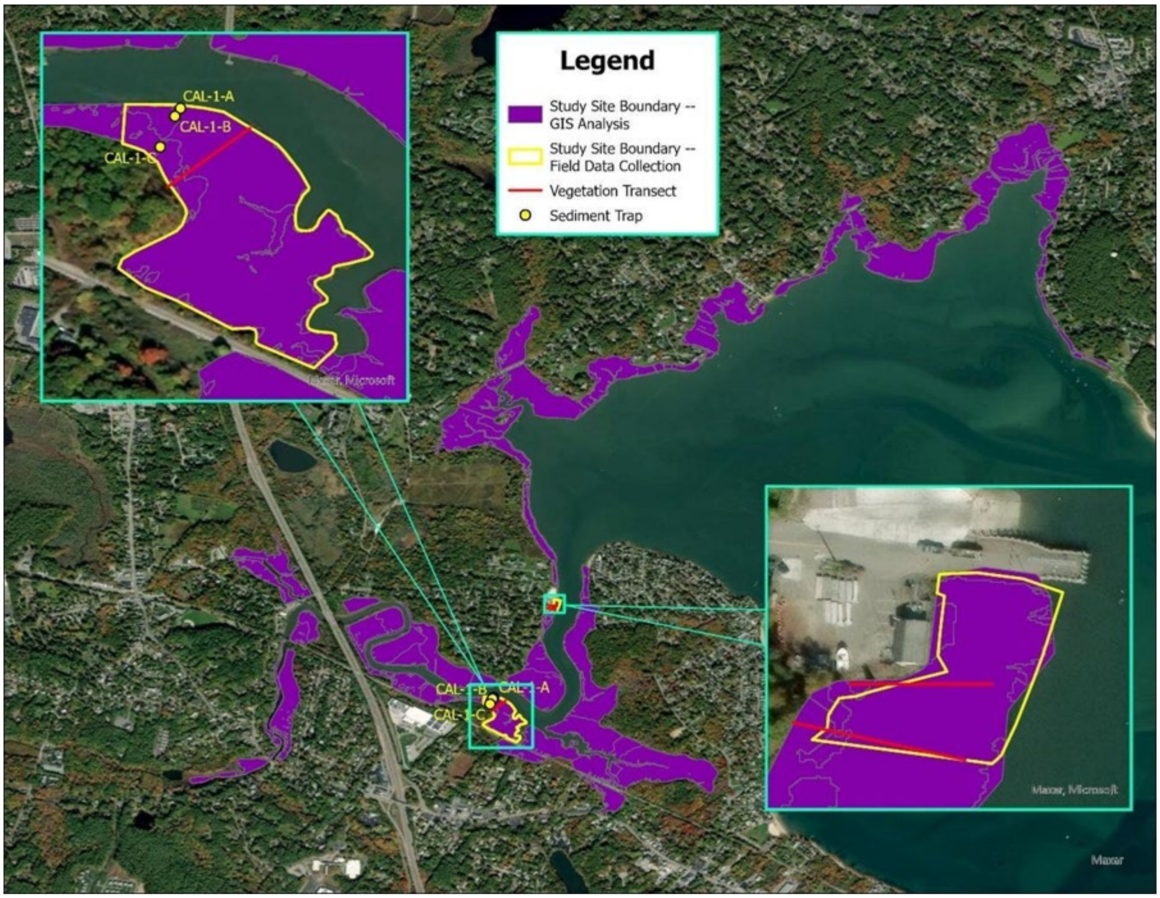

Figure 2. Map of the Jones River/Kingston Bay Marsh Unit and Field Sites

Within this marsh unit there were two individual parcels studied during this project, described below. Both of these sites were included in the 2014-2015 'Jones, North, and South Rivers Salt Marsh Assessment' (Mansfield & Grady 2015).

2.1.1.1 Calista Property, Kingston

This parcel is located at the first bend on the Jones River where Smelt Brook enters from the Southeast. The property was purchased by the Town of Kingston in 2010 as part of a larger open space parcel. The site is bordered to the South by Massachusetts Bay Transportation Authority

(MBTA) railroad tracks. In addition to the railroad the site shows signs of previous alteration where remnants of former piers exist, dating back to the 17th & 18th centuries. However, the site does not have any current human uses and is somewhat inaccessible. Significant alterations have not occurred in many decades.

2.1.1.2 Kingston Harbormaster

This small marsh is located at the mouth of the Jones River at Kingston's Town Landing and boat ramp. The marsh is truncated on the North side by the town pier and on the West by the Harbormaster's office. The site is heavily altered by construction of the pier and harbormaster building. Natural processes (especially flow) at the site are also impacted by the location of the solid pier adjacent to the marsh and the town slips in front. Significant flow from the confluence of the river and the bay impacts the marsh site that is adjacent to the town slips, floats and pier. The marsh is generally sheltered from boat wakes but is impacted from localized stormwater runoff and the harbormaster's shack

2.1.2 Duxbury Bay/Cut River/Back River

This marsh unit includes the extensive salt marshes of northern Duxbury Bay (North of the Powder Point Bridge). The unit covers approximately 1,140 acres of salt marsh bounded by Duxbury barrier beach to the east, with a series of named creeks draining the mainland from the North and West. These include the Back River, the Cut River which extends into Marshfield to the North, and other smaller creeks. This unit has relatively limited surrounding infrastructure besides residential roads and a few small tidal restrictions. The watershed is largely residential, although it does include golf courses and a large school complex.

Within this marsh unit there was a single parcel studied for vegetation and sediment accretion. The parcel is located just off the Duxbury Beach public parking (Figure 3).

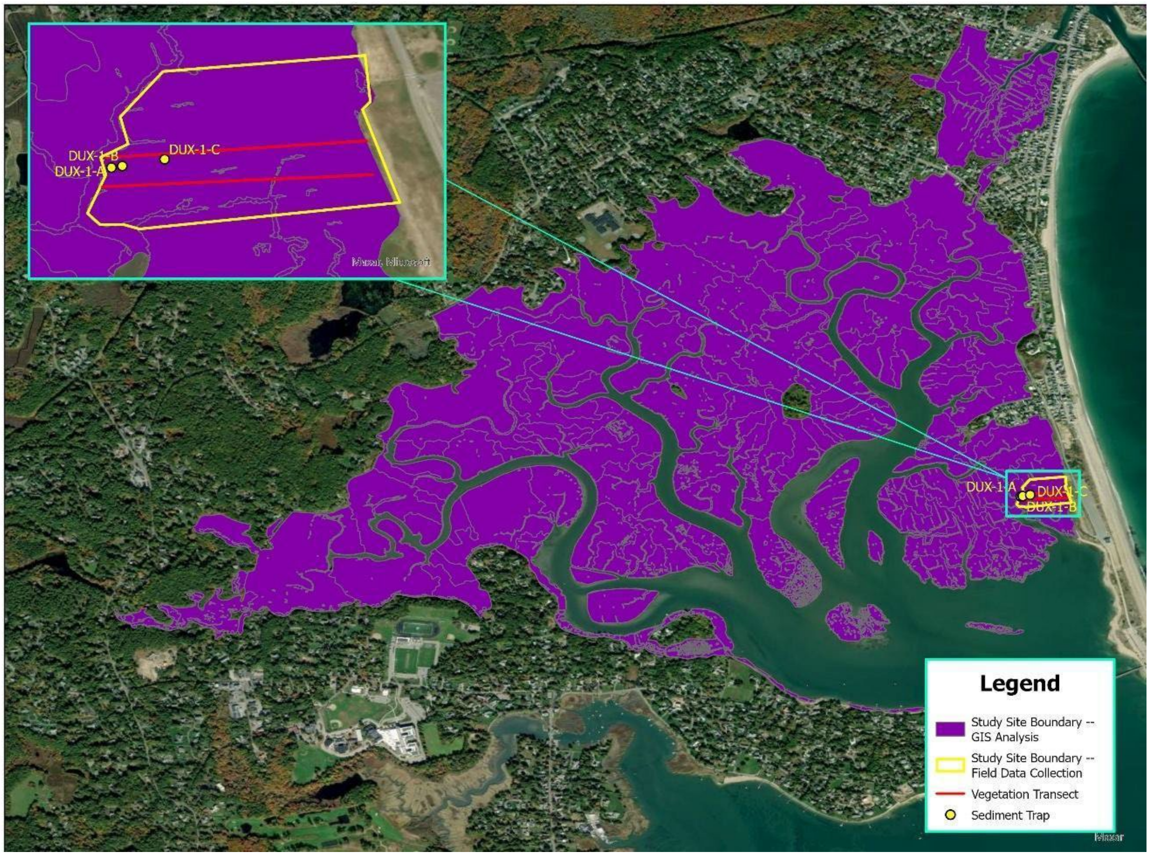

Figure 3. Map of the Duxbury Marsh Unit and Field Sites

2.1.3 Green Harbor, Marshfield

This small (82 acres) marsh unit lies primarily on the North side of Green Harbor and the Green Harbor River downstream of the Route 139 tide gate (Figure 4). Green Harbor is a highly altered system with at least three prominent tide gates, a sewer treatment plant, two marinas, a town pier, and a large mooring field. The harbor and entrance channel are also routinely dredged for navigation. The entrance channel was man-made in the early 1800s and expanded by the Army Corps in 1969. The entrance channel extends 4,000 feet from deep water to a six-foot deep turning basin located below the Route 139 Bridge and tide gate.

Within this marsh unit there was a single parcel studied for vegetation and sediment accretion. The parcel is located on the West side of the larger study unit, close to Route 139 and the tide gate.

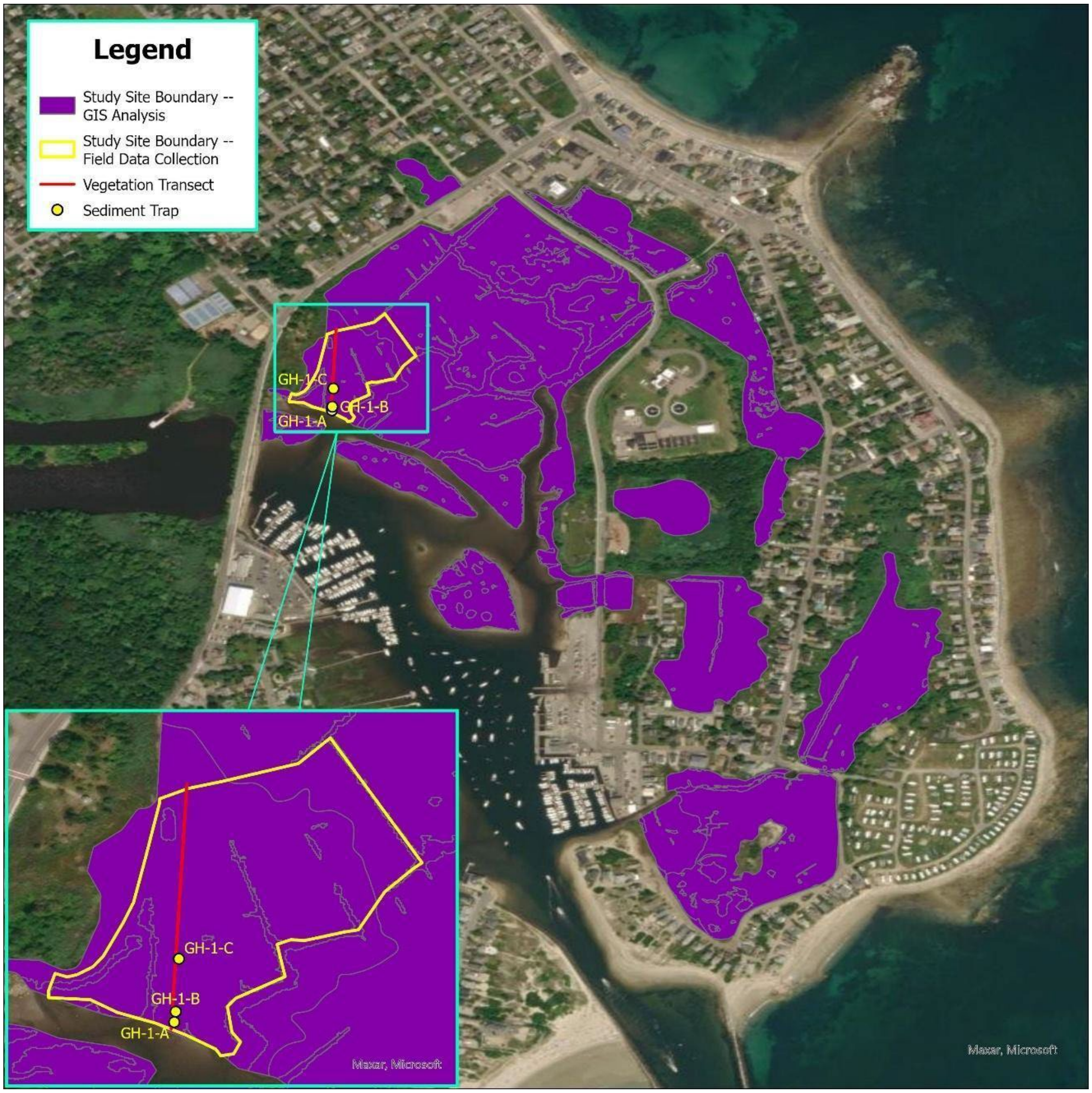

Figure 4. Map of the Green Harbor Marsh Unit and Field Sites

2.1.4 South River

This extensive marsh consists of 790 acres of salt marsh extending from Ferry Hill in Scituate near the mouth of the South River, upstream to the head of tide near Willow Street in Marshfield (Figure 5). Despite the large size of this unit, the surrounding environment is dominated by residential neighborhoods and open space. Commercial infrastructure and impervious surfaces are dominant only in the very upper reaches of this unit.

Within this large marsh unit there was a single parcel studied for vegetation. This parcel, the Marshfield Recreation property (AKA 'Coast Guard') had been previously studied by NSRWA in 2001, 2014, and 2023. It is sandwiched between the residential area on the landward side of the

South River and the residences of the Marshfield Hills, and is located on Clapp's Creek, which drains into the South River. This property is owned by the Marshfield Recreation Department. This was previously the Coast Guard Communications Center, which was built in 1943 to transmit weather information and track shipping along the Atlantic coast.

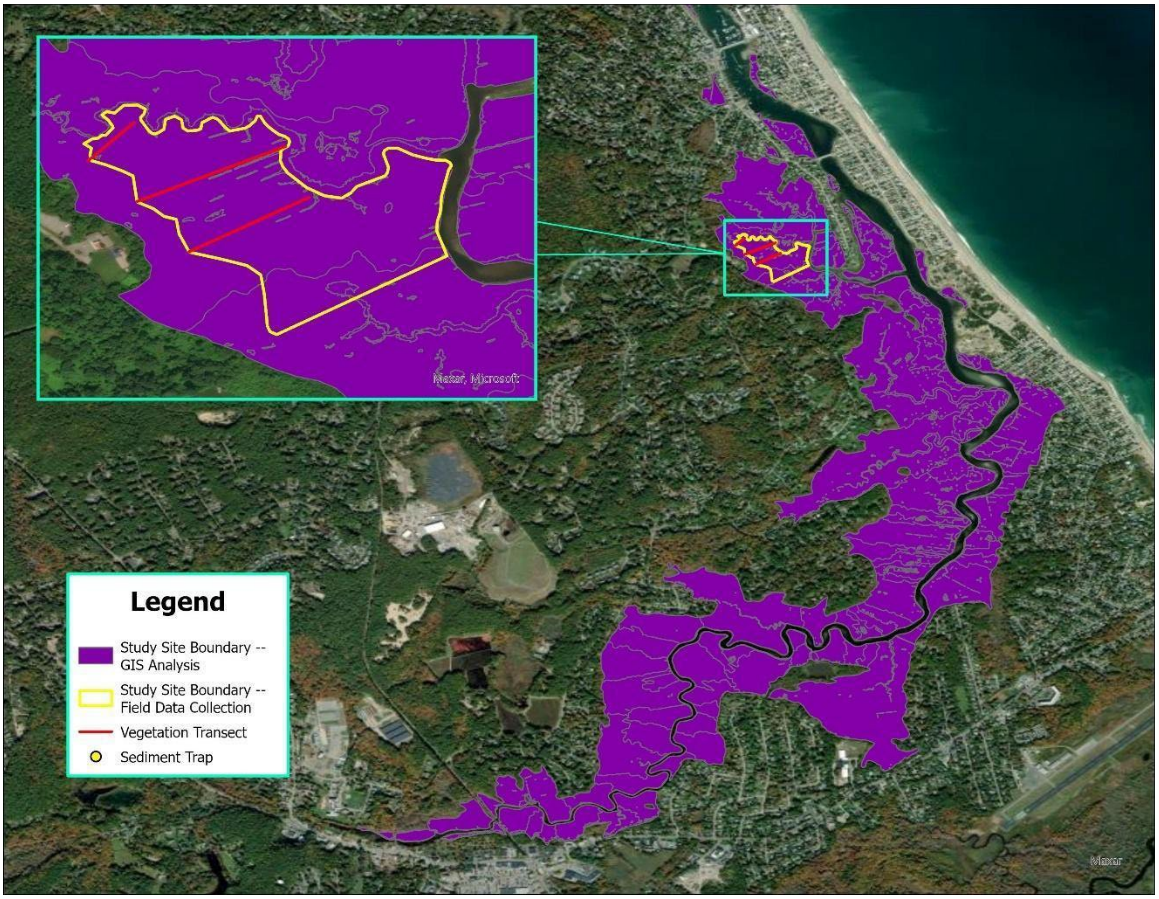

Figure 5. Map of the South River Marsh Unit and Field Sites

2.1.5 North River Mid-Upper Reaches

This marsh unit comprises 450 acres on both sides of the North River from Union Street bridge Marshfield (Bridge St, Norwell) to Route 3 (Figure 6). The upper reaches of this unit are located near the head of salinity. Marsh ownership is a mix of private residential, NGO land protection (Mass Audubon, Trustees of Reservations), and town conservation. The transition from salt to fresh at this site is evident in the mixed vegetation. Within this marsh unit there was a single parcel studied for vegetation. This parcel is accessed through private property.

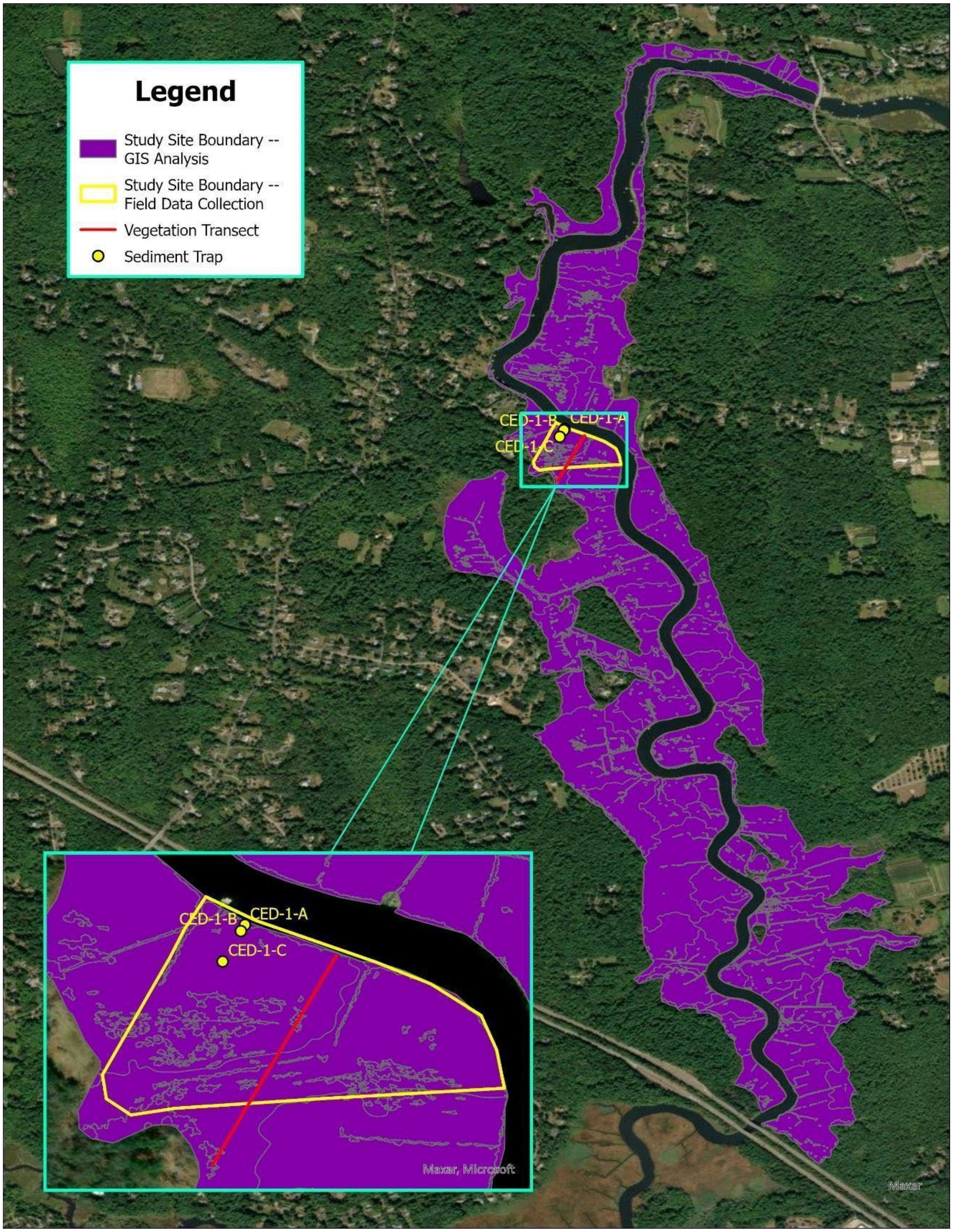

Figure 6. Map of the Mid-Upper North River Marsh Unit and Field Sites

2.1.6 North River Lower Reaches

This broad marsh unit is located on the North side of the North River from the mouth of the river at Third Cliff to just west of Route 3A on the North River, Herring Brook, and First Herring Brook (Figure 7). The unit covers approximately 600 acres. The majority of the land use surrounding this unit is residential or open space. However, some portions do contain significant infrastructure including a wastewater treatment plant, former landfill, golf courses, marinas, roads, and some commercial properties.

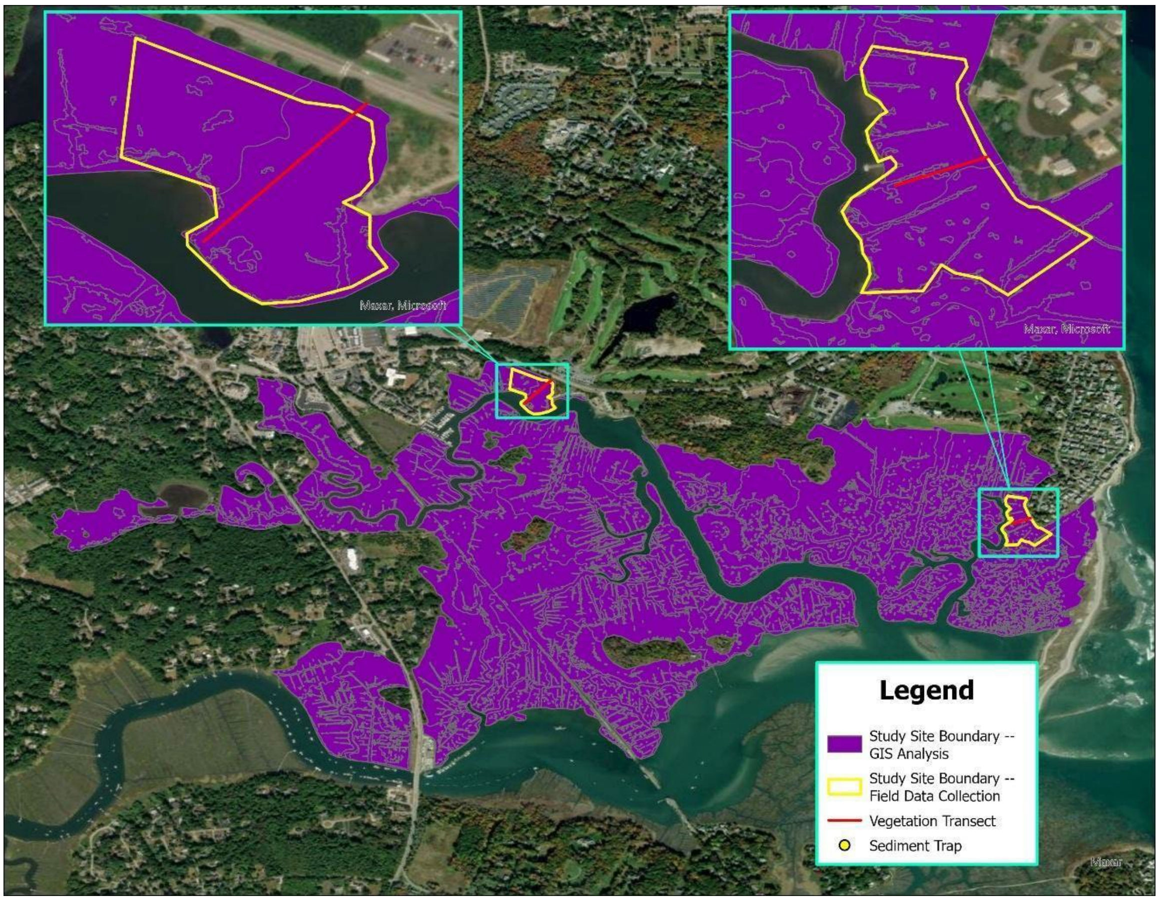

Figure 7. Map of the Lower North River Marsh Unit and Field Sites

Within this marsh unit there were two individual parcels studied during this project, described below.

2.1.6.1 Scituate Conservation

This parcel, located midway along the North River on the northward side, is very wide with a few interspersed tributaries and ponds. Sediment at this site is always very soft and wet, which suggests that it is poorly drained. It is quite disturbed, bordered by a main road on the upland side, with a landfill across that road, and a marina upstream. Various areas of the marsh and the surrounding dunes are covered in concrete left by the previous owner, the Boston Sand and

Gravel Company, which launched sand and gravel barges from the site to support the construction of runways at Logan Airport in Boston. This site was previously surveyed by NSRWA in 2001, 2014, and 2023.

2.1.6.2 Third Cliff, Scituate

This marsh is on the northward side of the North River almost at the point where it meets the South River. It is extensive and has many wide drainage ditches, and is bordered by the North River, dunes that separate it from the Atlantic, and an area that is a mix of woodlands, and residential use. The main 50-acre parcel belongs to the North and South Rivers Watershed Association (NSRWA 1997).

2.1.7 Peggotty/Kent Street, Scituate.

This small 114-acre marsh unit is located between the Peggotty barrier beach to the east, Kent Street to west, and extends into Scituate Harbor to the north (Figure 8). Ownership of the marsh is primarily by the Town of Scituate, with some small private residential parcels. Within this marsh unit there was a single parcel studied for vegetation. This parcel is accessed from the inside of Peggotty Beach. Selection of this site was additionally based on opportunities for outreach. With assistance from NSRWA, a team from Scituate High School developed a plan to conduct monitoring at this marsh. NSRWA was able to coordinate with the school to bring students out on field surveys.

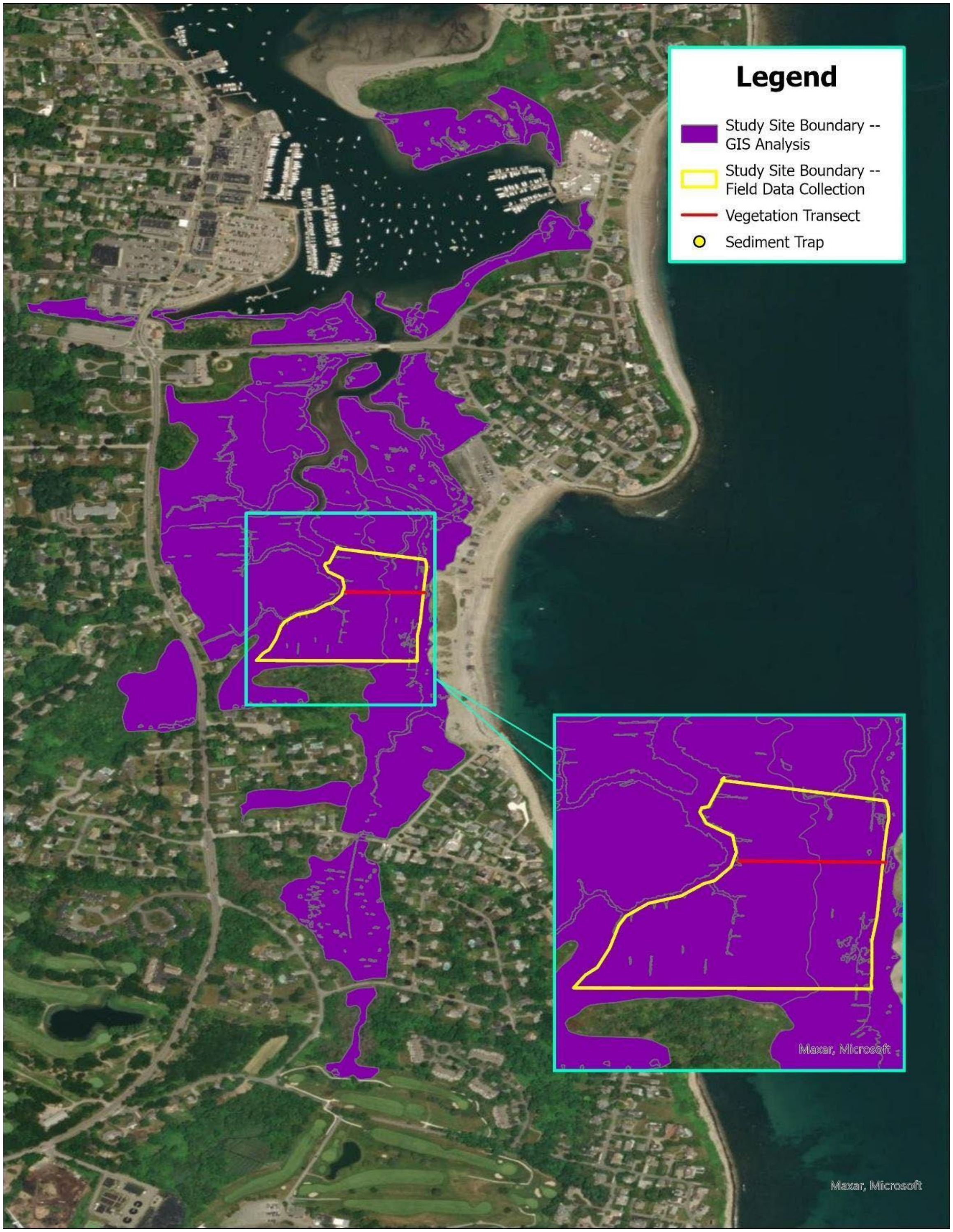

Figure 8. Map of the Peggotty/Kent Street Marsh Unit and Field Sites

2.1.8 Gulf River and Musquashcut Brook, Scituate

This 285-acre marsh unit is located on both sides of the Gulf River and Musquashcut Brook in Scituate (Figure 9). On the Gulf River the unit extends from approximately Supper Island upstream to just above Hollett Street. All of Musquashcut Brook is included from the Gulf River to the entrance of Musquashcut Pond. This marsh unit is primarily surrounded by residential neighborhoods, although a golf course is present on the north side of Musquashcut Brook. Within this marsh unit there was a single parcel studied for vegetation on the south side of Musquashcut Brook. This parcel is town-owned but accessed through private property on Sedgewick Drive, Scituate. Musquashcut Brook was previously dredged and dredge spoils have been intermittently placed on the marsh surface on this side of the tidal channel which might influence hydraulics of wet/dry which might not be reflective of the entire marsh.

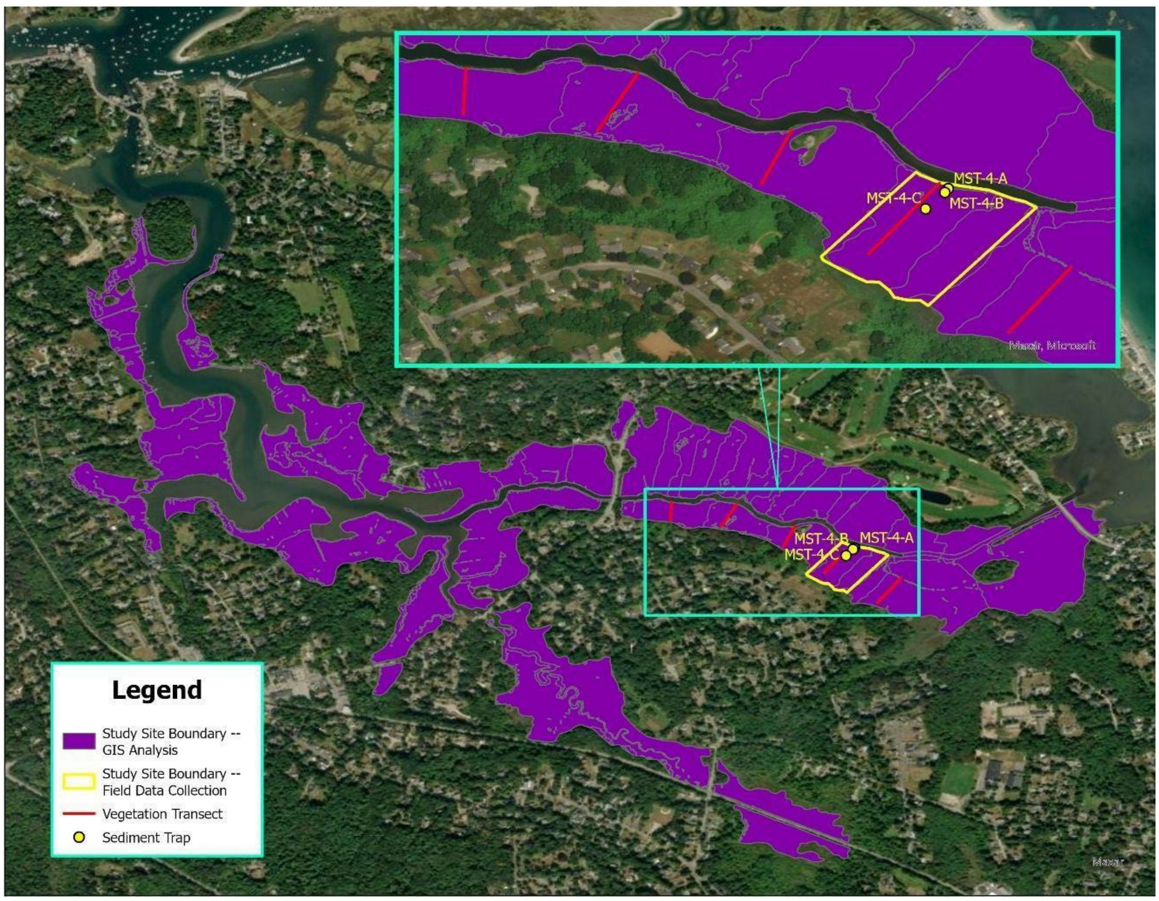

Figure 9. Map of the Musquashcut Marsh Unit and Field Sites

2.2 GIS Analysis

2.2.1 Marsh Area and Change in Marsh Area

Total marsh area was defined as the range between High Tide Line (“HTL”) and Local Mean Sea Level (“LMSL”). In order to ascertain the total area of marsh present at each study unit, elevational data were plotted using the most recent comprehensive LiDAR dataset (USGS, 2021: Central Eastern Massachusetts). A Digital Elevation Model (“DEM”) for each study unit was created using these LiDAR point cloud data. To create a DEM of bare-earth surface elevations, only ground points were included. In order to correct for site-based differences in tidal range, NOAA’s local tidal datum stations were consulted, and a unique tidal range was constructed for each study site, based on data from the nearest tidal datum station. LiDAR data were then clipped to the extent of each study site, and contour intervals were plotted using site-specific HTL and LMSL data. Site-specific HTL data were obtained using the Buzzards Bay Interactive Tidal Datum Viewer, which was generated using NOAA’s VDatum software. Marsh range polygons were then constructed from the contour intervals, and area was calculated using ArcGIS Pro.

In order to evaluate the change in marsh area over time, the same process was repeated using USGS’s 2011 Northeast (NY to ME) LiDAR dataset. This dataset was selected as being the most comparable dataset available to the 2021 dataset in terms of vertical and horizontal accuracy, although there have been improvements in resolution since 2011 (3.7 cm vertical accuracy in 2021, versus 7.1 cm in 2011). The area within the resulting 2011 marsh range polygons was calculated, and 2021 results were subtracted from 2011 results to arrive at the change in marsh area over that ten-year timeframe. However, due to the difference in source data accuracy, it is possible that change in marsh area could be either over- or under-represented in the final analysis. Furthermore, this is strictly an elevational approach and does not take the presence or absence of vegetation into consideration. For example, it is possible that certain shallow unvegetated areas, such as pannes or pools, were forming, yet present, at an elevation in 2011 that would include them in total marsh area for that year, whereas they may have dropped out of the marsh elevation area in 2021. This would result in a misrepresentation of loss, since the 2011 pool was not functioning as vegetated marsh to begin with. Similarly, in some cases intrusion of *Phragmites* may result in apparent LiDAR elevations that are above the HTL and are therefore categorized as marsh loss.

The 2021 LiDAR elevation data was compared to field-measured elevation points collected during the sediment trap deployments and retrievals. Survey equipment was provided by UMass Boston utilizing an Emlid Reach RS2+ GNSS in RTK mode. The RTK system provides a vertical accuracy of 1.4cm. Field data points were not initially intended for LiDAR comparison, but rather to establish sediment trap elevations along a transect from marsh edge to upland edge. As a result, RTK data is only available from a small subset of overall marshes representing the five field sites that included sediment traps. Thirty-one total points were collected and compared to the 2021 LiDAR elevation data. RTK measured elevations averaged 6.45cm lower ($r^2 = 0.968$) than the comparable

LiDAR points. This discrepancy may be due to the RTK unit capturing the true marsh surface whereas the LiDAR data may be influenced by vegetation on the surface resulting in a perceived higher elevation. LiDAR data were not corrected. Since no comparable RTK data was available for the 2011 LiDAR data set we chose to compare the LiDAR datasets directly with no RTK-based corrections.

2.2.2 Percent Resilient

The percent of a salt marsh that is considered to be resilient is the percent that lies between Mean High Water ("MHW") and the HTL (Buzzards Bay Coalition, 2023). To determine what percentage of each study unit fell within this range, 2021 LiDAR data were added to the map, and clipped to the extent of each study unit. A contour interval was then determined, using site-specific tidal data, with its lower boundary being the MHW line and its upper boundary being the HTL. A contour polygon was constructed using these intervals, and the area of that polygon was calculated using ArcGIS Pro. This process was repeated for each study site. Note that this method did not incorporate tidal restrictions. Prior to any focused restoration planning, tidal restriction influence should also be considered.

2.2.3 Marsh Lifespan and Unvegetated-Vegetated Marsh Ratio

Each conceptual marsh unit (CMU) has been categorized within two mesotidal mean tidal ranges along the South Shore, greater than or less than 2.28m (a natural breakpoint in tidal range for the region) (Ackerman et al, 2021). The lifespan of each CMU was divided into Low <75 years (i.e. by 2100), Med 75-175 years (i.e. by 2200), High >175 years, using the 1-meter sea level rise by 2100 scenario (Defne et al, 2023). The unvegetated-vegetated marsh ratio (UVVR) of each CMU was categorized according to whether it was lower or higher than the median UVVR for that tidal range across the state of Massachusetts, with more vegetation lower than the median and less vegetation higher than the median (Ackerman et al, 2021). This is a dataset derived from analysis of National Agricultural Inventory Program (NAIP) imagery of vegetated and unvegetated areas by USGS. This created six categories based on lifespan and UVVR (Low, Medium, and High lifespan; more or less vegetation). On the South Shore, marshes fell into four out of the six potential categories – marshes with high lifespans and either more or less vegetation, marshes with medium lifespans and less vegetation, and marshes with low lifespans and less vegetation.

2.2.4 Marsh Migration Potential

CZM's Marsh Migration Areas dataset, derived from the Massachusetts Sea Level Affecting Marshes Model (SLAMM) (CZM, 2016), was used to calculate the potential for marsh migration at each study site. This model predicts adjacent upland and wetland areas that could accommodate marsh migration during predicted sea level rises scenarios for the years 2050, 2070, and 2100. The Marsh Migration Areas dataset differentiates between migration into upland areas and into other vegetated wetland areas (OVW) which includes the following: tidal swamp, tidal fresh marsh, inland fresh marsh, and nontidal swamp. The area gained by potential future marsh migration at each site was compared to the current area of marsh present, and overall potential marsh migration at each study site in 2050, 2070, and 2100 is represented as a percentage.

2.3 Vegetation surveys

Plant community, species, and percent cover at the field sites were assessed using a combination of belt transect and quadrat methods. Along each transect, plant zones or “belts” were determined based on the dominant (or co-dominant) plant species along the transect tape. Beginning and end coordinates of each transect were determined by handheld GPS (Garmin eTrex 22x). As each transect was walked the beginning and ending of each plant zone was documented on the data form. Plant zones change when the dominant or co-dominant plant species changes. In addition to dominant species, belt boundaries were defined by pannes, pools, creeks, ditches, bare/mudflat, open water, or other physical features. Zones were measured to the nearest 0.25m. Quadrat measurements (1m^2) were conducted every 10m along the transect to determine percent cover and percent cover of each species present. Vegetation transect lengths ranged from 50m to 190m.

Integrating belt transect vegetation data with the larger GIS analysis proved challenging for this study. While the vegetation transects provide high-resolution data at targeted field sites, they were not always representative of all portions of the larger CMUs. Vegetation results were useful in evaluating specific marsh conditions such as panne and pool formation, low versus high marsh transitions, surface stability, crab burrows, and other fine-scale details. Vegetation results are provided as narrative, qualitative descriptions supporting recommendations in this report.

2.4 Sediment Supply and Deposition

Sediment supply is central to salt marsh development and resilience. Most salt marshes in the Northeast US initially develop on estuarine muds (Braswell et al., 2020), which accumulate in sheltered settings and provide substrates at the appropriate elevation for salt marsh grass to colonize. After initiation, salt marshes continue to build elevation through the incorporation of suspended sediment deposited on the marsh and in-situ production of root biomass by marsh grasses. Sea level rise makes continually increasing platform elevation necessary for salt marsh survival. Suspended sediment transported into the sheltered areas that host salt marshes therefore makes up a critical foundation and building block for salt marsh development and persistence. The proportional contribution to marsh platform elevation from in-situ vegetative growth versus from sediment deposition remains an area of active research. However, several studies have shown that external sediment supply is vital to marsh resilience (Ganju et al., 2017; Peteet et al., 2018; Yellen, Woodruff, et al., 2023).

The South Shore is characterized by limited suspended sediment delivery from rivers. The South Shore’s mostly coarse textured soils tend to maximize recharge to deep aquifers, bypassing rivers, and instead draining directly to the ocean via submarine groundwater discharge. What rivers do exist tend to run clear, carrying little sediment, due to the low relief of the region and limited silt and clay sized particles in the soils.

While the region's rivers supply little sediment to the coast, the South Shore has numerous bluffs made up of glacial material – till and outwash – which as it erodes, supplies coarse and fine sediment directly to the littoral zone. Fine sediment (<63 µm) is comprised of silts (4-63 µm) and clays (less than 4 µm) and forms the primary sediment input to salt marshes and muddy intertidal habitats (Woodruff et al., 2024). Coarse sediment, mostly sand and gravel, makes up beaches and dunes. Glacial till deposited directly by ice, and tends to have a mix of grain sizes, including 10-40% fine grained material (Yellen et al., 2016). Coarse outwash material was deposited by glacial meltwater streams, and lacks abundant fine-grained material being more than 90% sand and gravel on average (Roy et al., 2025). The northern portion of our study region is predominantly glacial till, while areas south of Marshfield are mostly made up of sandy outwash.

Given the low sediment yields of South Shore rivers, salt marshes here derive most of their sediment from marine sources, delivered during higher flooding tides of the spring-neap cycle (Baranes et al., 2022). Marine sediment is transported via longshore currents and derived from a few sources including erosion of glacial bluffs and wave base erosion of high-energy shallow marine settings.

The sediment resilience of our study marshes was assessed via field-based and GIS/remote sensing. For our field assessment, sediment traps were deployed during the stormy spring season, March-June of 2024, and during the relatively quiescent summer season of June-August 2024. Sediment traps were deployed following methods outlined in Woodruff et al. (2024) and described briefly here. Sediment traps consisted of centrifuge tubes (50 ml, 2.7 cm diameter opening) with 0.6 cm netting affixed to the top to exclude crabs and inserted into the marsh platform such that the opening of the tube was roughly 1 cm above the sediment. Sediment trap transects were deployed perpendicular to the main tidal creek at each site, with three traps placed at each station 3 m, 10 m, and 40 m from the channel. Upon retrieval, outliers were disposed, and remaining traps were processed for total mass deposited, organic deposition, and mineral deposition by drying and combusting the trapped sediment. Samples were first triple rinsed in deionized water to remove salt mass. Sediment traps were initially deployed on March 22, 2024, redeployed on June 30, 2024, and removed on August 12, 2024.

Suspended sediment availability for each site was assessed using the suspended sediment product detailed in Teng et al. (2025), with both the average suspended sediment concentration (SSC) and change in SSC recorded for each site. This product was used to extract median SSC based on Landsat reflectance from the query polygon for every Landsat capture date for each polygon since 1984 (n~800 per site). We then took the long term mean of the spatial medians. The coastal ocean adjacent to each study site was queried within a polygon shown in Figure 10. SSC query locations were chosen to capture littoral zone ocean conditions as representative of marine sediment sourcing.

Figure 10. Map of Suspended Sediment Concentration Query Locations

Salt marsh sediment demand was assessed based on the modeled mineral density of salt marsh sediments at each location combined with an estimate of past sediment accumulation rates. Modeled sediment mineral density for each marsh was taken from a publicly available data product Northeast US Blue Carbon Rasters (Yellen et al., 2023), which provides modeled sediment properties for Northeast salt marshes. Accumulation rates were taken from Cook et al. (2023), with South Shore average salt marsh accumulation rates based on the median value from the database excluding ^{14}C-derived dates, which reflect pre-modern conditions when sea level rise and marsh accumulation were much lower than today. Last, to estimate total marsh sediment demand, we multiplied the current salt marsh mineral sediment density (gM / cm^3) by the calculated median vertical accumulation rate (cm/yr) by the marsh area to derive the mass of sediment necessary for the marsh to accrete at steady state.

We estimated a site-specific vertical accumulation rate for each sediment trap site by combining our sediment trap results with a paired surface bulk density sample collected adjacent to the sediment traps. Surface samples included 0-10 cm depth with a volume of 480 cm^3. Samples were dried, homogenized, then a subsample combusted to calculate the mineral density of the marsh sediment at each site. The mineral deposition rate (g/cm^2/yr) was multiplied by the inverse of the sediment bulk density (gM/cm^3) to estimate how much time that 10 cm represented based on the current sediment delivery rates. This method assumes that the observational period was representative of typical conditions, that there is no erosion of the marsh sediment, and that current sediment delivery is similar to the time represented by the 10 cm of surface sediment accumulation. Generally, these 10 cm sediment samples represent roughly the past 20 years (Turek et al., 2025).

2.5 Other Analyses

In addition to the methods and results contained in this report, we also evaluated diadromous fish migratory habitat, shellfish classification areas, and Natural Heritage & Endangered Species Program priority habitat. The results are not reported here as they did not directly contribute to the conclusions. However, they are provided in Appendix A and are available for future study of individual sites.

Tidal restrictions were plotted on maps for each of the sites. Layer data was provided by Christina Kennedy of MA Division of Ecological Restoration (DER) from the Draft Tidal Crossing Geodatabase version effective April 5, 2024. Tidal restrictions were considered in qualitative assessments but no formal analyses of these tidal restrictions was conducted. The MassBays National Estuaries Program is currently conducting a regional tide gate assessment that may be valuable for future evaluations.

3 PROJECT RESULTS AND RECOMMENDATIONS

The following subsections present overall data across all study sites. Section 3.4 provides detailed results and discussion for each individual study site.

3.1 Marsh Area and Change in Marsh Area

Marsh loss from 2011 to 2021 across all study sites, as defined by net elevational loss within the boundaries of each designated study unit, was approximately 1,554,250sq ft (2.6 acres) (Table 1). This represents a total loss of 1.2%. The maximum loss of 1.86% was seen on the South River and the minimum loss of 0.46% in Duxbury. Note that, as discussed in section 2.2, due to the difference in source data accuracy, it is possible that change in marsh area could be either over- or under-represented in the final analysis. Additionally, this is strictly an elevational approach, and does not take the presence or absence of vegetation into consideration. For example, it is possible that certain shallow unvegetated areas, such as pannes or pools, were forming, yet present, at an elevation in 2011 that would include them in total marsh area for that year, whereas they may have dropped out of the marsh elevation area in 2021. This would result in a misrepresentation of loss, since the 2011 pool was not functioning as vegetated marsh to begin with. Percent loss for each site is discussed in more detail in the sections below.

Table 1. Marsh Loss from 2011 to 2021 at All Studied Sites

Marsh Unit	2011	2021	change (square feet)	percentage lost (%)*
Jones River/Kingston Bay	10,274,149	10,092,513	-181,636	1.77
Duxbury Bay/Cut River/Back River	47,422,832	47,202,463	-220,369	0.46
Green Harbor	3,042,050	2,987,845	-54,205	1.78
South River	33,194,743	32,576,129	-618,615	1.86
North River Mid-Upper Reaches	18,348,079	18,120,367	-227,712	1.24
North River Lower Reaches	22,631,109	22,277,478	-353,631	1.56
Peggotty/Kent Street, Scituate	4,431,931	4,352,213	-79,718	1.80
Gulf River/Musquashcut Brook	11,739,252	11,627,360	-111,892	0.95
Total	129,070,746	127,516,496	-1,554,250	1.20

*Colors for visual reference only, highlighting the range of values.

3.2 Percent Resilient

The percent of a salt marsh that is considered to be resilient is the percent that lies between Mean High Water (“MHW”) and the HTL (Buzzards Bay Coalition, 2023). Based on the 2021 LiDAR data, South Shore salt marshes ranged from 29% resilient in the upper reaches of the

North River to a high of 90% resilient in Duxbury (Table 2). Percent resilient for each site is discussed in more detail in section 3.4.

Table 2. Percent Resilient as of 2021

Marsh Unit	2021 marsh range LMSL to HTL (sq ft)	MHW to HTL (sq ft)	percent Resilient (%)*
Jones River/Kingston Bay	10,092,513	8,594,632	85.16
Duxbury Bay/Cut River/Back River	47,202,463	42,291,754	89.60
Green Harbor	2,987,845	2,342,871	78.41
South River	32,576,129	25,218,784	77.41
North River Mid-Upper Reaches	18,120,367	5,323,476	29.38
North River Lower Reaches	22,277,478	10,918,320	49.01
Peggotty/Kent Street, Scituate	4,352,213	3,586,243	82.40
Gulf River/Musquashcut Brook	11,627,360	6,351,750	54.63
Total	149,236,369	104,627,830	70.11

*Colors for visual reference only, highlighting the range of values.

3.3 Marsh Migration Potential (SLAMM)

Table 3 provides a summary of marsh migration potential (total area and percent of existing) for each marsh unit in 2050, 2070, and 2100. Conditional formatting in Table 3 is based on percent gain for each projected year. Table 4 shows marsh migration potential broken out by both upland gain and “other vegetated wetland” (OVW). “Other vegetated wetland” includes the following SLAMM wetland classes: tidal swamp, tidal fresh marsh, inland fresh marsh, and nontidal swamp (MA CZM https://www.arcgis.com/home/item). Interestingly, while Duxbury is the largest of the study areas, it has relatively modest potential for migration both in terms of overall area and percentage gain. In contrast, the South River is the second largest study site and has the greatest potential migration gains in terms of area across all of the sites and all of the projected years. By 2100 the South River marsh complex has potential for 1.5 million sq ft (36 acres) of migration which represents 28% of the current size. These gains come predominantly in the upland (32 acres) versus OVW (4 acres). In terms of best percent gain, the Gulf River/Musquashcut Brook has a potential to increase by 47% (22 acres) by 2100. Again, those gains are predicted to be largely in the upland versus the OVW. The North River (both the upper and lower reaches) are the only study sites where migration potential is dominated by OVW instead of upland gains.

It should be noted that this summary analysis used CZM's gross potential marsh migration dataset for 7.1 ft of SLR which includes developed lands. The percent of developed lands was not analyzed in the provided marsh migration scenarios shown in Table 4. Any future work at targeted sites should include a focused evaluation of developed sites in terms of marsh migration potential.

Table 3. Total Marsh Migration Potential

Marsh Unit	Current Area sq ft	Total 2050 gain sq ft (% of original area)	Total 2070 gain sq ft (% of original area)	Total 2100 gain sq ft (% of original area)
Jones River/ Kingston Bay	1,854,360	56,959 (3.1)	205,648 (11.1)	486,905 (26.3)
Duxbury Bay/Cut River/Back River	8,176,718	43,921 (0.5)	166,052 (2.0)	416,738 (5.1)
Green Harbor	560,588	17,455 (3.1)	64,293 (11.5)	107,498 (19.2)
South River	5,697,568	313,438 (5.5)	739,250 (13)	1,578,804 (27.7)
North River Mid-Upper Reaches	3,139,059	189,790 (6)	351,623 (11.2)	639,549 (20.4)
North River Lower Reaches	4,133,906	60,976 (1.5)	155,174 (3.8)	351,845 (8.5)
Peggotty/ Kent Street, Scituate	812,067	37,669 (4.6)	197,289 (24.3)	347,161 (42.8)
Gulf River/ Musquashcut Brook	2,036,678	248,788 (12.2)	597,563 (29.3)	960,749 (47.2)
Total	26,410,947	969,000 (3.7)	2,476,897 (9.4)	4,889,254 (18.5)

*Colors for visual reference only, highlighting the range of values.

Table 4. Upland vs OVW Marsh Migration Potential

Marsh Unit	Current Area sq ft	2050 upland gain sq ft	2070 upland gain sq ft	2100 upland gain sq ft	2050 OVW gain sq ft	2070 OVW gain sq ft	2100 OVW gain sq ft
Jones River/ Kingston Bay	1,854,360	23,849	108,726	277,055	33,109	96,922	209,849
Duxbury Bay/Cut River/Back River	8,176,718	32,275	123,918	355,234	11,645	42,133	61,504
Green Harbor	560,588	13,362	56,355	99,536	4,093	7,938	7,962
South River	5,697,568	230,157	601,652	1,398,386	83,281	137,597	180,417
North River Mid-Upper Reaches	3,139,059	2,840	4,819	78,618	186,949	346,804	560,931
North River Lower Reaches	4,133,906	1,911	5,033	53,754	59,064	150,141	298,091
Peggotty/Kent Street, Scituate	812,067	18,834	138,778	265,388	18,834	58,511	81,773
Gulf River/ Musquashcut Brook	2,036,678	184,452	450,402	774,919	64,336	147,161	185,830
Total	26,410,947	507,684	1,489,686	3,302,894	461,316	987,211	1,586,359

3.4 Sediment Traps

Sediment deposition at our sites tended to decrease with distance from the channel (Figure 11). Panel A shows the amount of mineral sediment deposited at increasing distances from a tidal creek at each of our sentinel sites during the spring (March-June) and Summer (July and August) of 2024. Panel B shows the fraction of organic material deposited, consistent with observations from the literature (Moskalski & Sommerfield, 2012; Temmerman et al., 2003). We would expect sediment delivery to the marsh during the windy and stormy spring to exceed that during the calmer summer months, and this is the case at Cedar Point in the upper North River and Duxbury sites. However, for the most part, sediment deposition across seasons was more consistent than we expected.

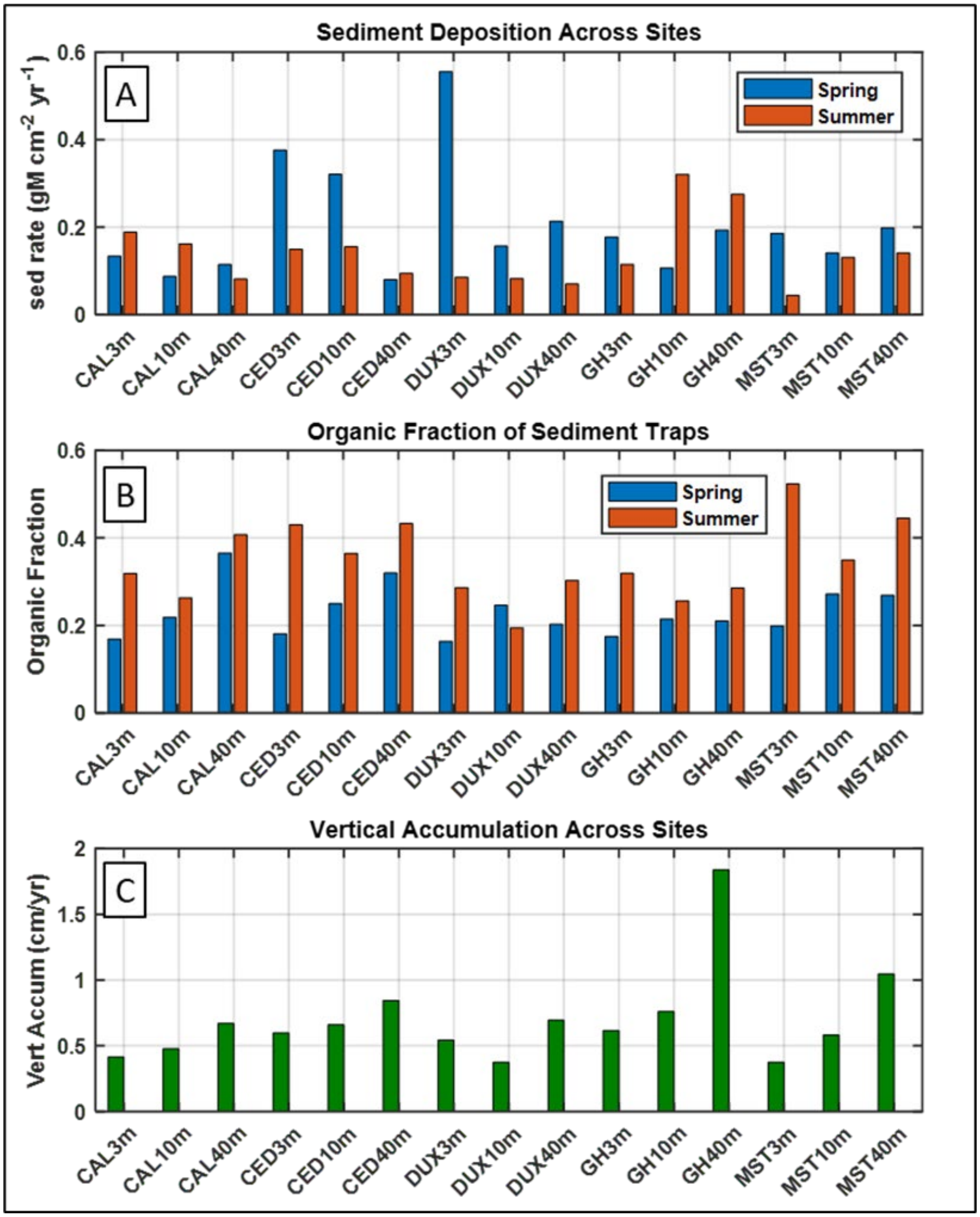

Figure 11. Panel A shows the amount of mineral sediment deposited at increasing distances from a tidal creek at each of our sentinel sites during the spring (March-June) and Summer (July and August) of 2024. Panel B shows the fraction of organic material deposits

Table 5. Sediment trap summary for spring and summer 2024 across the five assessed sites. Deposition rates for spring and summer are only the mineral component of the deposited sediment and normalized per year to enable comparison. Vertical accumulation is estimated.

Site / Distance	Spring Dep ($g/cm^2/yr$)	Spring Org	Summer Dep ($g/cm^2/yr$)	Summe r Org	Average Dep Rate ($g/cm^2/yr$)	BD (g/cm^3)	Org bulk	Min Dep (gM/cm^3)	Vert Acc (cm/yr)
CAL 3m	0.13	0.17	0.19	0.32	0.16	0.48	0.19	0.3888	0.41
CAL 10m	0.09	0.22	0.16	0.26	0.12	0.34	0.23	0.2618	0.48
CAL 40m	0.11	0.37	0.08	0.41	0.10	0.24	0.39	0.1464	0.67
CED 3m	0.38	0.18	0.15	0.43	0.26	0.53	0.17	0.4399	0.60
CED 10m	0.32	0.25	0.16	0.36	0.24	0.44	0.18	0.3608	0.66
CED 40m	0.08	0.32	0.09	0.43	0.09	0.17	0.39	0.1037	0.84
DUX 3m	0.56	0.16	0.09	0.29	0.32	0.68	0.13	0.5916	0.54
DUX 10m	0.16	0.25	0.08	0.19	0.12	0.41	0.22	0.3198	0.37
DUX 40m	0.21	0.20	0.07	0.30	0.14	0.28	0.27	0.2044	0.69
GH 3m	0.18	0.17	0.12	0.32	0.15	0.33	0.28	0.2376	0.62
GH 10m	0.11	0.21	0.32	0.26	0.21	0.36	0.22	0.2808	0.76
GH 40m	0.19	0.21	0.28	0.29	0.23	0.19	0.33	0.1273	1.84
MST 3m	0.19	0.20	0.04	0.52	0.11	0.42	0.27	0.3066	0.37
MST 10m	0.14	0.27	0.13	0.35	0.14	0.33	0.29	0.2343	0.58
MST 40m	0.20	0.27	0.14	0.44	0.17	0.28	0.42	0.1624	1.05

Sediment deposition on the marsh platform is highly dependent on spring tides. Therefore, differences in sediment deposition across time at a given site can be influenced by the timing of the observations with respect to the spring-neap cycle. To assess whether this might explain the relatively similar deposition across spring and summer observational seasons at our South Shore sites, we evaluated tidal water levels at the closest NOAA gauge (Boston) across the study duration. Figure 12 shows hourly water levels at Boston in meters relative to mean sea level. While we expected that high water levels in the summer deployment (June to August) might have explained the surprisingly similar deposition rates across spring and summer, average high water levels were actually higher during spring. Average daily high during the spring deployment was 1.37 m versus 1.31 m during the summer deployment.

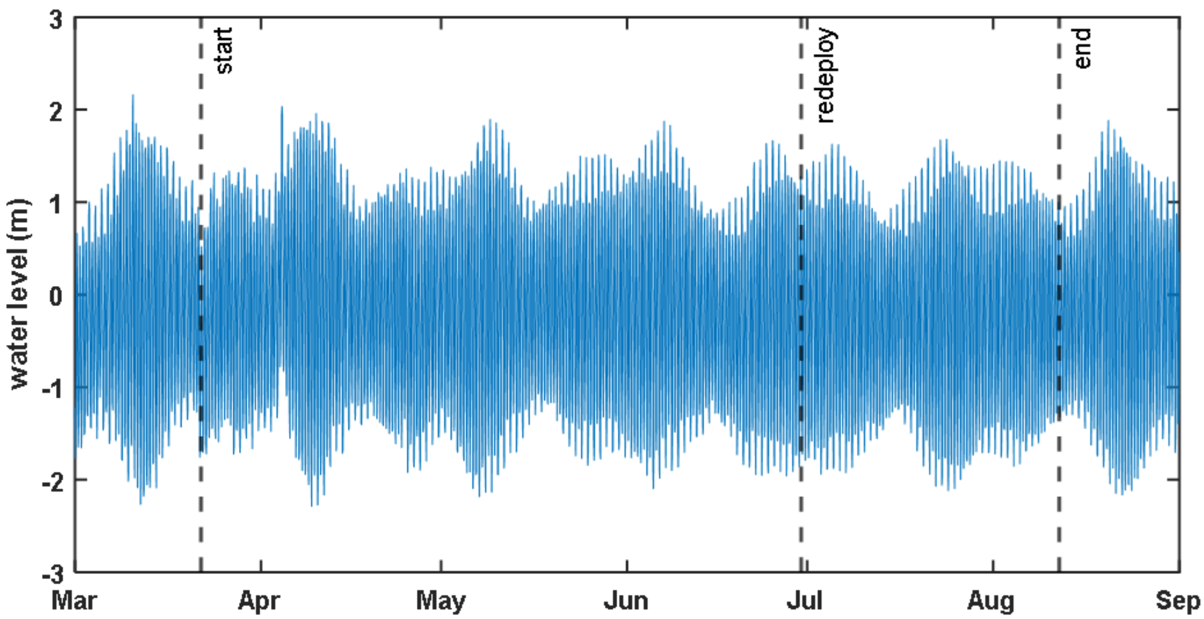

Figure 12. Water levels relative to MWL at the Boston tide gauge across the sediment trap study deployment. Black dashed lines indicate the dates of sediment trap deployment.

When sedimentation rates in terms of mass per unit area were converted to vertical accumulation rates using the mineral bulk density of the in-situ soil at the sediment trap location, we found that these marshes are generally keeping up with sea level rise. Median inferred vertical accumulation rates were 6.2 mm/yr. The slowest apparent accumulation was observed at the Calista site, with an average of 5.2 mm/yr; the greatest accumulation rate was observed at Green Harbor at 10.7 mm/yr. However, when an outlier observation is removed there, that site average fell to a more modest 6.9 mm/yr. A compilation of modern salt marsh accumulation rates from Cape Cod Bay based on radiogenic nuclides showed an average of 5 mm/yr (O'Keefe Suttles et al., 2021), consistent with our results.

3.5 Suspended Sediment Observations

Suspended sediment concentrations (SSC) based on satellite observations from 1984 to present across the region are generally low, with mean SSC values for all the sites ranging from a low of 4.7 mg/l at Duxbury Littoral to a high of 11 at Musquashcut (Figure 13). In general, SSC values were higher within tidal marsh systems than in the littoral zone outside the mouth of the estuary. This is typical for estuarine sites to display higher SSC as tidal currents and estuarine turbidity maxima resuspend sediment. However, the ultimate source of sediment for most, if not all, of these sites is from the marine side. Therefore, littoral zone SSC is more indicative of sediment supply. Temporal change in SSC at these nearshore locations can be attributed to changes in net sediment supply.

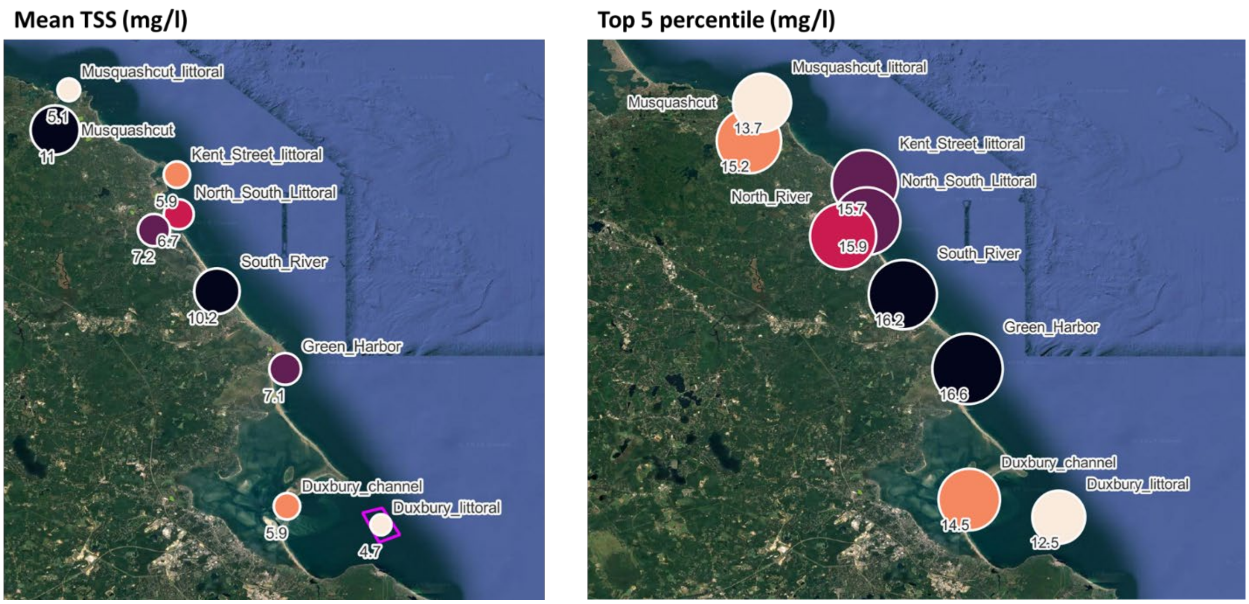

Figure 13. Mean and top 5 percentile suspended sediment concentrations at the sites evaluated in this study.

Using the same publicly available suspended sediment mapping tool that we used to map average SSC in the coastal water column, we also assessed the change in average SSC over time, 1984 to present. Across all nine assessed sites, SSC has been decreasing, with a regional average of -0.11 mg/yr, which equates to a decline of 4 mg/l over the past 40 years. This decline is substantial, representing a decline of 30-40% in marine sourced sediments (Figure 14). There is no clear north-south geographic pattern in SSC declines, but declines have generally been steeper in littoral zone settings rather than inside tidal creek systems. This discrepancy may be an artifact of collecting data from satellite observations, which may be biased by bottom reflectance.

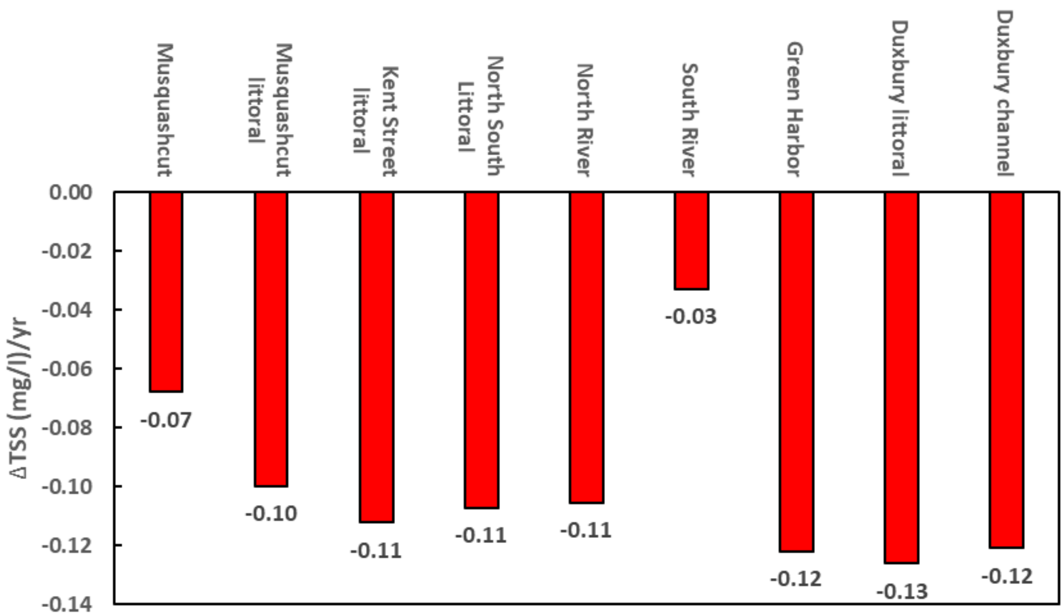

Figure 14. Change in average SSC 1984 to present at assessed sites.

3.6 Individual Sites

3.6.1 Jones River/Kingston Bay

The Jones River marsh units cover 256 acres extended along the western shore of Kingston Bay, into Island Creek, and up the Jones River to the head of tide at the former Elm Street Dam (removed 2020). Tributaries include Smelt Brook, Stony Brook, Tussock Brook, and Stony Brook. The marsh unit has a relatively high number of tidal restrictions. It also includes a variety of surrounding infrastructure including a state highway (Rte. 3), active and inactive railbeds, and a marina.

Marsh loss from 2001 to 2021 in this unit was approximately 181,636 sq ft (4.2 acres) representing 1.77% of the total salt marsh. As seen in Figure 15 loss was predominantly seen at both the marsh edge where calving, erosion, and submersion has occurred and also at large portions of the upland edge where *Phragmites* has intruded into the saltmarsh. Marsh edges are important biologically and edge loss is often cited as anecdotal evidence of marsh deterioration. However, edge loss is also a natural salt marsh process that can support sediment deposition and increase of the surface elevation. A cost benefit of this needs to be considered to any restoration of edges which may interfere with these processes.

Figure 15. Map of Marsh Loss in Jones River/Kingston Bay

Marsh lifespan projections for the conceptual marsh units (CMU) are overall favorable in this study area (Figure 16). The majority of CMUs are classified as "Protect – High lifespan, more vegetation" meaning that restoration in these areas is not as urgent but efforts should be made to protect these parcels from further stressors and evaluate them for restoration to improve conditions prior to major sea level rise impacts. The categories are intended to represent a spectrum of conditions that would lead to increasing intensity of restoration action with worsening conditions. This analysis and categorization was a first step towards a more in-depth and nuanced framework to guide restoration that is currently being developed by partners at Mass Audubon. This is also consistent with percent resilient estimates which identified this study area as 85% resilient, the second highest of the South Shore sites (section 3.1.2). Most of these parcels are currently in private, residential ownership, with a smaller number owned by the town(s), and a few parcels owned by Wildlands Trust. Of the CMUs that are classified as "Restore/Protect" at least two are owned by the Town of Kingston and have relatively high potential for conducting restoration efforts. Those two parcels, Kingston Harbormaster and Callista, are discussed in greater detail below.

Marsh migration potential is moderate in the study area (Figure 16). As discussed in section 3.1.3 migration potential by percent of existing area was 3% in 2050, 11% in 2070, and 26% in 2100. Gain here is projected to be almost evenly split between upland and OVW. Limitations on marsh migration in this area are largely driven by topography, although surrounding infrastructure is also a limitation.

Figure 16. Map of Potential Marsh Migration and Lifespan in Jones River/Kingston Bay

The Jones River Estuary Assessment of Restoration Opportunities Kingston, Massachusetts (Beals and Thomas 2023) included a number of salt marsh restoration recommendations of this area. This included:

- Creating a Jones River Protection Zone.
- Salt Marsh ditch remediation
- Establishing a program to monitor the biological and physical characteristics of the Jones River Estuary and in particular its salt marshes.

Within the Jones River/Kingston Bay there were two targeted study sites.

3.6.1.1 Calista Property, Kingston

This ~5.5-acre parcel is located at the first bend on the Jones River where Smelt Brook enters from the Southeast. Portions of the property were purchased by the Town of Kingston in 2010 as part of a larger open space parcel. The remainder of the parcel is part of the Kingston Conservation District. The site is bordered to the South by Massachusetts Bay Transportation Authority (MBTA) railroad tracks. The site does not have any current human uses and is somewhat inaccessible.

Vegetation transects conducted on the site in both 2014 and 2024 show the site is generally in good health with high percent cover of native saltmarsh species, >60% dominated by *Spartina Patens*, >20% *Spartina alterniflor*a, and the remainder generally made up of *Distichlis spicata* and *Iva frutescens*. In 2014 there was evidence of a forming salt panne, but the 2024 data showed the panne had decreased in size with new *Spartina* growth in this area. While the marsh surface appears overall healthy, and perhaps even improving in the past ten years, there is observable loss at the marsh edge. Based on GPS points, and visual observations, there was a calving of ~2m of marsh edge (Figure 17), while the specified accuracy of the handheld GPS unit (Garmin eTrex 22x) is 3m, the unit proved reliable for returning to discreet features on the marsh surface (ditches, edges) ten years after the 2014 surveys. The loss can also be seen on both banks along most of the Jones River. This is generally consistent with the 1.8% marsh loss calculated across this entire study area. Marsh edges are important biologically and edge loss is often cited as anecdotal evidence of marsh deterioration. However, edge loss is also a natural salt marsh process that can support sediment deposition and increase of the surface elevation. A cost benefit of this needs to be considered to any restoration of edges which may interfere with these processes.

Given the town ownership, high percent resilience, high lifespan projections, and sediment accretion rates of ~0.5cm/year this site is in relatively good condition but does appear to be losing marsh edge at a rate of about 1.8% per ten years. These same factors may also contribute to high potential for pilot-scale restoration efforts.

Figure 17. Marsh Edge Loss at Callista Property, Kingston

3.6.1.2 Kingston Harbormaster

This very small marsh (< 0.5 acres) is located at the mouth of the Jones River at Kingston's Town Landing and boat ramp. The marsh is truncated on the North side by the town pier and on the West by the Harbormaster's office. The site is heavily altered by construction of the pier and harbormaster building. Natural processes (especially flow) at the site may also be impacted by the location of the solid pier adjacent to the marsh and the town slips in front. Significant flow from the confluence of the river and the bay impact the marsh site that is adjacent to the town slips, floats and pier. The marsh is generally sheltered from boat wakes, but may also be impacted by small boat traffic on the inside portions of the floating dock. Google Earth orthographic images often show small boats directly on or against the salt marsh (e.g. 2016, 2021). In 2014 the town installed BMPs at the end of River St to intercept stormwater flow. These BMPs seem to be functional and effective. However, during this assessment, stormwater runoff to the marsh from the harbormaster's parking area and pier area was observed.

Vegetation transects revealed the marsh to be in poor health, especially as compared to the 2014 surveys. In 2024 the marsh was highly unstable across most of the surface. Pannes, pools, and unvegetated areas made up as much as 50% of the quadrats. Microbial mats covered much of the unvegetated areas associated with anoxic sediments and strong a Sulphur smell. *Phragmites* is encroaching the marsh at the upland edge.

Despite this poor condition, this site may present an opportunity for restoration. The site is town owned, highly visible, easily accessible, and small. Additionally, many of the stressors are readily apparent, including the stormwater impacts. A pilot-scale restoration of the site could begin with altering the stormwater flow and repairing lost marsh through sediment placement and replanting. Because the scale is so small and the site is so visible, it may be an opportunity to engage the community where they can observe the benefits of salt marsh restoration.

3.6.2 Duxbury Bay/Cut River/Back River

This marsh unit includes the extensive salt marshes of northern Duxbury Bay (North of the Powder Point Bridge). The unit covers approximately 1140 acres of salt marsh bounded by Duxbury barrier beach to the east, with a series of named creeks draining the mainland from the north and west. These include the Back River, the Cut River which extends into Marshfield to the north, and other smaller creeks. This unit has relatively limited surrounding infrastructure besides residential roads and a few small tidal restrictions. The watershed is largely residential, although it does include golf courses and a large school complex.

Marsh loss from 2001 to 2021 in this unit was minimal at approximately 220,369 sq ft (5 acres) representing only 0.46% of the total salt marsh. As seen in Figure 18, loss is primarily attributed to edge loss in the many channels as well as some pool formation on the marsh surface.

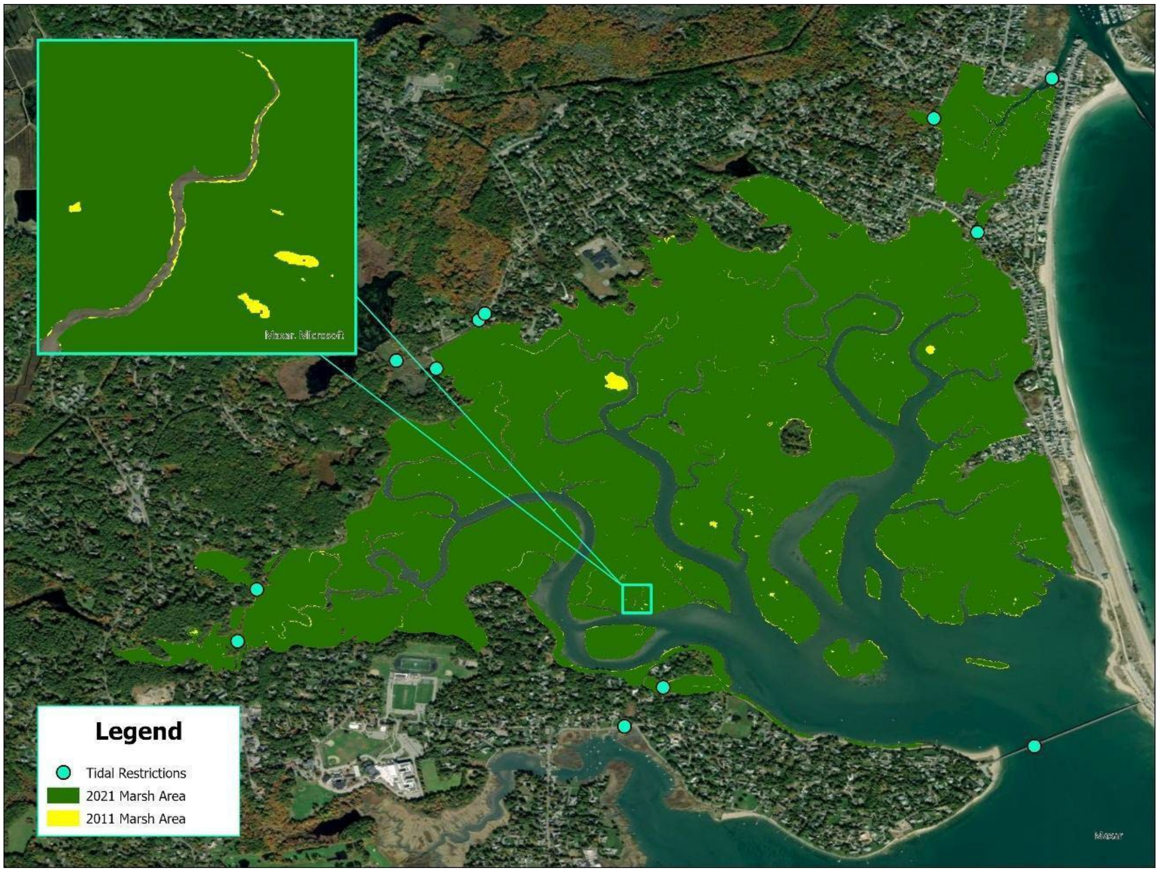

Figure 18. Map of Marsh Loss in Duxbury Bay/Cut River/Back River

Marsh lifespan projections for the conceptual marsh units (CMU) are overall favorable in this study area (Figure 19). Almost all of the CMUs are classified as “Protect – High lifespan, more vegetation” meaning that the there are no current restoration needs, but effort should be made to protect these parcels from further stressors. This is also consistent with percent resilient estimates which identified this study area as 90% resilient, the highest of the South Shore sites (section 3.1.2). Most of these parcels are currently owned by the Town of Duxbury, the Town of Marshfield, or Duxbury Beach Reservation Inc. Smaller parcels, mostly around the western edges are in private residential ownership. Of the CMUs that are classified as “Restore/Protect” the largest, in the northern part of the study site on the Cut River, is owned by the Town of Marshfield.

Marsh migration potential in the Duxbury study area is the lowest of all the South Shore sites (Figure 19). As discussed in section 3.1.3 migration potential by percent of existing area was only 0.5% in 2050, 2% in 2070, and 5% in 2100. The minimal gains available here are almost all towards the upland. Limitations on marsh migration in this area are largely driven by topography.

Vegetation surveys and sediment transport analysis were consistent with the above GIS-based results. The vegetation surveys found a fairly uniform healthy marsh dominated by *Spartina patens* and *Distichlis spicata* with short form *Spartina alterniflora* found near the marsh and creek edges. The presence of some *Salicornia sp.* mixed in with other vegetation may suggest a trend towards a lack of full marsh draining and should be monitored going forward to anticipate the formation of pannes or pools.

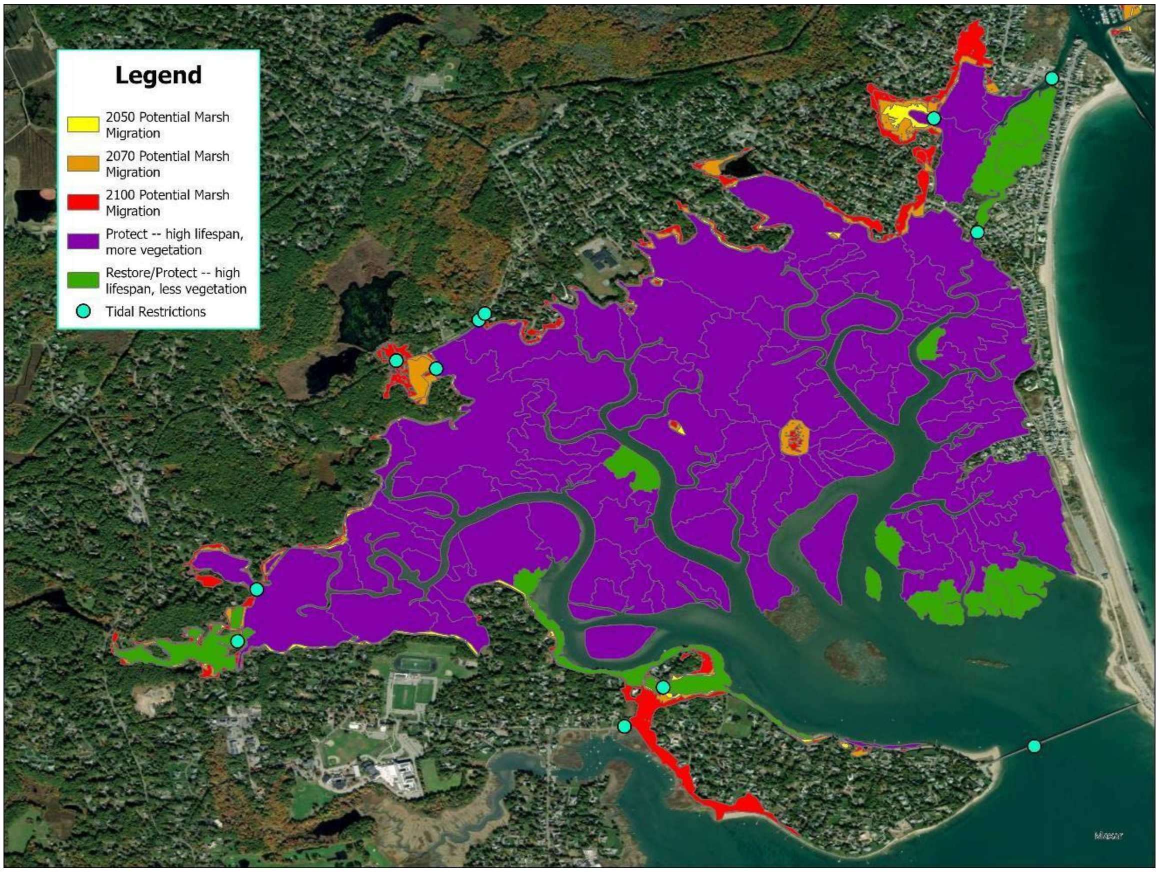

Figure 19. Map of Potential Marsh Migration and Lifespan in Duxbury Bay/Cut River/Back River

Overall, the Duxbury marsh complex has little current need or opportunity for restoration. The greatest risk to long-term marsh health is catastrophic failure of the Duxbury barrier beach that protects this large salt marsh from the ocean. The Duxbury Beach Reservation Inc and the Town of Duxbury are highly invested in maintenance of the beach and conduct year-round efforts to ensure its integrity.

3.6.3 Green Harbor, Marshfield

This small (82 acres) marsh unit lies primarily on the North side of Green Harbor and the Green Harbor River downstream of the Route 139 tide gate. Green Harbor is a highly altered system with at least three prominent tide gates, a sewer treatment plant, two marinas, a town pier, and a large mooring field. The harbor and entrance channel are also routinely dredged for navigation. The entrance channel was man-made in the early 1800s and expanded by the Army Corps in 1969.

The entrance channel extends 4,000 feet from deep water to a six-foot deep turning basin located below the Route 139 Bridge and tide gate.

Marsh loss from 2001 to 2021 in this unit was approximately 54,205 sq ft (1.2 acres). While this was the least actual areal loss of all the sites, this was only due to it being a small overall site. The percent loss was 1.78% of the total salt marsh. As seen in Figure 20 loss was due to a number of factors including marsh edge loss along creeks, pool formation, and *Phragmites* intrusion at upland edges.

Figure 20. Map of Potential Marsh Migration and Lifespan in Duxbury Bay/Cut River/Back River

Marsh lifespan projections for the conceptual marsh units (CMU) are generally favorable in this study area (Figure 21). Although, compared to most of the sites there are less CMUs that classified as “Protect – High lifespan, more vegetation” where there are no current restoration needs. Even some of the CMUs with this classification have potential mid-term risk if they are encroached by *Phragmites* or are impacted by failures in surrounding infrastructure. Protecting these parcels from these stressors will be critical to their long-term health. The majority of the Green Harbor CMUs are classified as “Restore/Protect” which is also consistent with percent resilient estimates which identified this study area as 78% resilient, the fourth highest of the South Shore sites (section 3.1.2). These parcels are mostly owned by the Town of Marshfield.

Marsh migration potential is moderate in the study area (Figure 21). As discussed in section 3.1.3 migration potential by percent of existing area is 3% in 2050, 11% in 2070, and 19% in 2100. While these percentages are nearly the same as the Jones River/Kingston Bay study area, the source of potential gain is quite different. For Green Harbor the potential marsh migration dominated by migration to the upland versus OVW. However, these model estimates may overstate realistic marsh migration potential as significant portions are currently hard infrastructure (parking lots, roads) that would take substantial human intervention to convert to salt marsh.

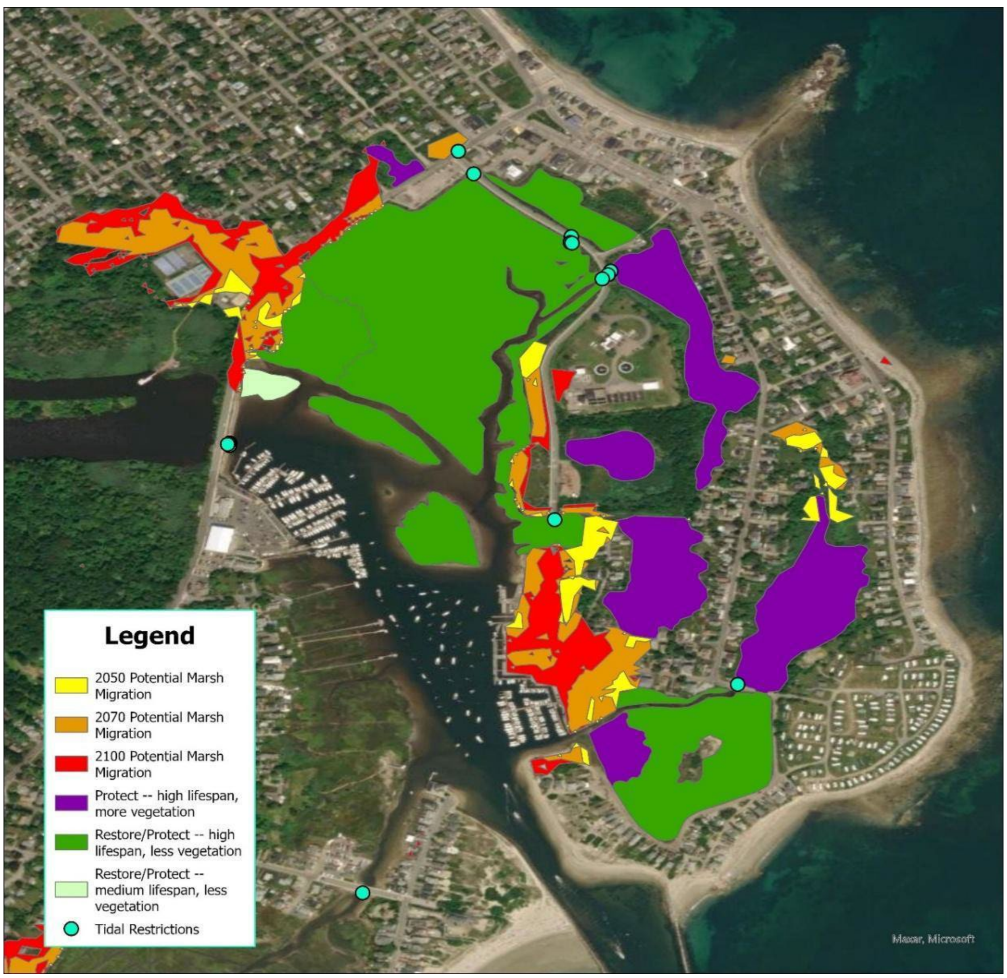

Figure 21. Map of Potential Marsh Migration and Lifespan in Green Harbor

The vegetation surveys in Green Harbor describe a marsh in decline. Marsh edges are virtually devoid of vegetation, covered in algal growth, and are eroding and calving (Figure 22). Short form *Spartina alterniflora* and *Salicornia sp.* are found across much of the marsh suggesting frequent tidal inundation and poor drainage. Fiddler crab burrows are prolific in the marsh and may be contributing to erosion.

Figure 22. Photo of Green Harbor Marsh Edge

For a small marsh complex Green Harbor is subject to extensive infrastructure stressors. The marsh is largely surrounded by impervious surfaces (roads, large parking lots, docks, etc). There are two high-traffic marinas as well as a large mooring field. Maintenance dredging of the harbor and channel occurs nearly every year. Commercial and municipal properties include a sewer treatment plant, boat yards, and restaurants. There are more than six significant tidal restrictions. The largest tidal restriction is MA TideGate ID #Marshfield-04 which separates the Green Harbor River from the Green Harbor. Note that the current study did not evaluate this tide gate or the extensive marsh habitats upstream from this tide gate and is recommended for future work. Other tide gates in the study area include Marshfield-01 and Marshfield-02. These similarly designed tide gates are located under Joseph Driebeek Way and regulate tidal exchange to two separate salt marsh parcels on the east side of the road. These tide gates are currently under review as part of MassBays National Estuary Partnership study.

Similar to the Kingson Harbormaster site, Green Harbor may present opportunities for restoration. The majority of the marsh is town owned, very highly visible, and easily accessible. A pilot-scale restoration of the site could begin with repairing lost marsh through sediment placement and replanting. Because the scale is so small and the site is so visible, it may be an opportunity to engage the community where they can observe the benefits of salt marsh restoration.

3.6.4 South River

This extensive marsh unit consists of 790 acres of salt marsh extending from Ferry Hill in Scituate near the mouth of the South River, upstream to the head of tide near Willow Street in Marshfield. Despite the large size of this unit, the surrounding environment is dominated by residential neighborhoods and open space. Commercial infrastructure and impervious surfaces are dominant only in the very upper reaches of this unit.

Marsh loss from 2001 to 2021 in this unit was approximately 618,615sq ft (14.2 acres). This was both the largest total areal loss and the highest percentage loss (1.86%) of all the sites. As seen in Figure 23 loss was primarily due to marsh edge loss along the main channel and creeks.

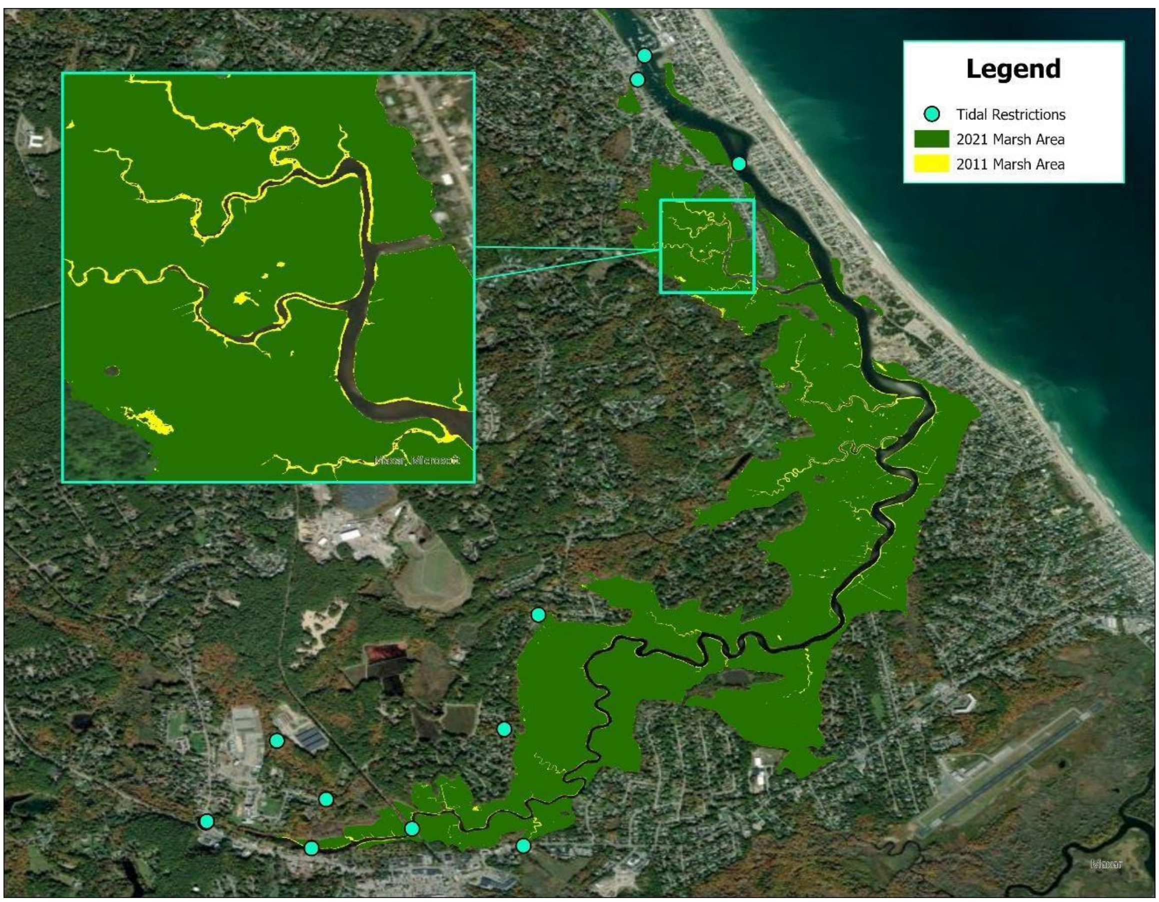

Figure 23. Map of Marsh Loss in the South River

Marsh lifespan projections for the conceptual marsh units (CMU) are highly favorable in this study area (Figure 24). Almost all of the CMUs are classified as "Protect – High lifespan, more vegetation" meaning that there are no current restoration needs, but effort should be made to protect these parcels from further stressors. This is generally consistent with percent resilient estimates which identified this study area as 77% resilient (section 3.1.2). Ownership along the South River corridor is a mix of private residential and the towns of Scituate and Marshfield. There are very few CMUs in the South River study area that were classified as "Restore/Protect".

Marsh migration potential in the South River study area is the greatest area of all the South Shore sites due to it being a very large study area, although it is moderate in terms of percentage (Figure 24). As discussed in section 3.1.3 migration potential by percent of existing area was 5.5% in 2050, 13% in 2070, and 28% in 2100. The gains available here are almost all towards the upland versus OVW.

Vegetation surveys were not entirely consistent with the GIS results, although the field site comprises only a very small piece of the overall marsh unit. The field site was characterized as "Protect – High lifespan". However, the vegetation surveys found large salt pannes and shallow pools in much of the marsh (Figure 25). Additionally, there is substantial *Phragmites* intrusion into the high marsh and small pockets within the marsh.

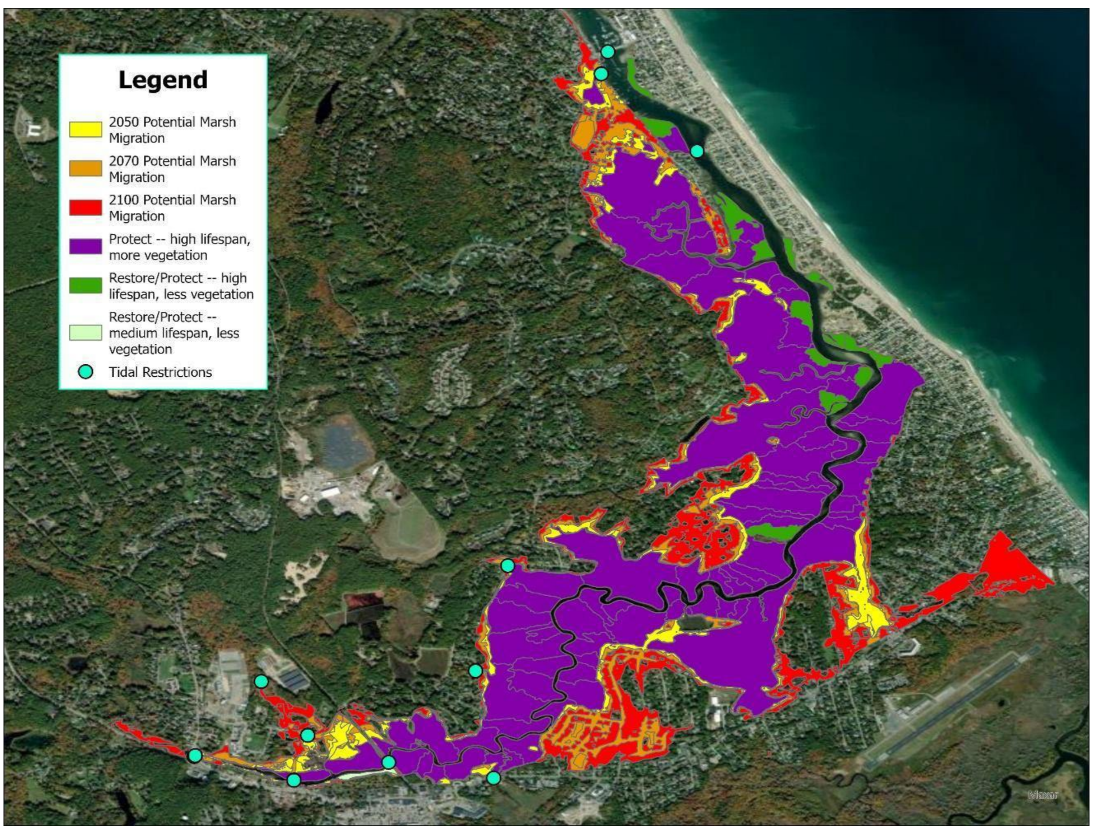

Figure 24. Map of Potential Marsh Migration and Lifespan in the South River

Figure 25. Salt Panne and Pools on South River Field Site

Restoration opportunities in the South River Corridor are limited. Based on the marsh lifespan and percent resilience metrics, most of the area does not have urgent restoration needs.

3.6.5 North River Mid-Upper Reaches

This marsh unit comprises 450 acres on both sides of the North River from Union Street bridge Marshfield (Bridge St, Norwell) to Route 3. The upper reaches of this unit are located near the head of salinity. Marsh ownership is a mix of private residential, NGO land protection (Mass Audubon), and town conservation. The transition from salt to fresh at this site is evident in the mixed vegetation. Within this marsh unit there was a single parcel studied for vegetation. This parcel is accessed through private property.

Marsh loss from 2001 to 2021 in this unit was approximately 227,712sq ft (5.2 acres) representing 1.24% of the total salt marsh. As seen in Figure 26 loss was primarily due to marsh edge loss along the main channel and creeks.

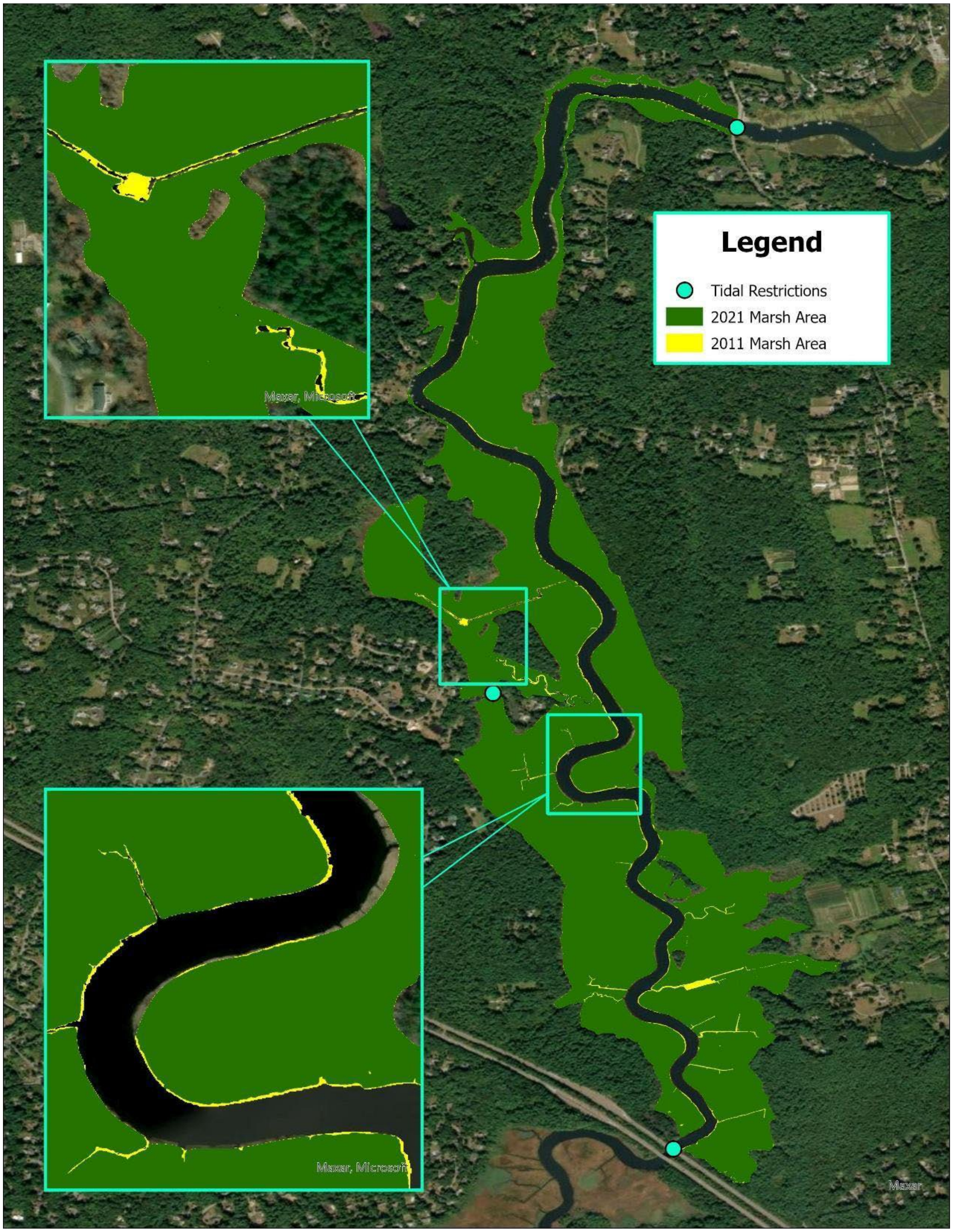

Figure 26. Map of Marsh Loss in the North River Mid-Upper Reaches

Marsh lifespan projections for the conceptual marsh units (CMU) are overall favorable in this study area (Figure 27). The majority of CMUs are classified as "Protect – High lifespan, more vegetation" meaning that there are no current restoration needs, but effort should be made to protect these parcels from further stressors. This is in contrast to the percent resilient estimates which is the lowest of all the study sites at 29% resilient (section 3.1.2). While many of the smaller parcels are currently in private residential ownership, land protection has been robust along this corridor. The majority of large parcels are owned by the towns of Marshfield and Norwell, Trustees of Reservations, and Mass Audubon. Of the CMUs that are classified as “Restore/Protect high lifespan” the majority are owned by the towns and NGOs listed above. Of the CMUs that are classified as “Restore/Protect medium lifespan” unfortunately the ownership is generally private which may limit restoration opportunities. The town owned properties with this classification are largely inaccessible.

Marsh migration potential is moderate in the study area (Figure 27). As discussed in section 3.1.3 migration potential by percent of existing area was 6% in 2050, 11% in 2070, and 20% in 2100. The gains available here are almost all towards OVW versus upland. This is driven by the study site’s location at the approximate head of salinity on the North River.

The field study site for this area was named “Cedar Point” and was located on a mix of private residential property and a Mass Audubon parcel. The access was through private property. The vegetation survey results aligned well with marsh migration projections for OVW. The Cedar Point site has a mix of low and high marsh species *Spartina, Distichlis, Iva* and freshwater wetland species *Typha Latifolia* (Figure 28). For both vegetation types the percent cover was generally high with no signs of panne or pool formation. There is substantial *Phragmites* intrusion at the upland edge, as well as a small stand of *Phragmites* at the river edge.

Overall, the North River Mid-Upper Reaches complex has little current need or opportunity for restoration. Land protection has already been accomplished throughout much of this corridor. At this point in time, the primary recommendation is long-term monitoring of these marshes including tracking the transition from freshwater to saltwater marsh species over time

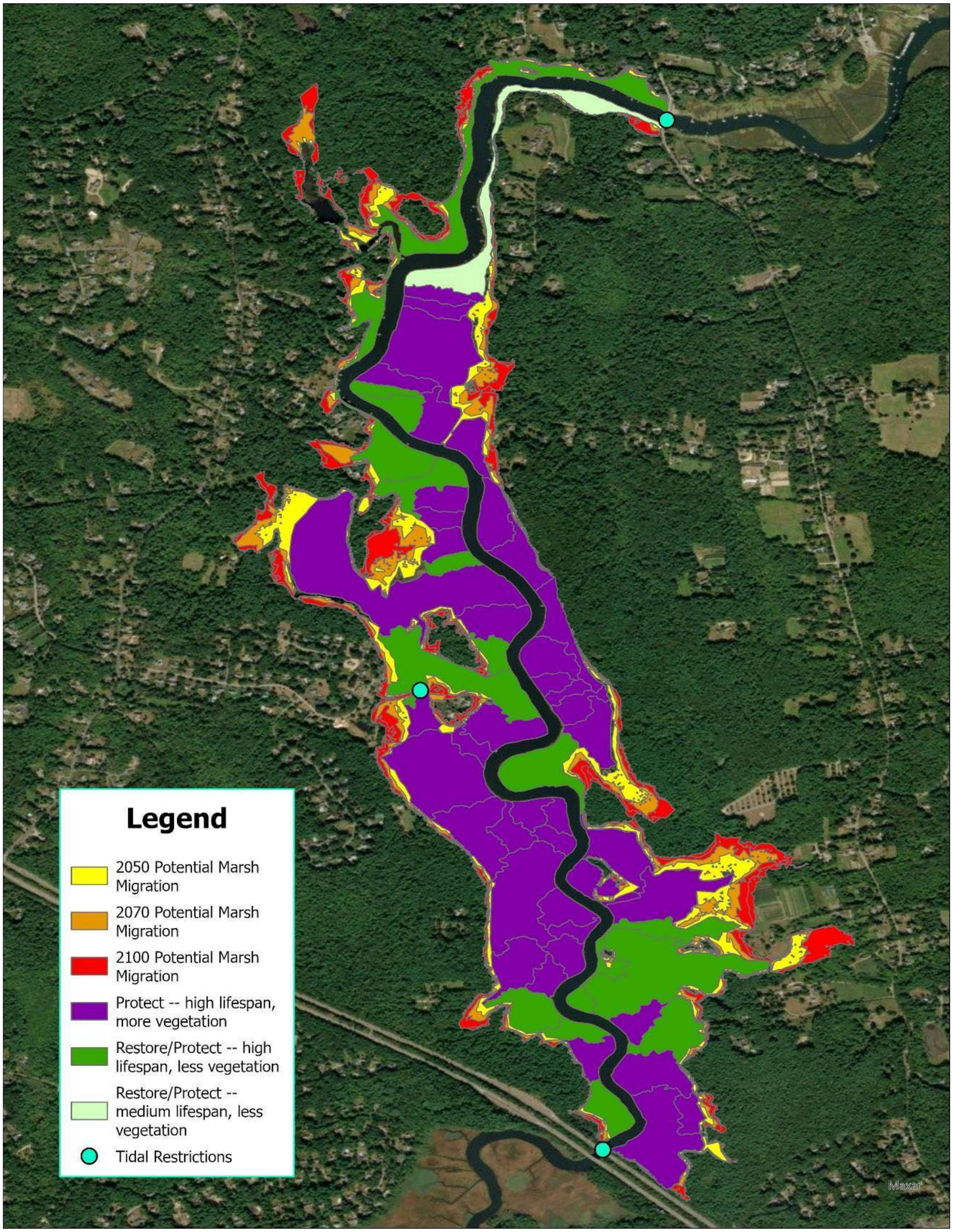

Figure 27. Map of Potential Marsh Migration and Lifespan in the North River Mid-Upper Reaches

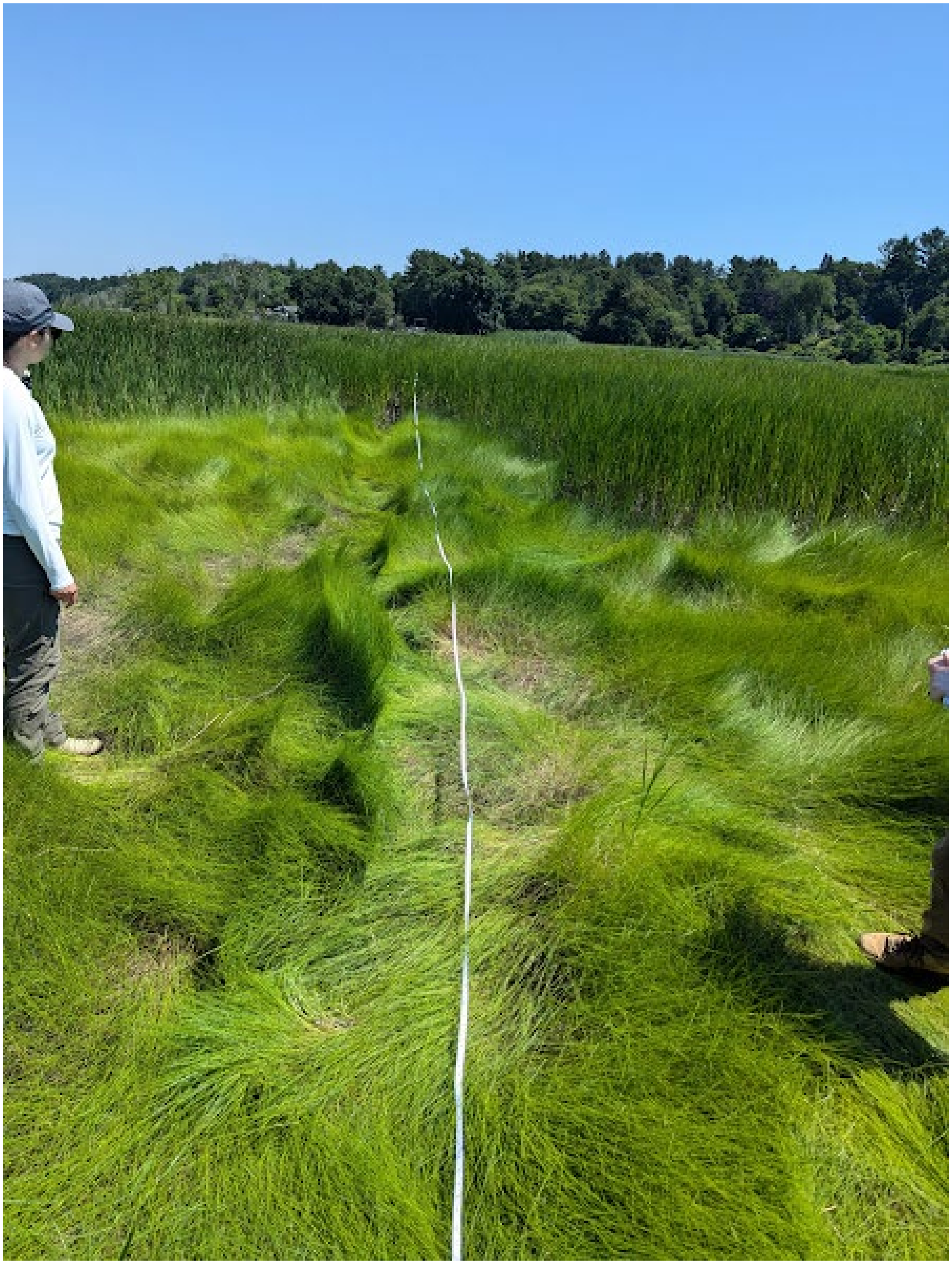

Figure 28. Upper North River Transition from Salt Marsh to Freshwater Wetland

3.6.6 North River Lower Reaches

This broad marsh unit is located on the North side of the North River from the mouth of the river at Third Cliff to just west of Route 3A on the North River, Herring Brook, and First Herring Brook. The unit covers approximately 600 acres. The majority of the land use surrounding this unit is residential or open space. However, some portions do contain significant infrastructure including a wastewater treatment plant, former landfill, golf courses, marinas, roads, and some commercial properties.

Marsh loss from 2001 to 2021 in this unit was approximately 353,631sq ft (8.1 acres) representing 1.56% of the total salt marsh. As seen in Figure 29 loss was due to a combination of marsh edge loss along the main channel and creeks, pool formation on marsh platform, and over wash from the Third Cliff barrier beach.

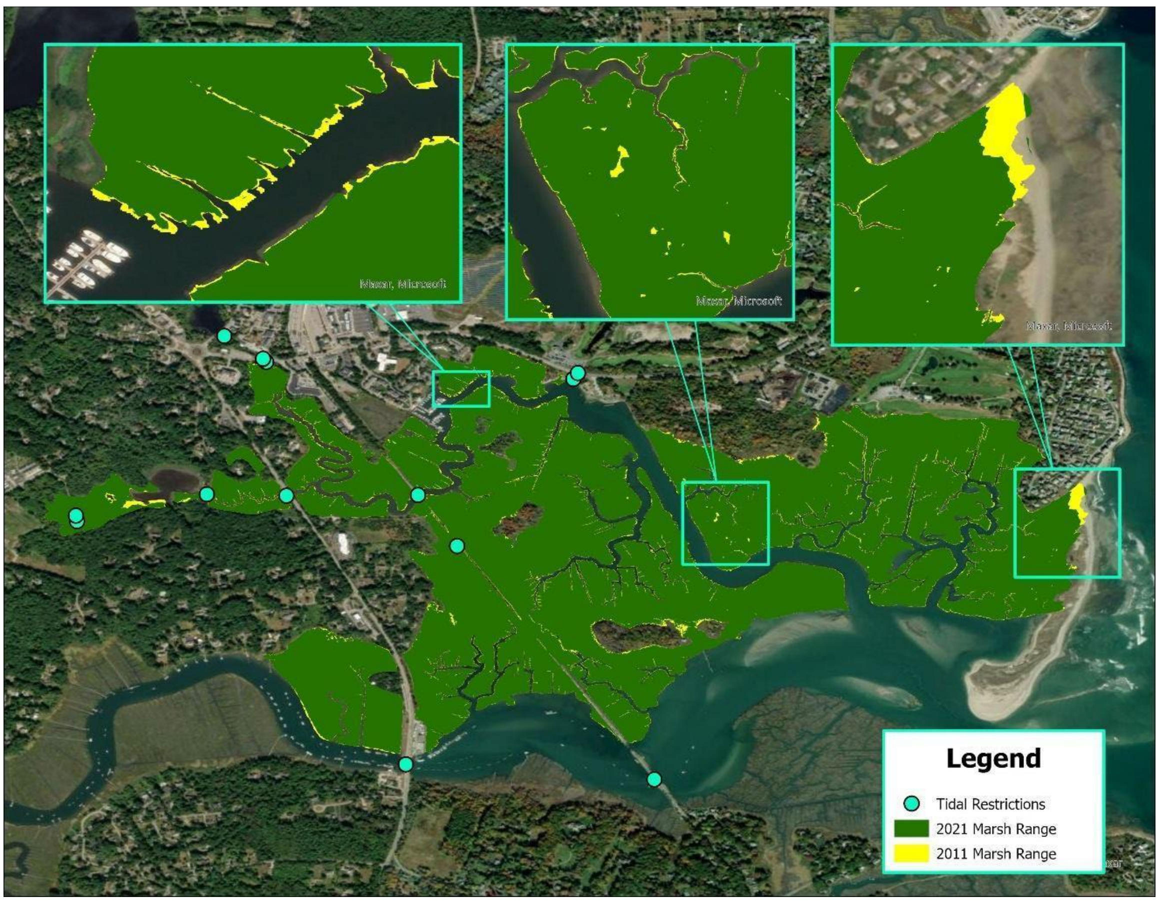

Figure 29. Map of Marsh Loss in the North River Lower Reaches

Marsh lifespan projections for the conceptual marsh units (CMU) are moderate in this study area (Figure 30). More than any other study site, the majority of CMUs are classified as "Restore/Protect high lifespan, more vegetation". This area also had the highest proportion of "Restore/Protect medium lifespan" CMUs. This is consistent with the moderate percent resilient estimate of 49% which was the second lowest of all sites (section 3.1.2). While many of the parcels are currently in private residential the majority of salt marsh area is owned by the town of Scituate.

Marsh migration potential in the lower North River study area is the second lowest of all the South Shore sites (Figure 30). As discussed in section 3.1.3 migration potential by percent of existing area was only 1.5% in 2050, 4% in 2070, and 9% in 2100. The minimal gains available here are primarily OVW versus upland. Limitations on marsh migration in this area is largely driven by surrounding infrastructure and topography.

Within this marsh unit there were two individual parcels studied during this project. They are described below and represent two distinct marsh types and restoration opportunities in this area.

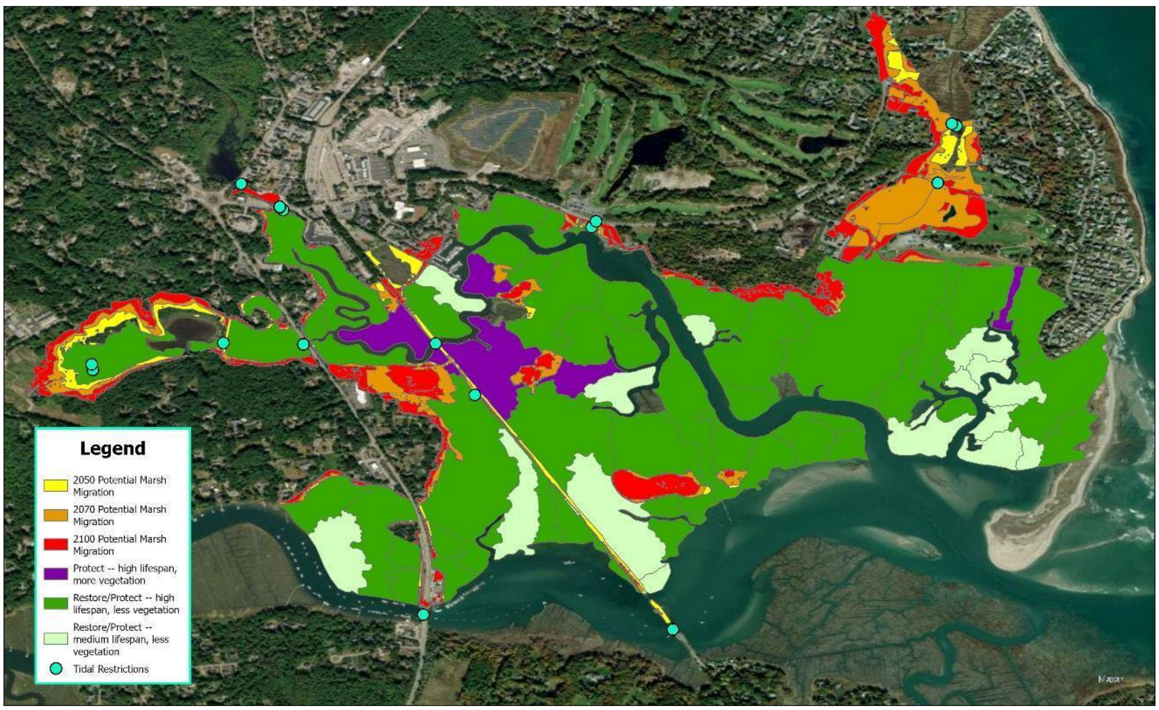

Figure 30. Map of Potential Marsh Migration and Lifespan in the North River Lower Reaches

3.6.6.1 Scituate Conservation

This town-owned parcel located midway along the North River on the northward side along the Driftway makes up approximately 8-acres of the 334-acre Driftway Conservation Park on Scituate Conservation land. The parcel is highly impacted by the surrounding infrastructure and past activities. Portions of the marsh and the surrounding dunes are covered in concrete left by the previous owner, the Boston Sand and Gravel Company, which launched sand and gravel barges from the site to support the construction of runways at Logan Airport in Boston. Directly upland from the marsh are a golf course and former landfill. The former 29-acre municipal landfill was capped in 2000 and eventually transitioned to a solar field in 2013. Adjacent to the former landfill is a 120-acre golf course on the former Boston Sand and Gravel Company property. Stormwater and groundwater from these two large parcels enter the marsh complex at the upland edge.

Vegetation surveys identified large salt pannes, pools, and additional wet areas dominated by *Salicornia sp.* (Figure 31). There is also significant marsh edge calving and erosion. Marsh edges are important biologically and edge loss is often cited as anecdotal evidence of marsh deterioration. However, edge loss is also a natural salt marsh process that can support sediment deposition and increase of the surface elevation. A cost benefit of this needs to be considered to any restoration of edges which may interfere with these processes. Microbial mats covered much of the unvegetated areas and creek beds associated with anoxic sediments and strong a Sulphur smell.

The Scituate Conservation marsh presents some clear opportunities for restoration. The site is town owned, highly visible, easily accessible, and relatively small. Additionally, many of the stressors are readily apparent. A pilot-scale restoration of the site could include removal of concrete debris on the marsh, runneling to drain existing pools, sediment placement and planting to restore lost marsh, and evaluation of nutrient loading from discharges. A first recommendation is that targeted field surveys be conducted to develop high resolution mapping of elevation and areal extent of the pannes, pools, and ditches on this marsh. Because the scale is small and the site is so visible, it may be an opportunity to engage the community where they can observe the benefits of salt marsh restoration.

Figure 31. Pools and Pannes on the Scituate Conservation Marsh

3.6.6.2 Third Cliff, Scituate

This marsh is on the northward side of the North River just west of Third Cliff in Scituate. It is extensive and has many wide drainage ditches, and is bordered by the North River, dunes that separate it from the Atlantic, and an area that is a mix of woodlands and residential use. Vegetation surveys revealed mixed conditions. Portions of the marsh have healthy dense vegetation, while other areas are pocked with small pools. This includes some that have breached and created new drainage creeks along the marsh.

This site could benefit from some restoration activities to runnel and/or fill shallow pools. However, in contrast to the Scituate Conservation parcel, this site is largely inaccessible and does not offer the same benefits of public visibility.

3.6.7 Peggotty/Kent Street, Scituate

This small, 114-acre marsh unit is located between the Peggotty barrier beach to the east, Kent Street to west, and extends into Scituate Harbor to the north. Ownership of the marsh is primarily by the Town of Scituate, with some small private residential parcels. Within this marsh unit there was a single parcel studied for vegetation. This parcel is accessed from the inside of Peggotty Beach.

Marsh loss from 2001 to 2021 in this unit was approximately 79,718sq ft (1.8 acres). While the total area lost was relatively small it represented 1.80% of the total salt marsh, which was the second highest in the study. As seen in Figure 32 loss was largely due to overwash from Peggotty beach, large pool formation, and marsh edge loss to a lesser extent.

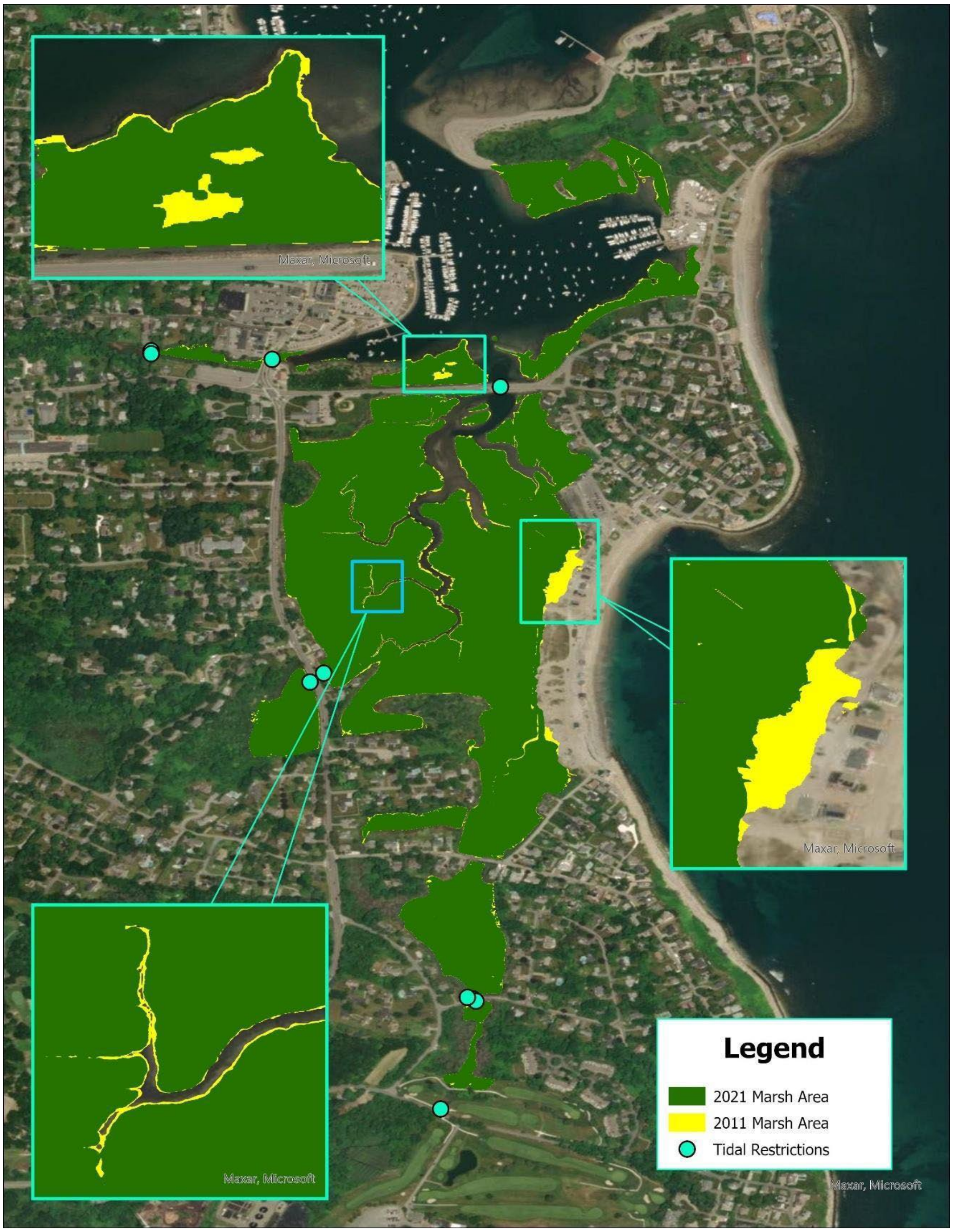

Figure 32. Map of Marsh Loss in the Peggotty/Kent Street Marshes

Marsh lifespan projections for the conceptual marsh units (CMU) are generally favorable in this study area (Figure 33). Although it is the only site of this study that included a classification of “Accept - Low Lifespan” meaning that restoration is unlikely to be feasible and the CMU should be expected to complete degrade. This small (<0.3-acre) marsh ‘island’ is already highly degraded and separated from the rest of the marsh. The rest of the marsh area is mostly split between “Protect – High lifespan and “Restore/Protect high lifespan, more vegetation”. Percent resilience is fairly high at 82% (section 3.1.2). While many of the parcels are currently in private residential the majority of salt marsh area is owned by the town of Scituate.

Marsh migration potential in the lower in this study area is the second highest of all the South Shore sites (Figure 33). As discussed in section 3.1.3 migration potential by percent of existing area was only 5% in 2050,2 4% in 2070, and 43% in 2100. The migration gains available here are primarily in the upland versus OVW.

Restoration opportunities at this site may be unique amongst the study area and may be more operational than physical. As seen in Figure 32 there is frequent overwash from the beach onto the marsh. While some marsh loss has been attributed to the overwash, the overall process may present an opportunity to improve marsh conditions. The marsh behind the barrier beach includes a series of lateral ditches that run parallel to the beach (Figure 34). When overwash occurs, these ditches fill with sand. Routine dredging of these lateral ditches is conducted to remove the sand. However, overwashed sand may be a benefit to long-term salt marsh accretion. Future studies could evaluate operational approaches to utilize the sand for marsh health while balancing the needs for marsh drainage and flood reduction.

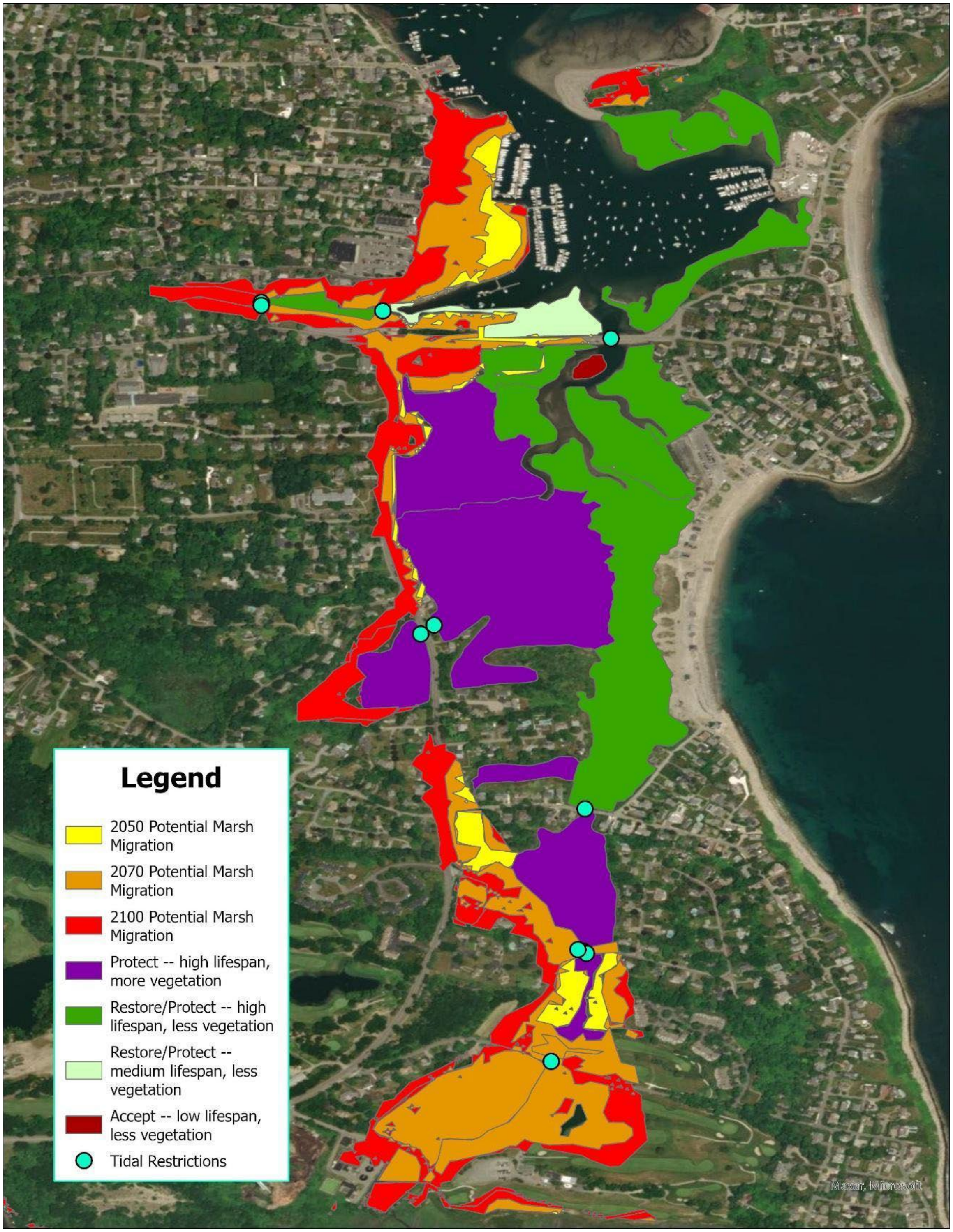

Figure 33. Map of Potential Marsh Migration and Lifespan in the Peggotty/Kent Street Marshes

Figure 34. Lateral Ditches on Peggotty/Kent Street Marshes

3.6.8 Gulf River/Musquashcut Brook, Scituate

This 285-acre marsh unit is located on both sides of the Gulf River and Musquashcut Brook in Scituate. On the Gulf River the unit extends from approximately Supper Island upstream to just above Hollett Street. All of Musquashcut Brook is included from the Gulf River to the entrance of Musquashcut Pond. This marsh unit is primarily surrounded by residential neighborhoods, although a golf course is present on the North Side of Musquashcut Brook. There is a natural pinch point for this marsh where it connects to Cohasset Harbor. Although this is a (relatively) natural feature it is a hydraulic restriction that influences the tidal exchange in the Gulf River. The culverts on Gannett Road, Hatherly Road, and Hollett Street are all undersized which may impact hydraulics and associated mechanisms such as marsh inundation and sediment/organic material deposition. At some point these culverts will come to the end of their useful lifespan and when replaced considering coastal and ecological resiliency should be considered as part of the redesign/replacement criteria.

Marsh loss from 2001 to 2021 in this unit was approximately 111,892sq ft (2.6 acres) representing 0.95% of the total salt marsh, which was the second lowest in the study. As seen in Figure 35 loss was largely marsh edge and some pool formation.

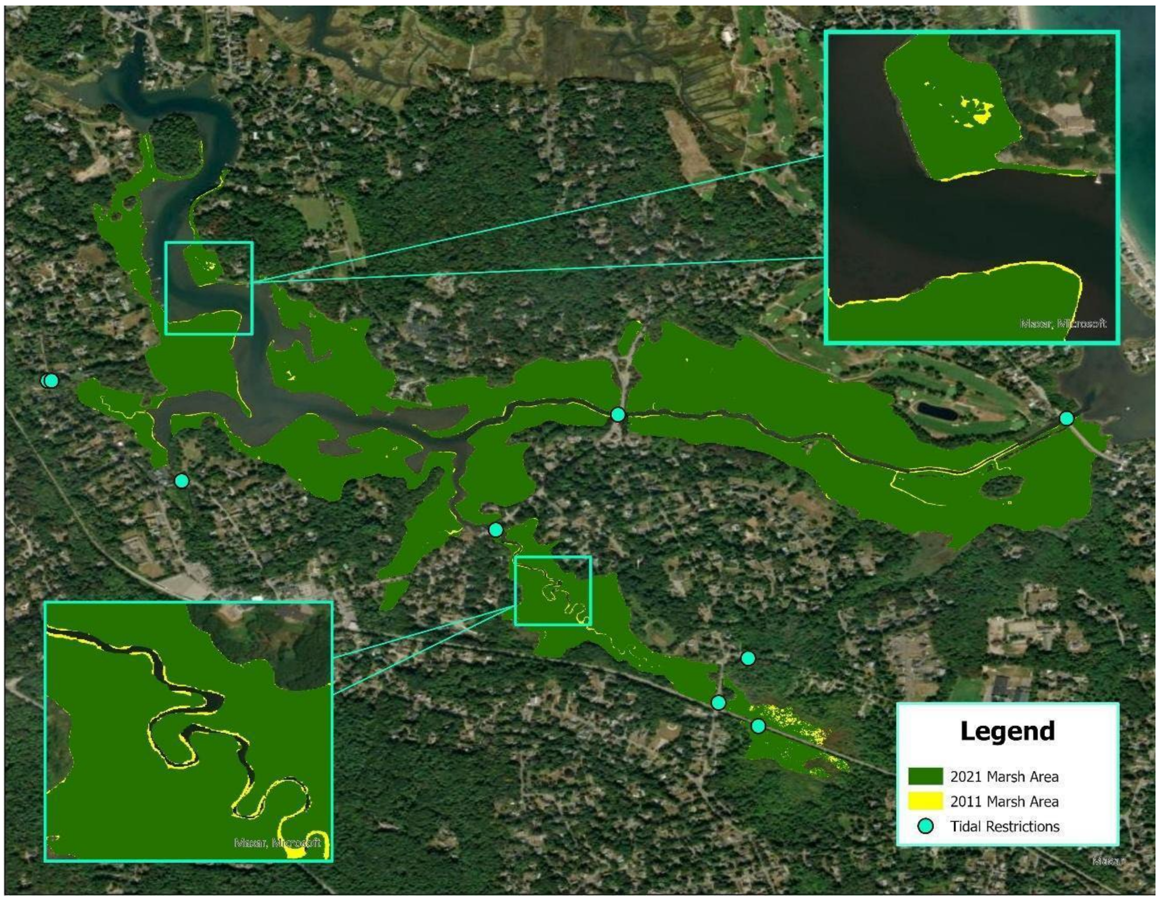

Figure 35. Map of Marsh Loss in Gulf River/Musquashcut Brook

Marsh lifespan projections for the conceptual marsh units (CMU) are overall favorable in this study area (Figure 36). The majority of CMUs are classified as “Protect – High lifespan, more vegetation” meaning that there are no current restoration needs, but effort should be made to protect these parcels from further stressors. This is consistent with the percent resilient estimates of 55% resilient (section 3.1.2). While many of the smaller parcels are currently in private residential ownership the majority of large parcels are owned by the towns of Scituate and Cohasset. However, access is challenging and is largely through private property. Of the CMUs that are classified as “Restore/Protect high lifespan” property ownership is a mix of public and private which may limit restoration opportunities.

Marsh migration potential is the highest of all sites in the study area (Figure 36). As discussed in section 3.1.3 migration potential by percent of existing area was 12% in 2050, 29% in 2070, and 47% in 2100. The gains available here are predominantly in the upland although substantial gains to OVW are also found.

Vegetation surveys found a mix of conditions. The marsh is somewhat unique in that the marsh edge appears to have been raised with sediment from ditches that were dug. This results in high marsh plants (*Iva frutescens*) along most of the marsh/river edge. Additional sediment from the ditches was used to create medium sized raised areas on the marsh surface that are now populated with high marsh plants, poison ivy, and cedar trees. Marsh health varied across the site. Some transects were dominated by robust saltmarsh vegetation and firm surfaces, others were extremely soft and wet with expansive pannes and pools. *Phragmites* stands are invading nearly all of the upland edge of this marsh complex.

While some of the degraded (pannes) portions of this marsh could benefit from restoration activities, access may present a significant obstacle. Long-term monitoring of this site is recommended to track degradation or improvement of marsh health.

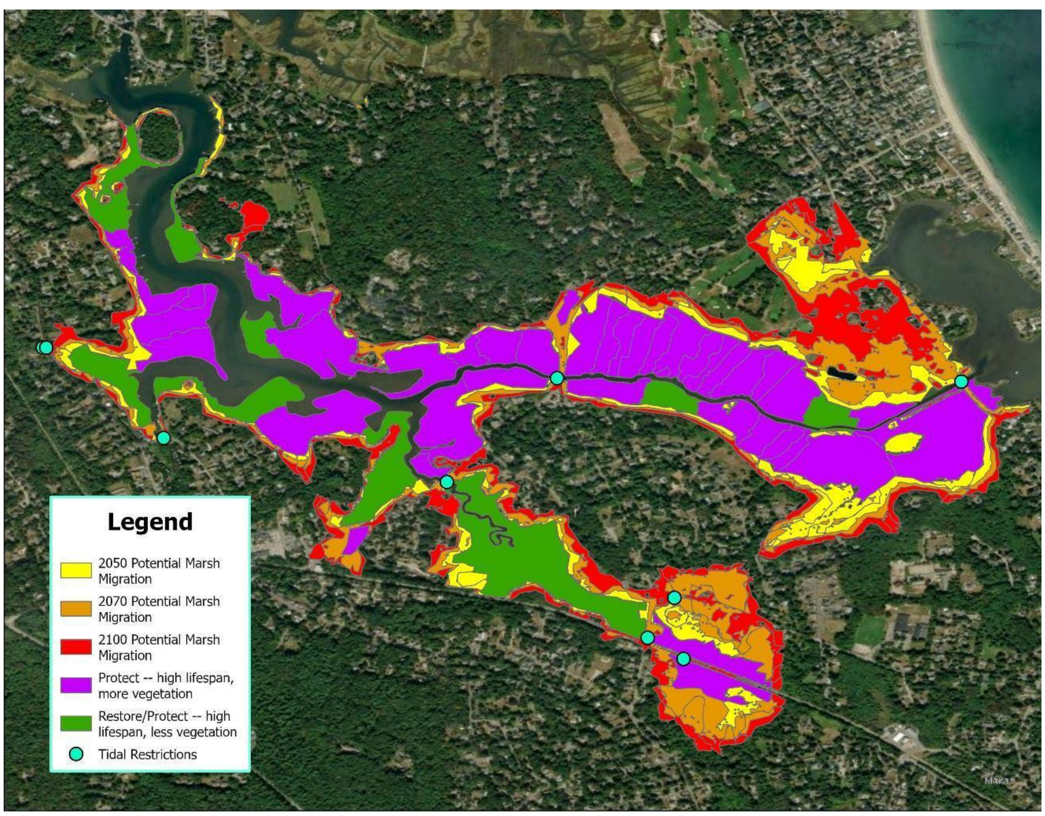

Figure 36. Map of Potential Marsh Migration and Lifespan in Gulf River/Musquashcut Brook

4 Summary Recommendations

This section provides a summary of the Section 3 results and recommendations. Restoration opportunities are grouped into short-, medium-, and long-term needs. Short-term opportunities generally mean that marsh lifespan categorization was determined as "Protect/Restore"; stressors and solutions are fairly obvious; access and parcel ownership is straightforward; and restoration approaches could advance in one to five years. Medium-term sites generally have less urgent needs or may have more challenging approaches in terms of access, ownership, size, or other factors. Restoration approaches at these sites are likely to take longer to develop and may be on a three to ten year timeline or more. Long-term sites generally have no immediate restoration needs. Actions at these sites may include land-protection, long-term monitoring, or larger scale protections.

For any site there may be an extensive permitting process associated with activities in jurisdictional resource areas. In all cases this will include the Wetlands Protection Act and Regulations at 310 CMR 10.00; Massachusetts Clean Water Act and Regulations at 314 CMR 9.00; and Section 401 of the federal Clean Water Act and Regulations at 33 U.S.C. 1341. Other federal, state, and local permits may also be required. MA CZM provides a comprehensive review of potential permit requirements, regulatory summaries, and review processes associated with coastal projects in their Environmental Permitting in Coastal Massachusetts permit guide, which can be found at the following link: https://www.mass.gov/info-details/environmental-permitting-in-coastal-massachusetts. Note that as of this writing there are several efforts underway to streamline environmental permitting pathways for salt marsh restoration.

4.1 Short-term priority sites and actions

4.1.1 Scituate Conservation

This marsh presents some of the lowest hanging fruit for restoration. The site is town owned, highly visible, easily accessible, and relatively small (~8-acres).

Actions:

- Engage the Town of Scituate to share study results and generate interest for pilot-scale restoration.
- Conduct targeted field surveys to develop high resolution vertical and horizontal mapping of key features including pools, ditches, and surrounding infrastructure.
- Conduct data mining effort targeting existing water quality conditions in the surface and groundwater discharges to the marsh. For example, there is likely to be ground water monitoring well data associated with the former landfill. Potential need to follow up with targeted water quality testing.
- Develop a restoration plan for the site that examines opportunities for:

  - Removal of debris from the site. This includes placement of new soils, regrading, and planting of native plants.
  - Detailed designs for runnels to drain pools, if appropriate based on the targeted field studies described above.
  - Potential sediment placement and replanting in existing pannes and pools, if appropriate based on the targeted field studies described above.

4.1.2 Kingston Harbormaster

While this site is extremely small (<0.5-acre) it presents an opportunity for low-cost, straightforward improvements that can be used as a highly visible demonstration of restoration techniques.

Actions:

- Engage the Town of Kingston to share study results and generate interest for pilot-scale restoration.
- Review previous BMP designs and as-builts.
- Conduct targeted field surveys to develop high resolution vertical and horizontal mapping of key features including pools, ditches, and surrounding infrastructure including stormwater flow patterns.
- Develop a restoration plan for the site that includes
  - Redirection of stormwater runoff, if appropriate based on field surveys,
  - Detailed designs for runnels to drain pools, if appropriate based on the targeted field studies described above.
  - Potential sediment placement and replanting in existing pannes and pools, if appropriate based on the targeted field studies described above.

4.1.3 Green Harbor Marshfield

Similar to the Kingston Harbormaster site, Green Harbor may present opportunities for restoration. The majority of the marsh is town owned, very highly visible, and easily accessible.

Actions:

- Engage the Town of Marshfield to share study results and generate interest for pilot-scale restoration.
- Conduct targeted field surveys to develop high resolution vertical and horizontal mapping of key features including pools, ditches, and surrounding infrastructure.
- Review operational plans for the tide gates in this area. Operational adjustments could provide a benefit in terms of tidal exchange and marsh draining. MassBays NEP is currently conducting a regional tide gate analysis that may provide relevant data.
- Develop a restoration plan for the site that includes

- Detailed designs for runnels to drain pools, if appropriate based on the targeted field studies described above.
- Potential sediment placement and replanting in existing pannes and pools, if appropriate based on the targeted field studies described above.

4.1.4 Peggotty/Kent Street Marshes

This site may benefit from operational changes to dredging by the Plymouth County Mosquito Control Project.

Actions:

- Engage the Town of Scituate and Plymouth County Mosquito Control Project to share study results and determine if changes can be made to maintenance dredging of the lateral ditches.
- Continue to monitor ditch filling and marsh change as a result of beach overwash during storm events.

4.2 Medium-term priority sites and actions

The sites listed below have less urgent needs and may be more complex in terms of access to and size of parcels.

4.2.1 South River

Restoration opportunities in the South River Corridor are limited. Based on the marsh lifespan and percent resilience metrics, most of the area does not have urgent restoration needs. However, the field study site (aka 'Coast Guard') itself could benefit from restoration efforts.

Actions:

- Continue to monitor the condition of the marsh surface for further degradation including expansion of existing salt pannes and pools.
- Conduct targeted field surveys to develop high resolution vertical and horizontal mapping of key features including pools, ditches, and other marsh features.
- Engage the Town of Kingston to share study results as part of a longer term goal of marsh protection.

4.2.2 Calista Property, Kingston

This site is relatively healthy and challenging access to the site may be an impediment to any restoration activities.

Actions:

- Engage the Town of Kingston to share study results and discuss interest in targeted study of cost benefit analysis of marsh edge loss.
- Conduct targeted field surveys to develop high resolution vertical and horizontal mapping of key features including marsh edge, ditches, tidal inundation, and wave action.

4.3 Long-term priority sites and actions

The sites listed below are in overall good health and do not have any immediate restoration needs. However, tracking future threats will be important across all sites.

4.3.1 Gulf River/Musquashcut Brook

While some of the degraded portions of this marsh might benefit from restoration activities, access may present and significant obstacle.

Actions:

- Long-term monitoring of this site is recommended to track degradation or improvement of marsh health.

4.3.2 Third Cliff

Like Musquashcut Brook, the Third Cliff marsh site does have some small, degraded portions that might benefit from restoration activities. However, access may present some significant obstacles and gains would be limited.

Actions:

- Long-term monitoring of this site is recommended to track degradation or improvement of marsh health.

4.3.3 Upper North River

The salt marshes in the upper reaches of the North River are in generally good condition. Marshes in the transition from salt to fresh water are of particular interest due the potential conversion to salt marsh.

Actions:

- Long-term monitoring of this area is recommended, in particular tracking the extent of upstream salt migration and any vegetative changes from freshwater tidal marshes to Salt marsh.

4.3.4 Duxbury

Overall, this was the healthiest site of the study. There are no immediate restoration needs for this marsh. The greatest risk to long-term health of this marsh system would be a catastrophic breach of the barrier beach.

Actions:

- Support Duxbury Beach Reservation and the Town of Duxbury in their maintenance and restoration of the barrier beach. This includes a recent project by CZM, Woods Hole Group, and the Stone Living Lab effort to study cobble berms and their effectiveness as nature-based shoreline protection measures.
- Long-term monitoring of this site is recommended to track changes and identify any issues before they become unmanageable.

5 References

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APPENDIX A

Additional data collected during the study

Site	DMF Shellfish Classification	NHESP Priority Habitat (acres)	Diadromous Fish Migratory Habitat
Jones River (Calista)	Prohibited	2.8	alewife, blueback herring, rainbow smelt, american eel, white perch, atlantic tomcod, sea lamprey, american shad
Jones River (Harbormaster)	Conditionally Approved to Prohibited	2.8	alewife, blueback herring, rainbow smelt, american eel, white perch, atlantic tomcod, sea lamprey, american shad
Duxbury Bay	Approved	82.5	american eel
Green Harbor	Prohibited	0	american eel
South River (Marshfied Rec)	Prohibited	0.6	alewife, blueback herring, rainbow smelt, american eel, sea lamprey, american shad
Upper NR (Cedar Point)	Prohibited	7	alewife, blueback herring, rainbow smelt, american eel, white perch, atlantic tomcod, american shad
NR Mouth (Driftway)	Prohibited	37.2	alewife, rainbow smelt, american eel
NR Mouth (Third Cliff)	Conditionally Approved to Prohibited	37.2	alewife, blueback herring, rainbow smelt, american eel, white perch, atlantic tomcod, american shad
Kent Street	Prohibited	3.9	none
Gulf River (Musquashcut)	Prohibited	0	alewife, rainbow smelt, american eel, atlantic tomcod