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Establishing Salt Marshes in the Narragansett Bay Research Reserve as Reference Marshes for Long-Term Ecological Monitoring

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Executive Summary

The ability to accurately evaluate efforts to restore degraded salt marshes suffers from a lack of reference sites and standardized sampling methdologies among projects. To help address these issues, the National Estuarine Research Reserve System (NERRS) and the NOAA Restoration Center entered into a three-year partnership (2008-2010) to monitor ecological responses and evaluate the success of 18 salt marsh restoration projects funded with Estuary Restoration Act Funds. As a key component of this project, the NERRS will establish salt marshes as reference sites for long-term monitoring at the Narragansett Bay (RI), Wells (ME), South Slough (OR), North Carolina (NC), and Chesapeake Bay (VA) Reserves. At all marshes, standardized protocols will be used to monitor emergent vegetation and hydrologic parameters, and vertical control will be established in order to monitor marsh adaptations to local sea level rise. At the Narragansett Bay Reserve, two marshes are being established as reference sites as part of this project. Vegetation and hydrology monitoring plots were established and sampled in both marshes in 2008. Similar sampling was also conducted at three tide-restricted and two restoring salt marshes around Narragansett Bay. Additional work in the Narragansett Bay Reserve included establishing four National Geodetic Service bench marks, purchasing automated water level loggers, and planning for establishing sediment elevation tables (SETs) in both reference marshes in 2009-2010. This project, which is currently in progress, will coordinate marsh restoration monitoring at a regional scale and establish long-term reference sites at each Reserve to better understand the effects of current and future restoration projects, and how marshes are changing with increasing rates of sea level rise.

Introduction

Salt marshes provide valuable habitats for economically important fish, crustacean, and waterfowl species; protect coastal areas against storm surges and floods; and enhance estuarine water quality by intercepting land-based nutrient inputs. Unfortunately, these and other ecosystem services were compromised when extensive areas of marsh along the coastal United States were either outright destroyed or otherwise degraded by humans dating back to colonial times. For example, Bromberg and Bertness (2008) have documented that 37% of original salt marshes have been lost throughout the New England region, with the highest rate of loss (53%) along the heavily-developed Rhode Island coast. More recently, an increased awareness of the values that salt marshes provide has resulted in a subsequent increase in the number of efforts to restore degraded marshes. Many restoration projects unfortunately suffer from a lack of quantitative ecological monitoring and equally problematic is the general lack of data from reference salt marshes to which data from restoration sites can be compared. To help address these needs, the National Estuarine Research Reserve System (NERRS) and the NOAA Restoration Center have entered into a three-year partnership to evaluate the success of eighteen restoration projects that were funded with Estuary Restoration Act Funds between FY00-FY06. The NERRS will monitor salt marsh habitats within five reserves to establish reference conditions while simultaneously monitoring restoration projects nearby the reserves. The Narragansett Bay National Estuarine Research Reserve (NBNERR) will be participating in this partnership, along with the Wells ME, South Slough OR, North Carolina NC, and Chesapeake Bay VA reserves.

At NBNERR, the primary goals of this study are to develop monitoring protocols, establish infrastructure at Coggeshall and Nag salt marshes, and begin initial monitoring. Once established, these marshes will serve as long-term reference sites that will be used to 1) evaluate how natural salt marshes are changing over time in response to the large-scale effects of global climate change and sea-level rise, and 2) evaluate the ecological changes at tide-restricted marshes around Narragansett Bay as they undergo hydrologic restoration. A secondary goal of this study is to conduct the same ecological monitoring at two marshes that were previously tide-restricted, but have recently been restored (Potter Pond Marsh, NBNERR and Walker Farm Marsh, Barrington), and at three marshes that remain tide-restricted but are slated for restoration within the time frame of this study (Gooseneck Cove Marsh, Newport; Jacob’s Point Marsh, Warren [tide-restricted portion only]; and Silver Creek Marsh, Bristol). Basic emergent vegetation (e.g., species composition, cover, height) and hydrologic (water table depth and soil salinity) parameters will be measured at all sites in this study. In addition, sediment elevation tables (SETs) and National Geodetic Survey (NGS) bench marks will be installed in association with both NBNERR reference marshes to track changes in marsh elevations and to establish vertical control, respectively.

Specific tasks during the first year of this project at NBNERR include purchasing equipment and supplies, training staff on monitoring protocols, establishing vegetation and hydrology transects, installing bench marks, and collecting and analyzing the first year of ecological monitoring data. The focus of years 2 and 3 will be to continue with data collection and analysis, while finishing remaining infrastructure development. Year 3 will also result in a cumulative analysis of all monitoring data conducted by the NBNERR and other participating reserves in the NERR-Restoration Center Partnership.

Methods

Study Sites

Three of the seven study marshes (Coggeshall Marsh, Nag Marsh, and the restoring Potter Pond Marsh) are located in NBNERR on Prudence Island, which lies in the geographic center of Narragansett Bay (Fig. 1). Walker Farm, Jacob's Point, and Silver Creek marshes are all nearby mainland sites that are located in the heavily developed East Bay section of the Bay. Gooseneck Cove lies just outside the mouth of Narragansett Bay along the southern shore of Newport. All seven marshes lie within 25 km of one another and range from approximately 2-25 ha in size (Table 1).

Coggeshall and Nag reference marshes are both located within NBNERR boundaries on the glacial-outwash-dominated northern end of Prudence Island (except for a small portion of Nag Marsh, which falls outside the boundaries) (Fig. 2). Coggeshall Marsh is a 25-ha marsh located behind a locked gate on the North End Unit of the NBNERR. Tidal exchange between the marsh and Narragansett Bay occurs along a long vegetated marsh edge and via two main tidal creeks (Fig. 3). Coggeshall Marsh has previously served as an experimental control for assessing the ecological effects of the restoration of Potter Pond Marsh (Raposa 2008). Nag Marsh is the site of one of the NBNERR's System-Wide-Monitoring-Program (SWMP) long-term water quality monitoring stations, which was established in 2002 (Figs. 2 and 4). Tidal exchange with Narragansett Bay occurs through a single tidal creek bisecting the marsh. Both Coggeshall and Nag marshes are dominated by *Spartina* grasses, contain a network of historic mosquito-ditches, and are generally lacking in marsh pools and the invasive common reed *Phragmites australis* (hereafter referred to as *Phragmites*). Both marshes are surrounded by undeveloped, natural habitat-types and have never had their tidal exchange restricted by an anthropogenic structure. In addition, researchers from Brown University have long used Nag and Coggeshall marshes as primary research locations (e.g., see Donnelly and Bertness 2001, Bertness et al. 2002, Bertness et al. 2008, among others). All of these qualities serve to make both marshes excellent reference sites that are representative of the urbanized, heavily-populated Narragansett Bay.

The other five marshes have all been subjected to altered tidal hydrologies from the construction of human-made barriers. Three marshes (Gooseneck Cove, Jacob's Point, and Silver Creek) remain tide-restricted, while both Potter Pond and Walker Farm marshes have recently undergone tidal restoration (Table 1). Potter Pond and Walker Farm marshes were restored in early 2003 and 2005, respectively; Silver Creek and Gooseneck Cove are both slated for tidal restoration in winter 2008-09, with restoration of the restricted section of Jacob's Point Marsh slated for soon thereafter (Cole and Ferguson, Save The Bay, personal communication). A detailed description of Potter

Pond has been published previously (Raposa 2008); descriptions, maps, and photographs of the other four tide-altered marshes have been developed by Save The Bay (www.savebay.org) and are provided in Appendix 1.

Vegetation

Permanent emergent vegetation monitoring transects were established in Coggeshall and Nag Marshes following the National Estuarine Research Reserve's (NERR) emergent vegetation biomonitoring protocols (Moore and Bulthuis 2003), which in turn are based directly on the protocols established for use in the National Park System (Roman et al. 2001). In each marsh, three transects were established that extended from the marsh/upland edge until intersecting with a primary water body (i.e., creek, pool, or pond; Figs. 3 and 4). The beginning location of each transect was randomly chosen using GIS software. Vegetation monitoring plots were then located at intervals of at least 10 m along each of the 6 transects. Plots were delineated in the field with 1-m wooden oak stakes and labeled accordingly (e.g., 3-1 for the first plot nearest the water body on the third transect in each respective marsh). The coordinates of each plot in both marshes were recorded using a Trimble GPS receiver, and these point locations were then exported into a shapefile for use in GIS software.

Vegetation monitoring transects were established in the five restricted/restoration marshes prior to the beginning of this project. All transects and plots were generally established according to the Roman et al. (2001) protocols; therefore, these same locations were used again in this project.

Vegetation plots were sampled at the end of the growing season in each marsh with 1-m^2 PVC quadrats. Quadrats were placed at a fixed offset from each stake in an effort to minimize vegetation trampling. When standing at a stake and facing the upland, the lower-left corner of the quadrat was placed at the stake and flipped once to the right (following Fig. 10 in Roman et al. 2001). Parameters monitored within each quadrat included species composition, percent cover, and *Phragmites* height and stem density when this species was present. Species composition was determined by identifying all species found within each quadrat. If additional species were found while assessing percent cover, they were added to the species composition list. Percent cover was determined using the point-intercept method in conjunction with a 50-point grid (Roman et al. 2001). Stem densities of *Phragmites* were quantified by placing a 0.0625-m^2 quadrat in the upper-right corner of each quadrat (i.e., the corner away from the stake and on the upland side) in which *Phragmites* was present and counting all live and dead stems. *Phragmites* height was quantified by measuring the heights of three randomly-chosen stems from each of the four corners of the quadrat. If twelve stems were not present in a quadrat, all available stems were measured. Measurements were taken from the base of the stem to the tip of the apical stem (without extending any of the upper leaves).

Hydrology

Emergent vegetation species in marshes are adapted to specific levels of salinity and to the amount of soil saturation. Salinity and water table levels were therefore also monitored at all sites included in this study. Small PVC wells were installed along one representative vegetation transect at each reference marsh according to the recommendations in Roman et al. (2001). As with vegetation, wells had been established at Gooseneck Cove, Jacob's Point, Silver Creek, and Walker Farm prior to the initiation of this study. They were not established along a single transect in each marsh; instead they were located at multiple points along multiple transects. However, these wells were designed according to Roman et al. (2001) and were therefore used in this study. Hydrology wells were not established in Potter Pond in 2008; installation will occur in 2009.

Water table levels were monitored in each marsh (except Potter Pond) periodically over the growing season by measuring the depth to the water table within each well. Soil salinity was monitored at the same time using a small sipper to extract porewater from the soil adjacent to each well. Extractions were made at a depth of 15-cm; if water could not be extracted at this depth, the sipper was pushed sequentially down to 30 and 45 cm depths; if extractions were still not possible, water was drawn directly from inside the well. Additional high-frequency data were to be collected from a subset of wells in each marsh using automated water level loggers but the equipment did not arrive in time for use in 2008; these loggers will be used beginning in the 2009 season.

Vertical Control

In order to define fine-scale elevation changes at both reference sites it was first necessary to locate or establish bench marks proximate to the sites of interest with a static defined elevation relative to a national spatial reference system, or geodetic control. A review of tidal and geodetic databases available on-line from NOAA's National Ocean Service (NOS) and the National Geodetic Survey (NGS) was first conducted to determine whether existing bench marks on Prudence Island would be suitable for this purpose. Seventeen geodetic control bench marks, established and/or described between 1843 and 1969, and two tidal bench marks were evaluated.

The majority of geodetic control bench marks that had been established on Prudence Island were considered lost or damaged (Table 2). Of the remaining stations which were considered within reasonable proximity (less than one mile) to reference sites or monitoring stations, only two were found (Nag 1913 and Prudence Use 1909). Nag 1913 was discovered in an established lawn on private property and Prudence Use 1909 was discovered in a closed canopy forest unsuitable for use with satellite based global positioning systems (GPS) technology or traditional leveling methods.

Of the two tidal stations established on Prudence Island, Potter Cove and Navy Pier, only the bench marks associated with the Navy Pier station were located. Both tidal and geodetic elevations were provided for these bench marks however the geodetic elevation had been derived from an average of several bench mark elevations relative to the tidal station datum, not by traditional leveling methods, and as a result was not considered to be sufficiently accurate for reference site monitoring.

Real time kinematic GPS (RTK) was used to determine elevation relative to the North American Vertical Datum of 1988 (NAVD 88) at one previously defined Navy Pier tidal bench mark (845 2555 Tidal 3). An RTK base station was set-up to occupy this site and record approximately seven hours of elevation data derived from the triangulation of multiple satellite transmissions. RTK base stations were also used to collect elevation data from three off-island control sites for a minimum of two hours per site during the same seven hour time period. Simultaneous data collection at control sites with known location (X,Y) and elevation (Z) are used to correct for data fluctuations which occur as the result of atmospheric attenuation and satellite configuration. Control sites included MC SPARRAN 4 (located in North Kingstown), E 28, and H 28 (both located in Portsmouth). Data were then submitted to NGS's On-Line Positioning User Service (OPUS) to determine a solution for the 'unknown' height.

Three additional geodetic bench marks were also established for Prudence Island to allow ready access to geodetic control for mapping and monitoring of elevation changes at reference sites and monitoring stations. A number of potential sites were evaluated for ease of access, stability of the substrate, and protection from disturbance. Once selected, each site was permanently marked either through etching or by the installation of a brass disk. In a similar manner to that described above, RTK base stations and an OPUS solution was used to determine elevation at each newly established bench mark relative to a control site. The control site in this instance was the Navy Pier tidal bench mark (845 2555 Tidal 3) for which elevation relative to NAVD 88 has been established.

Results and Discussion

Vegetation

Vegetation surveys were conducted at all marshes between August 19 and November 12, 2008. The number of quadrats sampled per marsh ranged from 19 to 27, for a total of 156 quadrats sampled during 2008 across all sites (Table 3). Twenty-six vegetation species were identified across all of the study sites (not including multiple unknown species or additional non-vegetated cover classes), and the number of species per site ranged from 6 to 16 (mean of 9.3 species per site). In terms of percent cover of live plants, the dominant species across all sites included *Spartina alterniflora* (33%), *S. patens* (30%), *Phragmites* (28%), and *Distichlis spicata* (14%). Eighteen species (again, only considering live plants) were found at mean percent covers of less than 1% (Table 3).

Mean percent cover of vegetation and other cover classes varied among reference, tide-restricted, and restoring salt marshes. The two reference marshes were dominated by typical New England salt marsh vegetation species such as *S. alterniflora*, *S. patens*, and to a lesser extent *D. spicata*, and *Iva frutescens* (Fig. 5). In contrast, the dominant vegetation species in tide-restricted marshes was live *Phragmites*, followed by the two *Spartina* species, dead *Phragmites*, and *D. spicata*. Live *Phragmites* was also the dominant species at restoring marshes, but these marshes also supported more dead *Phragmites*, *Salicornia europaea*, and bare/mud areas that the other marsh types; the latter three components often increase concurrently with restoration-induced increased tidal flows.

Phragmites cover, height, and stem density differed among reference and tide-altered marshes. Mean cover of *Phragmites* in tide-altered marshes was 39%, but *Phragamites* was absent from both reference sites (based on quadrat sampling; small patches of *Phragmites* actually are present at both sites, but no quadrats were established in them). Mean *Phragmites* height at the two restoring salt marshes was 107.75 cm, while height at the tide-restricted sites was nearly double (191.88 cm). Similarly, stem density at the one restoring marsh where these data were collected averaged 30.08 live stems m^{-2}; live stem density averaged across the three tide-restricted marshes was over double at 82.40 live stems m^{-2}.

Hydrology

Groundwater wells were established along one representative transect in Coggeshall Marsh and Nag Marsh in accordance with the NERR and Roman et al. (2001) protocols. Spot sampling for water levels and porewater salinity was conducted sporadically at all of the study marshes where wells were established. Although the goal was to conduct spot monitoring at 2-week intervals at each site, sampling actually occurred much less frequently, and at the two reference sites, it only occurred on one date (Table 3). In addition, high-frequency monitoring with automated water level loggers was planned, but did not happen at all due to difficulties in obtaining the equipment.

Since so little hydrologic data were collected, it is difficult to describe patterns among or within the marshes at this point. Even so, the limited data suggest that mean soil salinities are similar between reference and tide-restricted marshes (23.1 ppt and 22.2 ppt, respectively); based on three sampling dates, soil salinity at the lone restoring marsh was lower, at 15.8 ppt (Table 3). There were no patterns in water table depths among the three types of marshes; mean depths were 4.4 cm, 12.3 cm, and 10.4 cm at reference, restoring, and tide-restricted marshes, respectively. These data are extremely limited, and not yet useful for assessing patterns either within or among marshes. In 2009, spot sampling will occur at least biweekly at the reference sites (it is expected that a similar sampling frequency will occur at the tide-altered marshes in 2009 as occurred in 2008; this work is coordinated by Save The Bay), and automated, high-frequency sampling will occur for at least one two-week period at all sites.

Vertical Control

Geodetic control was established at four sites on Prudence Island to accommodate mapping and monitoring requirements of reference site monitoring. The four geodetic control sites are: 845 2555 Tidal 3, Chase Way, Potter Cove, and Long Point. Datasheets with site descriptions, locations, and elevations for the updated tidal bench mark as well as the three newly established bench marks have been submitted to the NGS for inclusion in their database. A draft report of the Narragansett Bay NERR Geodetic Control Project is attached as Appendix 2.

Summary and Future Work

Accomplishments at NBNERR during the first year of this project included establishing vegetation and hydrology monitoring plots in the two reference marshes, surveying in four NGS bench marks on Prudence Island, and purchasing automated water level loggers. In addition, initial data on emergent vegetation and hydrology were collected at the two reference marshes and five additional marshes with altered hydrology in 2008. The goals of year two of this project will be to finish establishing any remaining infrastructure, collect a second year of vegetation and hydrology data from all marshes, explore adding new monitoring parameters, and continue towards achieving vertical control at both reference sites.

The focus of this study is monitoring vegetation and hydrology, but some additional parameters may also be added as time and resources permit. A top priority is to establish surface elevation tables (SETs) in both Nag and Coggeshall marshes in order to monitor changes in marsh elevation over time in response to changing sea levels. Surface elevations were actually measured in both marshes in 2008 using older SETs that had been established by other researchers. However, while sampling, it was found that these SETs had not been installed properly; sampling was therefore terminated and all SETs were slated for removal. The intent now is to install and monitor three new SETs along one monitoring transect in both Nag and Coggeshall marshes. In order to further characterize ecological conditions over time, soil characteristics, nekton, and birds may also be monitored in reference and/or restoring marshes in future years.

The overall goal after three years is to have a fully-established salt marsh monitoring program in place that focuses on the two NBNERR reference marshes. This will allow for long-term monitoring at the reference sites in future years, which will provide a foundation for developing a broader-scale project to monitor ecological conditions of restoration salt marshes throughout Narragansett Bay. This will ultimately allow researchers and managers to track changes in marshes over time and understand how these systems are changing to multiple stressors associated with global climate change and other anthropogenic factors.

2009 Schedule

A tentative monitoring schedule in 2009 is provided in Table 4. More specific monitoring tasks in 2009 will include:

- Adding the collection of *S. alterniflora* stem density and height data to the standard emergent vegetation monitoring protocol;
- Increasing the frequency of groundwater spot sampling to at least a biweekly schedule;
- Beginning hydrologic monitoring at reference and tide-altered marshes with automated water level loggers;
- Installing PVC wells in Potter Pond Marsh;
- Exploring the installation of new SETs in Coggeshall and Nag marshes;
- Establishing vertical control on SWMP stations, vegetation plots, hydrology wells, and SETs (if installed);
- Developing digital elevation models (DEMs) of Nag and Coggeshall marshes;
- Monitoring additional parameters (e.g., soil characteristics, nekton and birds) as time allows.

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Table 1. Basic characteristics of the seven Rhode Island salt marshes included in this study.

	Coggeshall	Nag	Potter Pond	Walker Farm	Jacob's Point [1]	Silver Creek	Gooseneck Cove
Location	NBNERR, Prudence Island	NBNERR, Prudence Island	NBNERR, Prudence Island	Barrington	Warren	Bristol	Newport
Type	Reference	Reference	Tide-restored	Tide-restored	Tide-restricted	Tide-restricted	Tide-restricted
Size (ha)	25.5	15.3	2.3	6.5	6.7	5.6	22.8
Dominant vegetation	*Spartina alterniflora*	*Spartina patens*	*Spartina alterniflora/patens*	*Phragmites australis*	*Phragmites australis*	*Spartina patens*	*Spartina alterniflora*
Hydrologic features	Creeks, pools, ponds	Creeks, ponds	Pond	Creeks	Pools	Creeks, ponds	Channel, pools

[1] Characteristics are for the tide-restricted portion of Jacob's Point Marsh only. The entire marsh, including restricted and unrestricted portions, totals 15.4-ha and includes a mix of *Spartina*-dominated habitats, *Phragmites*, and tidal creeks and pools.

Table 2. Geodetic control bench marks on Prudence Island

Designation	Latest Report Date	Status
Barn M Cupola	1956	Station lost
Bat 1913	1943	Surface and reference marks missing; subsurface mark raised and surrounded by wooden fence
Bight 1913	1956	Offshore due to erosion
DER 1913	1956	Recovered in good condition but covered by dense vines/underbrush
Flagg	1912	Reported destroyed 1912
Nag 1913	1956	Recovered in good condition
North Point House Chimney	1956	Station destroyed
Pine Hill 1843	1960	Station recovered but damaged; position needs to be checked
Potters Cove Windmill	1956	Station destroyed
Prudence 1843	1869	Not found, considered lost
Prudence 2 1869	1897	Not found, considered lost
Prudence 3 1897	1912	Not found, considered lost
Prudence 4	1968	Four standard disks in concrete markers
Prudence Island Lighthouse	1956	Recovered in good condition
Prudence Island US Navy Tank	1969	Described (but tank no longer exists)
Prudence Use 1909	1956	Recovered in good condition
Windmill L	1956	Station destroyed

Table 3. Vegetation and groundwater characteristics at the seven salt marshes included in this study. n/a=*Phragmites* was not present in quadrats at these sites; data were therefore not available. ND=data were not collected from this site.

		Coggeshall	Nag	Potter Pond	Walker Farm	Jacob's Point (restricted)	Silver Creek	Gooseneck Cove	Mean
Vegetation sample dates		8/27/2008; 9/11/2008	8/27/2008	10/24/2008	8/19/2008	8/27/2008	11/4/2008; 11/12/2008	9/13/2008	
Number of quadrats		21	22	25	27	21	21	19	22.29
Percent Cover (%)	*Spartina alterniflora* (live)	61.8	39.0	28.2	25.6	0	7.6	67.2	32.77
	Spartina patens (live)	44.1	44.1	28.2	9.0	31.9	33.0	19.6	29.99
	Phragmites australis (live)	0	0	11.21	66.8	75.8	26.3	14.1	27.74
	Phragmites australis (dead)	0	0	16.07	48.5	0	26.0	14.1	14.95
	Distichlis spicata	15.1	22.2	14.1	0.4	10.7	22.2	13.4	14.01
	Iva frutescens	11.0	4.4	22.4	0	2.7	19.7	0	8.60
	Salicornia europaea	0	4.3	7.4	13.7	0	0	2.8	4.03
	Juncus gerardi (live)	2.5	4.7	0	1.1	8.8	0	0	2.44
	Bare/mud	1.2	1.6	12.07	1.3	0	0	0.3	2.35
	Juncus gerardi (dead)	10.0	1.1	0	0	0	0	0	1.59
	Open water	0	0	0	0	0.3	0	9.4	1.39
	Atriplex patula	0	0	0.4	8.6	0	0.2	0	1.31
	Unknown	0	0	0	0.4	7.4	0	0	1.11
	Solidago sempervirens	.1	0	0	5.6	0	0	0	0.81
	Limonium nashi	4.2	.5	0	0	0	0	0.3	0.71
	Malva spp.	0	0	0	0	3.9	0	0	0.56
	Acer rubrum	0	0	0	3.7	0	0	0	0.53
	Quercus spp.	0	0	0	3.7	0	0	0	0.53
	Pluchea purpurescens	0	0	0	3.3	0	0	0	0.47
	Wrack	0	2.1	0	0	0	0	0	0.30
	Scirpus spp.	0	1.9	0	0	0	0	0	0.27
	Stone	1.7	0	0	0	0	0	0	0.24
	Lonicera spp.	0	0	0	0	0	0	1.6	0.23
	Eleocharis parvula	0	0	0	1.5	0	0	0	0.21
	Ptilimnium capillaceum	0	0	0	0	1.5	0	0	0.21
	Baccharis halimifolia	0	0	1.4	0	0	0	0	0.20
	Agalinis maritime	0	.5	0	0	0	0	0.7	0.17
	Spartina alterniflora (dead)	0.7	0.5	0	0	0	0	0	0.17
	Typha angustifolia	0	0	0	0	1.2	0	0	0.17
	Spartina patens (dead)	0	0	0.8	0	0	0	0	0.11
	Scirpus maritimus	0	0	0	0	0.7	0	0	0.10
	Panicum virgatum	0	0	0.2	0	0	0	0	0.03
	Phytolacca americana	0	0	0	0.2	0	0	0	0.03
	Polygonum spp.	0	0	0	0.2	0	0	0	0.03
	Aster subulatus	0	0	0	0.1	0	0	0	0.01

Number of species		7	9	9	16	10	6	8	9.29
Mean *Phragmites* height (cm)		n/a	n/a	103.91	111.59	165.92	217.10	192.62	158.23
Mean *Phragmites* stem density (no. m^{-2})	Live	n/a	n/a	30.08	ND	137.44	61.76	48.00	69.32
	Dead	n/a	n/a	148.00	ND	48.00	70.88	212.00	119.72
	Total	n/a	n/a	178.08	ND	185.44	132.64	260.00	189.04
Number of groundwater sample dates		1	1	0	3	6	6	2	2.71
Mean # samples $date^{-1}$		7	8	ND	14.7	9.7	11	16.5	11.15
Mean water level depth (cm)		6.50	2.38	ND	12.31	10.40	16.03	4.83	8.74
Mean salinity (ppt)		22.10	24.10	ND	15.81	28.16	17.48	21.00	21.44

Table 4. Schedule of monitoring activities at reference and restoration sites in 2009. C=Coggeshall, G=Gooseneck Cove, J=Jacob's Point, N=Nag, P=Potter Pond, S=Silver Creek.

Monitoring Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Emergent vegetation								C, G, J, N, P, S	C, G, J, N, P, S			
Hydrology - Install wells						P						
Hydrology - spot surveys						C, G, J, N, P, S	C, G, J, N, P, S	C, G, J, N, P, S	C, G, J, N, P, S			
Hydrology – Aquatrolls						C, G, J, N, P, S	C, G, J, N, P, S	C, G, J, N, P, S	C, G, J, N, P, S			
Collect GPS points				C, N								
Investigate SETs, new parameters				X	X							
Install SETs (potential)						C, N	C, N	C, N				
Vertical Control						C, N	C, N					

Figure 1. Map of Narragansett Bay showing the locations of Coggeshall and Nag reference salt marshes and the five marshes with altered tidal flow. Land within the Narragansett Bay National Estuarine Research Reserve is indicated in black.

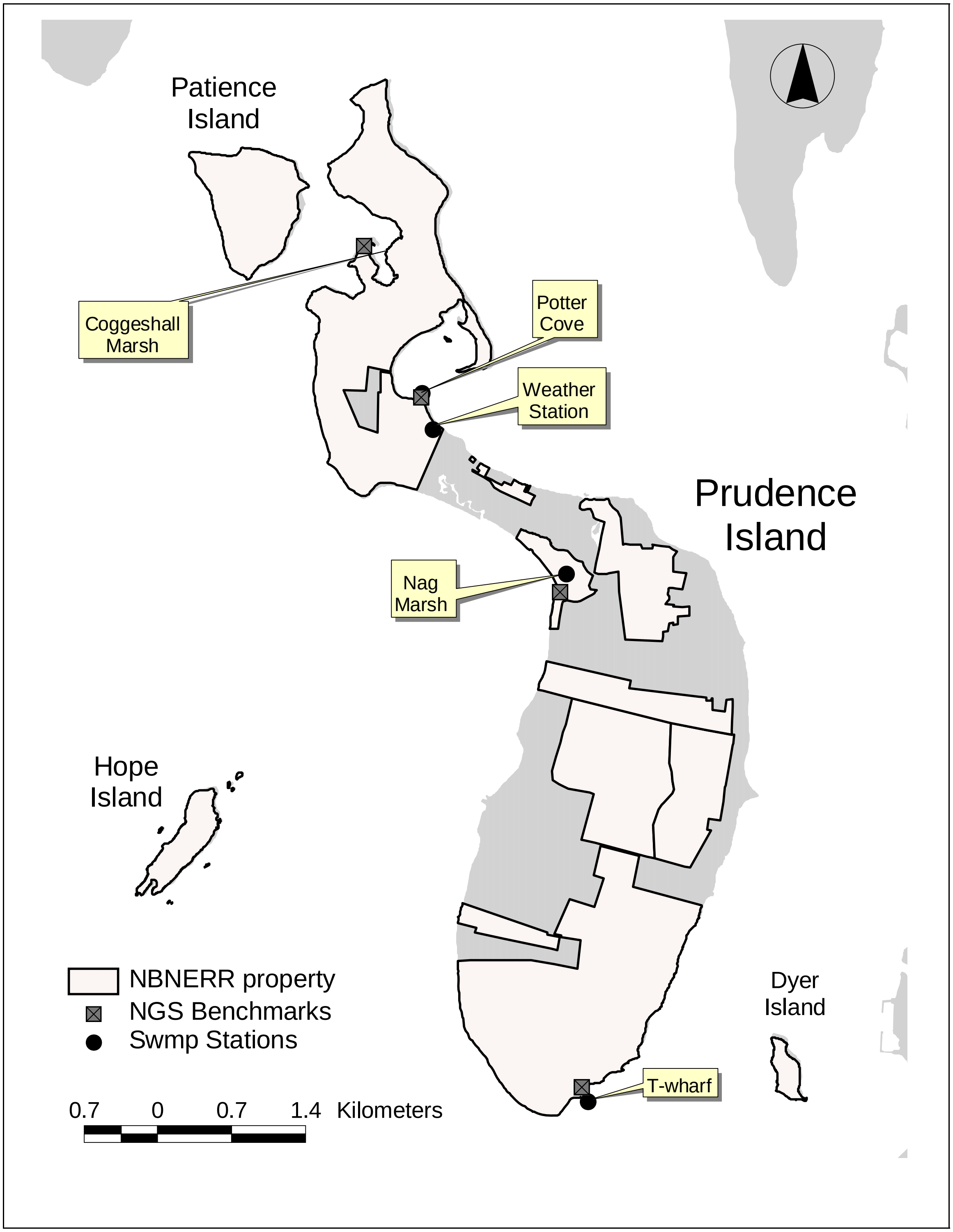


Figure 2. Map of Prudence Island and the Narragansett Bay National Estuarine Research Reserve showing the locations of the Coggeshall and Nag reference salt marshes. Locations of the three SWMP water quality stations, SWMP weather station, and four National Geodetic Survey bench marks are also indicated.

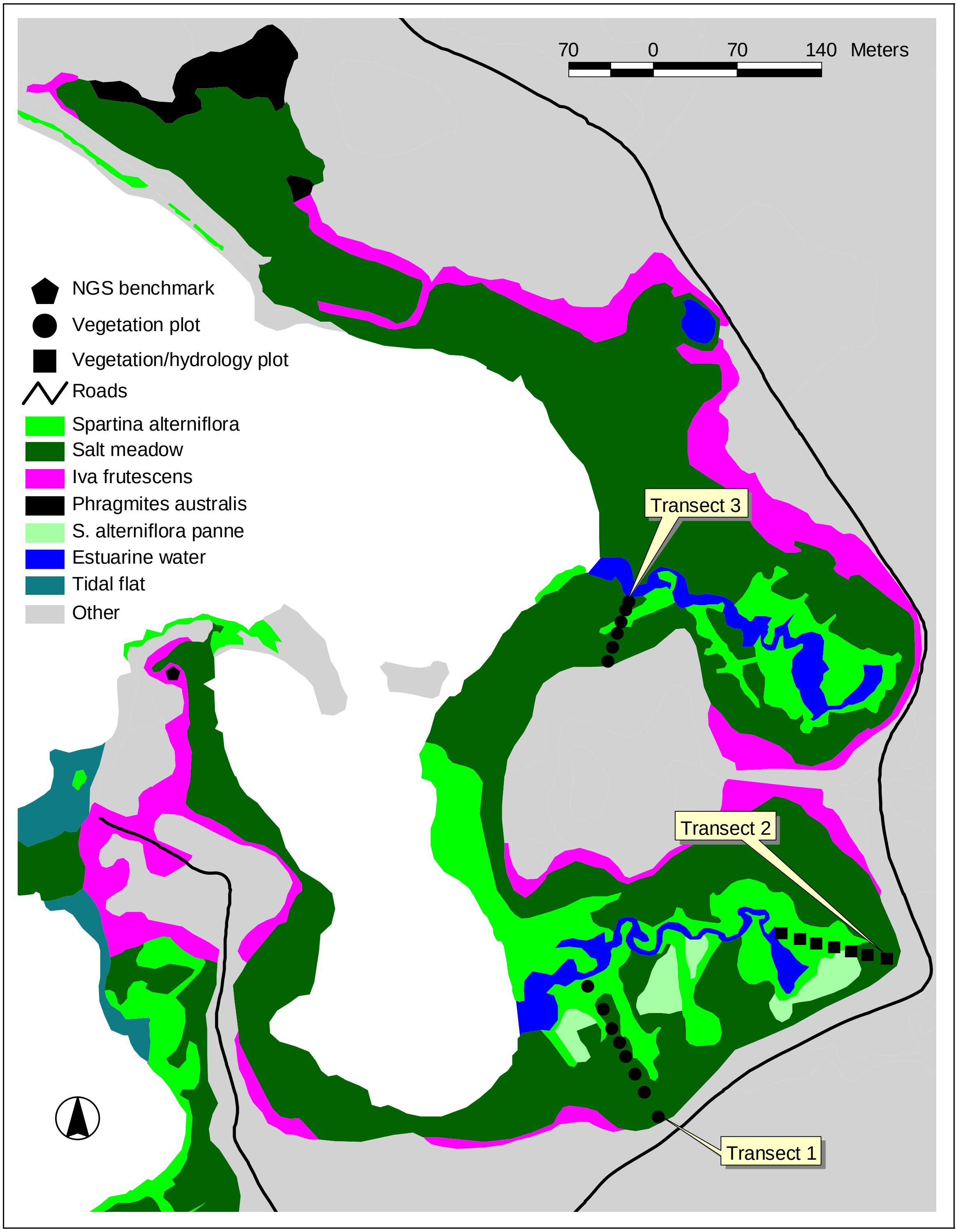


Figure 3. Map of Coggeshall Marsh showing the locations of vegetation and hydrology monitoring plots and an NGS bench mark overlaid on a habitat map of the marsh. The study marsh is bounded to the southwest by a road that passes along the marsh. Habitats were mapped and classified according to Kutcher et al. 2004.

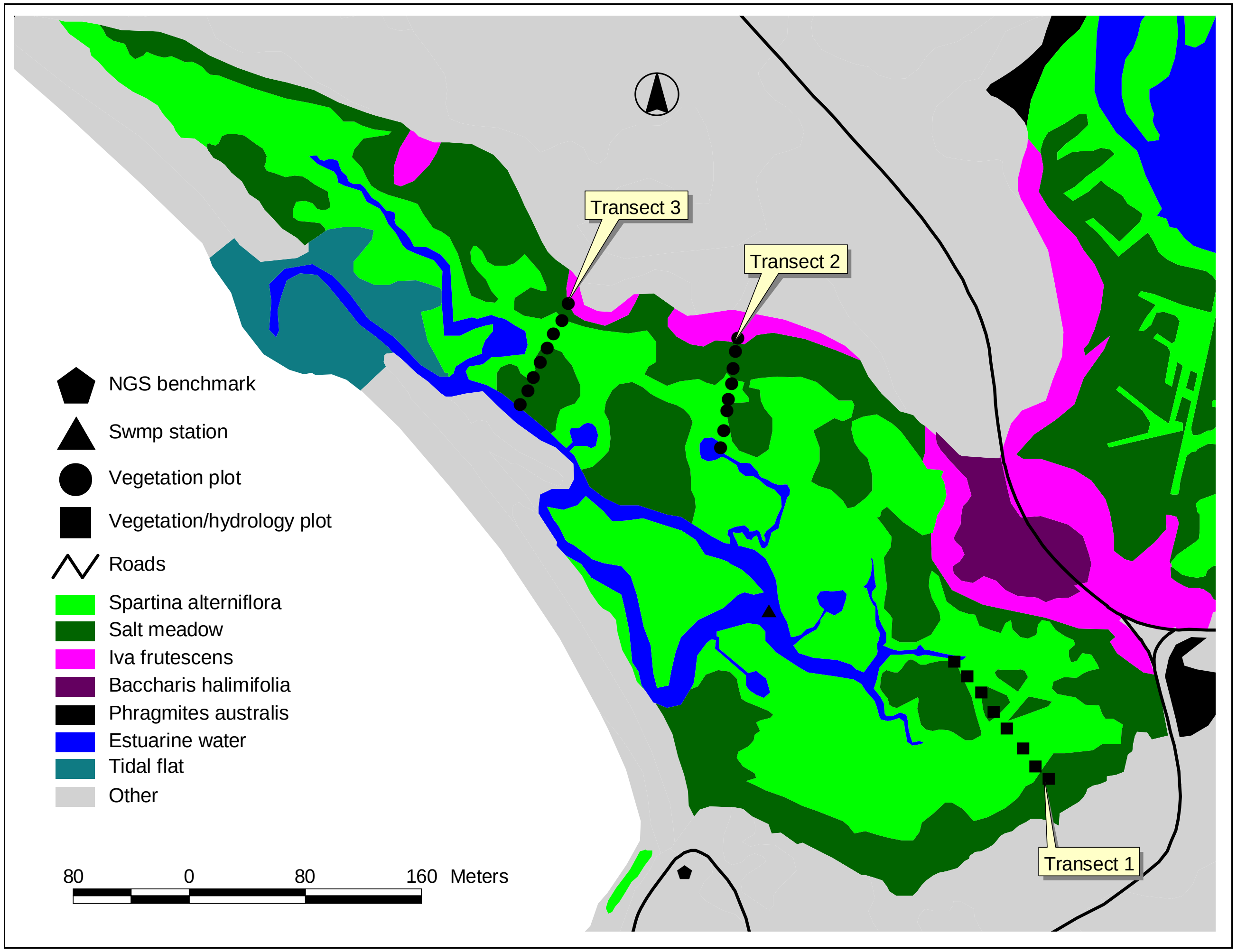


Figure 4. Map of Nag Marsh showing the locations of vegetation and groundwater monitoring plots, a SWMP station, and an NGS bench mark overlaid on a habitat map of the marsh. The study marsh is bounded to the northeast by a road that passes through an *Iva frutescens/Baccharis halimifolia* shrubland. Habitats were mapped and classified according to Kutcher et al. 2004.

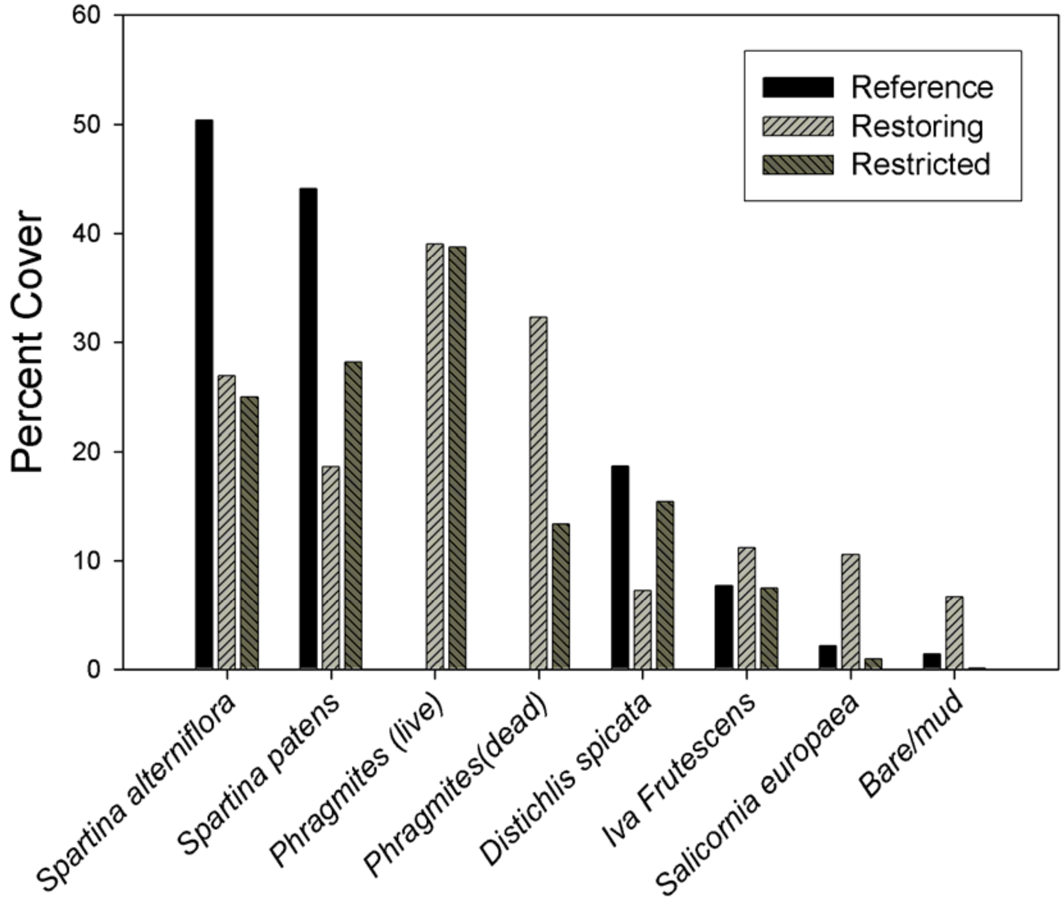


Figure 5. Mean percent cover of dominant vegetation and other cover classes in reference (Coggeshall and Nag), tide-restricted (Gooseneck Cove, Jacob's Point, and Silver Creek), and restoring marshes (Potter Pond and Walker Farm).

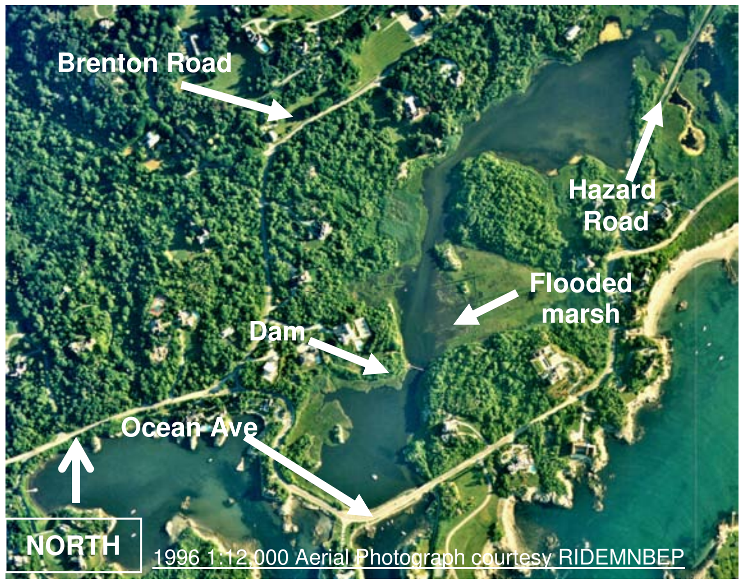
Appendix 1

Fact sheets for Gooseneck Cove, Jacob's Point, Silver Creek, and Walker Farm salt marshes. All marshes have been subjected to altered tidal hydrologies. All fact sheets provided by Marci Cole of Save The Bay (www.savebay.org).

Gooseneck Cove and Cherry Neck Creek Restoration Overview

Salt Marsh Restoration Goals:
Increase tidal flow through manmade structures to:

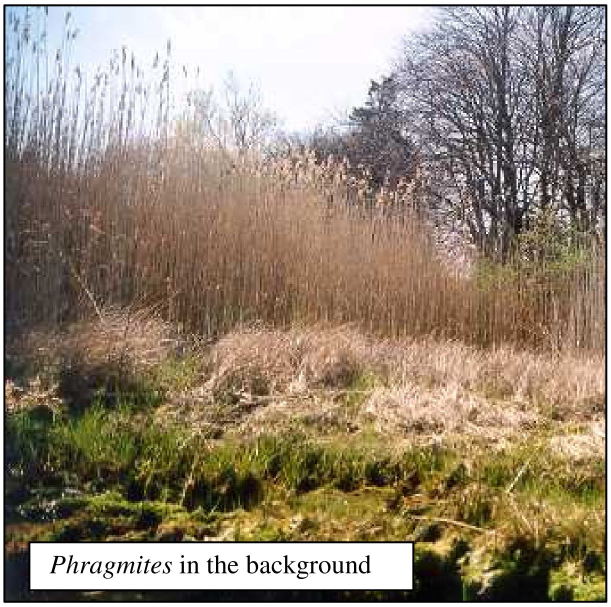
- Minimize the loss of salt marsh;
- Improve water quality and reduce nuisance algal blooms;
- Reduce the amount of the invasive, non-native common reed, *Phragmites australis*; and
- Enhance habitat of the cove for fish and other aquatic organisms.



Introduction: Gooseneck Cove and Cherry Neck Creek along the southern shoreline of Newport have been impacted by a variety of human activities over the last hundred and fifty years. In 1996, Save The Bay identified the cove as a potential restoration site based upon a salt marsh assessment conducted by volunteers and local citizens. The project partners including National Oceanic and Atmospheric Administration, the Natural Resources Conservation Service, Save The Bay and the City of Newport are working to develop a plan to restore the salt marsh and improve water quality of Gooseneck Cove. Funds have been secured for completing the feasibility study and design through NOAA and NRCS and a substantial portion of the construction funds have been secured through NRCS and the RI Coastal Habitat Restoration Trust Fund.

Impacts to the Cove and Creek: Gooseneck Cove and Cherry Neck Creek are tidally restricted and exhibit signs of habitat and water quality degradation. Saltwater flow into the cove is restricted by three major tidal restrictions: the Ocean Avenue causeway, a small dam that crosses the middle of the cove, and Hazard Road.

The three tidal restrictions impound water in the cove and creek. Flooded marsh plants die, slowly decompose, and without healthy plants to sustain it, the marsh surface sinks or subsides. Approximately 15 acres of historic salt marsh meadow have subsided since 1939 (the date of the first statewide aerial photographs). Based on recent monitoring data, the marsh is continuing to subside. Save The Bay installed devices (Surface Elevation Tables) in 2004 to monitor changes in the marsh elevation over time. Results from the monitoring showed that the marsh surface had subsided more than 1 inch in 2 years, a very high loss rate in comparison to healthy marshes that tend to increase in elevation. Gooseneck Cove salt marsh will continue to subside until restoration of the tidal flow occurs.



Phragmites in the background

Restricted tidal flow into the upper cove has changed the plant community due to the decreased salinity levels. The lower salinity levels create conditions suitable for the invasive plant, *Phragmites australis,* also known as Common Reed, to out-compete native salt marsh plants. *Phragmites* covers approximately 13 acres of the 28-acre salt marsh. This invasive plant does not provide as valuable a habitat for wading birds such as egrets and herons, nor is it as beneficial to marine life that spawn or feed in the salt marsh grasses. Extensive stands of *Phragmites* also are a potential fire hazard to local property owners.

Additionally, inadequate flushing of the upper cove and creek create more stagnant, pond-like conditions, promoting the growth of algae. A large algal bloom has covered up to 9.4 acres of the upper cove, approximately 26 % of the cove's open water. The algae shade out valuable underwater plants such as eelgrass. When the algal bloom dies and sinks to the bottom it consumes oxygen in the water. The result is low oxygen levels that stress marine life and lead to fish kills. Thick, dense mats of these filamentous algae also make the cove much less enjoyable for boating and recreation.

Save The Bay has conducted an assessment to determine the source of nutrients (nitrogen) fueling the algal bloom. Based upon this assessment, it was determined that wastewater, the suspected source of nitrogen, was not present in the cove. Save The Bay identified that the source of nitrogen fueling the algal bloom was decomposing salt marsh that subsided since the construction of the Ocean Avenue causeway and the dam. Removal and redesign of the artificial restrictions should allow nutrients to flush more quickly from the cove and, consequently, decrease the area of the bloom.

Tidal Restrictions: The first restriction, **<u>Ocean Avenue causeway</u>,** has two culverts that allow salt water into the cove. Water is impounded by the causeway's narrow openings. Ocean Avenue is the oldest tidal restriction on Gooseneck Cove, built prior to 1870 based upon a Newport Historical Society town atlas. The original opening of the Cove was approximately 500 feet wide. Today the only openings into the Cove are the two 4.5 feet diameter culverts under Ocean Avenue at Green Bridge.

The second restriction, a concrete **<u>dam</u>** constructed in the 1930s by the City of Newport, impounds freshwater and restricts salt water flow in and out of the upper cove. The dam has flooded the marsh on the Cove's eastern shore, which is evidenced by the flooded mosquito ditches that extend into the cove (See aerial photograph). This large marsh area to the north and east of the dam is continuing to sink resulting in more of the marsh being flooded by water.

The existing dam is in poor condition (See photo). The culvert in the dam is widening, and other openings have formed. The largest hole has notably increased in size over the last several years, and new fractures have developed more recently. Recent winter storms have threatened the integrity of the dam, creating a potential safety hazard.

The third restriction, **<u>Hazard Road</u>** located at the northern part of the cove, crosses the salt marsh and severely restricts tidal flow to the upper marsh owned by the Rhode Island Audubon Society. This road was built some time between 1883 and 1895. The salinity levels differ dramatically from one side of the road to the other. A small partially collapsed culvert under Hazard Road allows minimal flushing of the upper marsh. At high tide, salt water often floods the unimproved road.

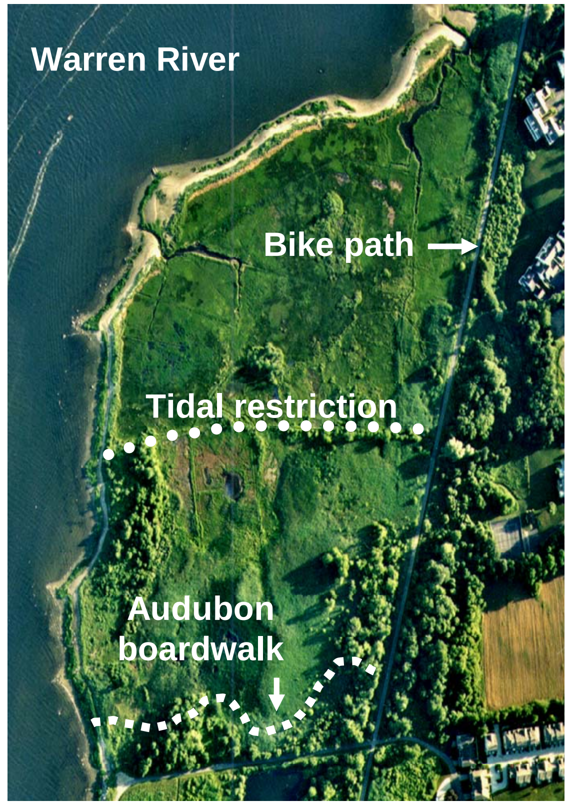
Hazard Road (see photo) is practically impassable at its southern end due to a persistent, deep pool of water. The road was once marsh, and the marsh peat underlying it is subsiding due to the weight of the road. The culvert under the road (about 1.5 foot in diameter) is partially collapsed and does not provide adequate tidal flow.

Restoration Assessment: To identify optimum restoration alternatives for Gooseneck Cove, the consultant used a model to estimate tide height based on the Cove's hydrology and depth. From these data, maps were created of expected vegetation types following restoration. Also costs were derived for each alternative. The consultant assessed many options for restoration including one to four culverts under Ocean Avenue, disposal of the dam material within and outside the Cove, and varying heights of Hazard Road. The following preferred restoration alternatives for each restriction were recommended based on their ability to meet the restoration goals and their cost.

Preferred Restoration Alternatives:

- Ocean Avenue**:** Since it is not feasible to fully open up the mouth of the Cove to its historic width, the preferred restoration alternative for Ocean Avenue is to install three additional culverts (4ft by 4ft each) under the causeway to the west of the existing Green Bridge.
- Dam**:** The preferred restoration alternative for the dam is to remove the dam due to the water it impounds and due to the poor structural integrity of the dam, and to dispose of the material off-site.
- Hazard Road: The preferred restoration alternative for Hazard Road is to replace the failing culvert with one 4 ft wide by 3 ft tall box culvert and increase the height of Hazard Road to 3.6 ft NGVD to prevent flooding of the road during most tidal conditions and to meet the City's goal of allowing access to Ocean Avenue for emergency vehicles.

Jacob's Point Salt Marsh



Salt Marsh Restoration Goals:

The goals of the Jacob's Point salt marsh restoration project are to:

- Reintroduce tidal flow to the marsh in order to reestablish the native high and low marsh plant communities.
- Decrease the height and vigor of the invasive reed *Phragmites australis*, while enhancing the population of native *Phragmites*
- Increase fish and bird usage of the marsh.
- Reduce the mosquito population.

Description: The Jacob's Point salt marsh is a 47 acre marsh along the Warren River, and is bordered by the East Bay Bike path and the Audubon Society of Rhode Island's education center. The Jacob's Point landscape includes salt marsh meadow, invasive *Phragmites australis*, cattails, purple loosestrife, open water, mudflats, and a rare stand of native *Phragmites*. Tidal flow into the interior of the marsh is restricted by an earthen footpath from the mainland to the upland at Jacob's Point. The footpath across the marsh to Jacob's Point restricts tidal flow between the northern and southern portion of the marsh due to two collapsed stone culverts. This has caused extensive invasion of *Phragmites australis*, an invasive marsh grass, over the past ten years.

History of the Salt Marsh: In 1915, Gerard T. Hanley Sr. built a dirt road across the marsh in order to access his seaplane docked on the banks of the Warren River. Today the road, now a footpath bordered by woody vegetation, continues to allow users access to the Warren River and other portions of the marsh, but has caused degradation of the adjacent marsh. The footpath restricts tidal flow into the southern portion of the marsh even at spring tides. The severity of this restriction is due to the footpath itself and the recent collapse of several stone culverts. Both open and clogged mosquito ditches run through the marsh as well. Members of the Land Trust have observed and noted the increase of the *Phragmites australis* along the bike path since its completion in 1992.

Restoration of Jacob's Point Salt Marsh:

The restoration strategy includes increasing tidal flow under the footpath by replacing the collapsed culverts while maintaining public access across the marsh and maintaining tidal creeks to improve flushing and to reduce mosquito production. Restoring the tidal hydrology of Jacob's Point will result in positive ecological changes to plant and animal communities. Based on similar restorations, it is anticipated that the Jacob's Point restoration will result in decreased density, height, and vigor of *Phragmites australis* allowing for the characteristic high and low salt marsh plant assemblages to reestablish. Restoration of the high marsh plants and reintroduction of tidal flow will result in increased usage of the salt marsh by fish, shellfish and wading birds.

Salt Marsh Monitoring of Jacob's Point:

Save The Bay has completed four years of pre-restoration monitoring including soil salinity, vegetation, and fish monitoring, funded by the partnership between NOAA's Community-based Restoration program and Restore America's Estuaries. Save The Bay recently expanded our monitoring transects into the unrestricted portion of the marsh to act as a healthy reference for all of our upper Bay restoration sites. Monitoring results showed that *Phragmites* does cover a significant portion of the marsh (nearly 60%) on the restricted side of the marsh. The tidal restrictions have indeed impounded freshwater in the restricted portion of the marsh, and water logged the soils. The collapsed culverts and the extent of *Phragmites* have also limited use of the marsh by fish and crabs in the fall. Save The Bay is collaborating with the Audubon Society of Rhode Island on monitoring the bird use of the salt marsh.

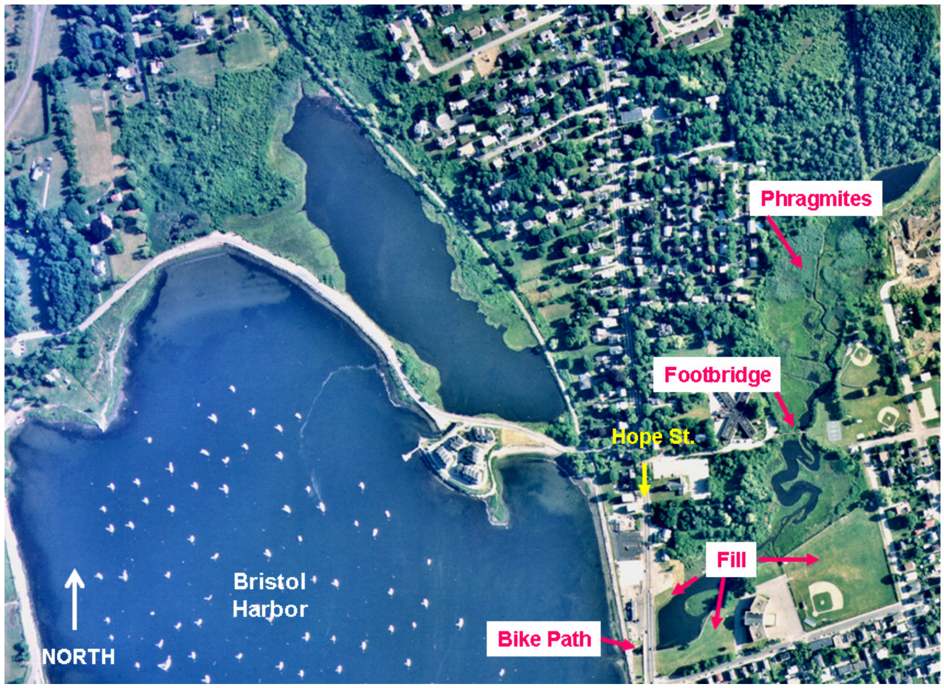
Project Partners: Project partners include Warren Land Trust, Save The Bay, the USDA Natural Resources Conservation Service, NOAA Restoration Center, RIDEM Mosquito Abatement, the Town of Warren, and the Audubon Society of Rhode Island.

Silver Creek Salt Marsh Restoration Overview

<u>Salt Marsh Restoration Goals:</u>

- Reintroduce tidal flow to the marsh in order to reestablish the native high and low marsh plant communities.
- Decrease the height and vigor of the invasive plant, *Phragmites australis*.
- Increase fish and bird use of the marsh.

<u>Introduction</u>:



Silver Creek is an approximately thirteen acre salt marsh in the eastern section of Narragansett Bay. The creek sits at the northern end of the historic town of Bristol. The creek is tidally restricted by a former railroad bridge, a road bridge and a foot bridge which have impacted the salt marsh plant community. These restrictions have impounded freshwater, diminished connectivity with Narragansett Bay, and have allowed for the expansion of *Phragmites australis* in the salt marsh. Further impacts to the marsh include historic filling of both sides of the creek and little to no buffer zone along portions of the marsh. The goals of this project will be addressed by removing the tidal restrictions, removing the invasive species; and, possibly removing the historical fill. By restoring the tidal flushing, the salinity levels will increase and the *Phragmites* population will be inhibited – this reduction in the *Phragmites* will reduce competition for tidal marsh restoration. The ultimate goals are to reduce the *Phragmites* population and restore bio-diversity within the Silver Creek and associated marsh. A secondary benefit to the project will be reducing the risk of flooding on properties within the Silver Creek watershed. Project partners include the Town of Bristol, Natural Resources Conservation Service, NOAA, and RI Department of Transportation.

Silver Creek is an important resource to the surrounding community for recreational, educational, historic, flood protection and aesthetic purposes. The marsh is a major feature of the landscape and is surrounded by residential properties, a school and playground, a nursing home, and commercial properties along Hope Street. The wetlands play a critical role in improving surface water quality by filtering pollutants and sediments and for flood storage.

Site History: The creek has three tidal restrictions, two at the mouth of the harbor including a former railroad bridge which is currently the East Bay bikepath and Route 114, and one restriction further upstream - a footpath between Creek Lane and Veteran's Park. These restrictions have created an impoundment and have allowed for the expansion of *Phragmites australis* above the third tidal restriction. Further impacts to the marsh include historic filling of both sides of the creek and little to no buffer zone along portions of the marsh.

Save The Bay conducted an analysis of the change in area of the Silver Creek salt marsh over time. Results showed that 55% of the native marsh habitat has been lost since 1939. *Phragmites* now covers 52% of the marsh, and the expansion of *Phragmites* has constricted the creek and reduced the open water area by 33%. Since 1939, 15% of the marsh has been filled, however a significant portion of the marsh was likely filled prior to 1939 due to the town landfill.

Due to chronic flooding problems of Route 114 and surrounding properties, the town of Bristol identified the bridge crossing at Silver Creek as their top priority in their Natural Hazard Mitigation Plan to FEMA. The impoundment at Route 114 prevents the freshwater from flowing into Narragansett Bay thereby flooding the state road, one of two main access roads to the town of Bristol. The town is interested in both restoring the salt marsh and mitigating the flooding problem.

Restoration Planning:
In 1996, Silver Creek was identified as a potential salt marsh restoration site through Save The Bay's evaluation of the ecological integrity of Narragansett Bay salt marshes. In 1999, the Silver Creek

restoration project was identified by the Army Corps of Engineers' Rhode Island Ecosystem Restoration Reconnaissance Report.
From 1999 to 2002, Save The Bay, the Save Silver Creek Coalition and the Town of Bristol collaborated on a WHIP grant to restore a native, coastal buffer adjacent to the creek and to manage invasive plants in the buffer

In 2003, the town of Bristol applied for an additional WHIP grant from the Natural Resources Conservation Service to restore tidal hydrology at the third tidal restriction. The WHIP funds in the amount of $68,000 were secured in the spring of 2004.

NRCS has completed a full topographic survey of the Silver Creek salt marsh project area including the area around the first two tidal restrictions. NRCS also set out tide data loggers. The data were used to develop a one-dimensional unsteady state flow model using the hydraulic modeling program HEC-RAS. The output from the model is being used by the project partners to determine the optimal size of the openings at the three restrictions to restore tidal hydrology and to improve freshwater drainage.

The results of NRCS' hydrologic model determined that the Route 114 restriction is not as restrictive as the first restriction, the bike path bridge. It also determined that a small rock sill upstream of the bike path bridge restricts water flow out of the marsh. This restriction could be removed more easily than resizing the culverts under the road or bike path. NRCS refined the hydrologic model to analyze the restoration benefits and the flooding improvements or impacts of removing the rock sill and opening up the bike path restriction. Their analysis found that there would be no negative impact to flooding by removing the rock sill or resizing the opening at the first tidal restriction.

NRCS has contracted out a consultant to conduct an assessment of the structural integrity of the second tidal restriction, the Route 114 bridge and to design and permit the rock sill removal. The reason for the additional engineering assessment is the Route 114 bridge could be negatively impacted by the removal of the rock sill just downstream of the bridge. The existing bridge abutments are showing signs of degradation.

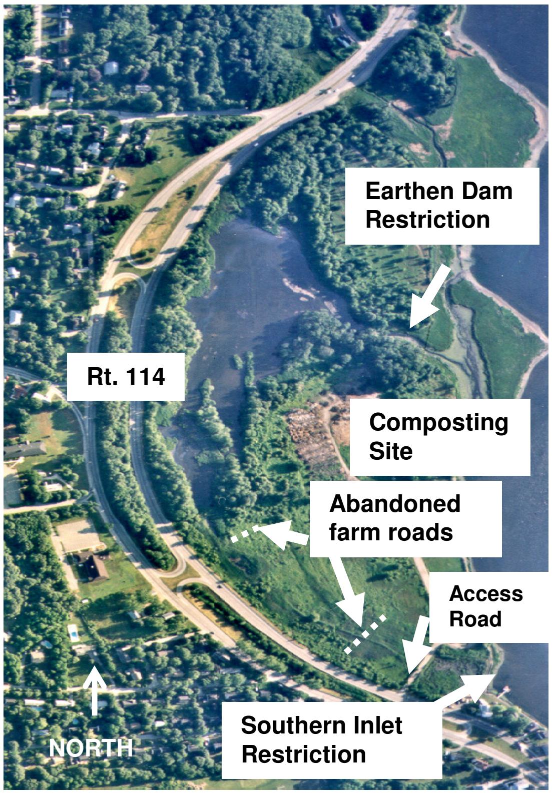
The footpath, the third restriction, restricts tidal flow to the upper marsh. Save The Bay's pre-restoration monitoring data shows lower soil salinity and greater *Phragmites* coverage upstream of the tidal restriction. NRCS will redesign the third restriction to improve tidal flow upstream of the restriction and decrease the extent and coverage of *Phragmites australis*.

Save The Bay, NRCS and the Town have developed a plan for removal of historic fill from the marsh on the northern side of Thomas Park along Silver Creek. The Town is seeking funding from NRCS for this portion of the project. The majority of Thomas Park is historic fill from the 1950s. The Town, NRCS and Save The Bay have identified an area where fill could be removed from the salt marsh and relocated further inland in Thomas Park. The Parks and Recreation's Department received funding from RI Department of Environmental Management's Historical Park grant to restore Thomas Park. A portion of these funds could be used to match the NRCS funds for fill removal.

Environmental Benefits: Restoring the tidal hydrology and habitat connectivity will result in increased use of the marsh by fish, shellfish, and wading and shorebirds. The Silver Creek salt marsh restoration will result in the reestablishment of native salt marsh plants, a decrease in the invasive plant, *Phragmites australis,* and increased density and diversity of recreational and commercially important fish species.

Pre-Restoration Monitoring Results: Save The Bay has developed a pre- and post-restoration monitoring plan for Silver Creek. Save The Bay monitored soil salinity, water table depth, and vegetation of the marsh during the 2004 and 2005 growing seasons. Fish and crab monitoring was conducted in July and September of 2005. Pre-restoration monitoring data confirms that plant and animal communities are significantly impacted by the fill and tidal restrictions. Fish and crab usage of the salt marsh is seriously suppressed by existing conditions. Vegetation monitoring has shown that *Phragmites australis* covers a very small portion of the marsh downstream of the footpath, but a significant portion of the marsh upstream of the footpath in both 2004 and 2005. *Phragmites* is common in marshes that have been severely degraded by tidal restrictions and eutrophication. Soils also tend to be fresher and more water logged above the third restriction, the foot path.

Walker Farm Marsh Restoration Overview



<u>Introduction</u>: Walker Farm Marsh is an historic salt marsh that was altered by a number of roads and dam structures that restrict the amount of inflowing salt water. Restricted tidal flow, decreased salinity in the marsh, and impoundment of open water have resulted in the invasion of Common Reed, *Phragmites australis,* throughout the wetland, and the flooding of the historic marsh. The spread of *Phragmites* in Walker Farm marsh was first identified in 1980 when the Osamequin Management Plan suggested controlling its growth. Plans to restore Walker Farm marsh were developed by Save The Bay in partnership with local, state, and federal government agencies. The goal of this restoration project is to increase the aerial of salt marsh to approximately 15 acres. The restoration occurred in the summer of 2005. Project partners include the Town of Barrington, Save The Bay, USDA Natural Resources Conservation Service, the National Oceanic and Atmospheric Administration's Community-based Restoration Program, Restore America's Estuaries, Ducks Unlimited, RI Coastal Resources Management Council, RIDEM Mosquito Abatement program, URI Department of Natural Resource Sciences, Narragansett Bay National Estuarine Research Reserve, ESS Group, VHB Inc. and RI Corporate Wetlands Restoration Partnership.

<u>Location</u>: Walker Farm in Barrington, RI is part of the Hundred Acre Cove estuary (identified in the U.S. Fish and Wildlife Service's North American Waterfowl Management Plan) in upper Narragansett Bay. The marsh lies to the east of Route 114, the Wampanoag Trail. This 16 acre marsh includes salt marsh meadow, open water, mudflats, brackish marsh and *Phragmites australis*. Today, the majority of the Walker Farm salt marsh is contained within the Osamequin Nature Sanctuary, owned by the Town of Barrington. The remaining section of the marsh is adjacent to the Town of Barrington's leaf composting area and community gardens. The southern tidal restriction is privately owned by an abutting landowner.

Site History: Historically, Walker Farm was used for grazing livestock. Local historic accounts mention the use of salt marshes for grazing in Hundred Acre Cove from as early as 1652. Dams were built in the early 1900s to block tidal flows and to facilitate the use of pastures. Dirt roads were built across the marsh to allow access to the farm. The marsh and adjacent lands across Route 114 were active pig farms until the town bought the land in 1968. Mosquito ditches were dug throughout the northern portion of the marsh sometime in the mid 1900s.

Impacts to the Salt Marsh: Salt water flow into the marsh is inhibited by five tidal restrictions (identified by arrows in the aerial photo). The **southern inlet restriction** is a permanent culverted dam structure that restricts tidal flow. This culvert allows tidal flow into a small portion of the marsh between the dam and the Walker Farm entrance road off Route 114. Saltwater cord grass, *Spartina alterniflora,* is the dominant plant in this section of the marsh. The next tidal restriction to the north is the entrance road off of Route 114 to the community gardens, boat ramp, and composting facility. The small culvert under the road allows minimum tidal flow into the interior marsh. Two overgrown farm roads, located north of the Walker Farm access road, cut across the marsh and prevent further tidal inundation into the interior marsh. At the northern end of the marsh, a flap-gated historic **earthen dam** was built approximately 60 years ago to allow agricultural use of the marsh. Sometime between 1965 and 1970, the Town of Barrington, made this original dam permanent to establish waterfowl habitat.

This dam flooded the salt marsh and created a brackish pond that only receives tidal flow during extreme high tides and storms. The dam also impounds freshwater from a tributary that discharges into the northeast corner of the pond, running under Route 114.

Restoration Planning: In 1996, Walker Farm marsh was initially assessed through Save The Bay's evaluation of the ecological integrity of Narragansett Bay salt marshes. Trained volunteers from the Town of Barrington assessed the major impacts to Walker Farm marsh. In 1999, the Rhode Island Coastal Habitat Restoration Team identified Walker Farm marsh as one of 70 candidates for ecological restoration in Rhode Island. Since 1996 Save The Bay and the Barrington Conservation Commission's Salt Marsh Working Group have been involved in advocating for the restoration of Walker Farm marsh. Save The Bay involved the Natural Resources Conservation Service and NOAA in the restoration project. NRCS has provided funding for the construction of the restoration plan through the Wetlands Reserve Program. National Oceanic Atmospheric Administration has provided funding for site assessment, prerestoration monitoring and design, engineering, and construction. The State of Rhode Island's Coastal Resources Management Council Habitat Restoration Fund also provided funds for restoration construction. Ducks Unlimited provided design engineering, construction oversight and construction funding. ESS, a local environmental consulting firm has conducted the permitting.

Restoration Design and Construction:

Construction occurred in the summer of 2005. The restoration project included modifying three existing tidal restrictions to improve flushing of the salt marsh. The southern structure includes water control structures to increase tidal flow. The structure under the access road was increased in size to allow for more tidal flow into the marsh interior. The former farm roads were removed from the marsh surface to improve tidal circulation within the salt marsh. The northern restriction also includes a water control structure. Analysis by URI of the marsh sediment determined that a large amount of sediment would be lost from the marsh if the tidal restoration was removed completely. To address the potential loss of marsh substrate, the northern restriction was designed with a water control structure to limit the initial tidal flow into the marsh. As the marsh revegetates, the water control structure can be modified to allow for greater tidal flow. The marsh spoils were placed in the upland adjacent to the marsh and planted with a conservation mix. A water control structure management plan will be developed based on monitoring trials during spring low and high tides. The water control structures will be maintained by the Town of Barrington in consultation with NOAA, NRCS, Ducks Unlimited, and Save The Bay.

Monitoring Results: Save The Bay monitored soil salinity, groundwater elevation, vegetation, and fish usage of the marsh for several summers prior to restoration. Results confirmed that plant and animal communities were significantly impacted by tidal restrictions and road fill. High water temperatures and reduction in the duration of tidal inundation of the marsh surface limited the use of this historic salt marsh by many fish species (monitored with the help of Narragansett Bay Research Reserve staff). Vegetation monitoring showed that *Phragmites australis* was the dominant plant species and replaced native salt marsh vegetation. Monitoring following restoration has shown promising results. The diversity of fish species using the marsh has nearly doubled. *Phragmites* height has decreased, likely in response to the introduction of more salt water. The area covered by *Phragmites* has stopped increasing, and is expected to begin decreasing this summer. Native low and high marsh plants are continuing to colonize the marsh in greater density. Results did show that only the smallest fish remained on the marsh at low tide, since nearly all the water was drained. In response, the project partners agreed to make changes to the tide gate to allow some water to remain in the marsh at low tide. Monitoring this summer will show if this adaptive management was effective at improving the fish habitat.

Appendix 2

Summary of four new National Geodetic Survey bench marks on Prudence Island, Rhode Island.

Please contact Kenny Raposa at the Narragansett Bay Research Reserve for a copy of Appendix 2. Kenny@nbnerr.org or (401) 683 7849.