

Project Monitoring Protocols

Developed by The New Jersey Chapter of The Nature Conservancy

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Project Title: The Beneficial Use of Dredged Material to Enhance Salt Marshes

Project Sponsor: New Jersey Department of Environmental Protection (NJDEP)

Monitoring Leads: The Nature Conservancy; GreenVest, LLC; Princeton Hydro, LLC; Rutgers University; The Wetlands Institute; NJDEP, Division of Fish and Wildlife

The purpose of this document is to provide relevant project background information and describe the monitoring activities that are being completed to assess project objectives. Detailed monitoring plans are presented in the Appendix.

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1. Project Background

Project Title: The Beneficial Use of Dredged Material to Enhance Salt Marshes

Project Sponsor: New Jersey Department of Environmental Protection (NJDEP)

Grant Period: August 2014 – October 2017

Funding Source: National Fish and Wildlife Foundation – Hurricane Sandy Coastal Resiliency Competitive Grants Program 2013

Project Summary and Objectives: NJDEP has undertaken this project in order to trial the beneficial use of dredged material to enhance salt marshes that benefit coastal communities in advance of the widespread use of this practice in the state. This practice combines salt marsh enhancement with routine and post-storm dredging required to keep waterways navigable. The coupling of dredging and enhancement may decrease the cost of dredging and can yield significant ecological and socio-economic benefits. Enhancement is accomplished by placing dredged material on a salt marsh site at varying depths to increase marsh elevation according to the specific site characteristics and enhancement objectives. Dredged material is transported to the site through a pipe as it is being dredged. Placement of dredged material is accomplished through direct pumping or broadcasting, depending on the desired result. This project will trial various placement techniques. The first technique is the placement of a layer of dredged material over an existing marsh platform to increase marsh elevation. The objective was to use raise the elevation of the marsh interior such that it would create positive drainage and alleviate the stress associated with increased depths and durations of flooding within the marsh interior. A secondary objective was to create some high marsh habitat within the area to contribute to wildlife habitat diversity. The second technique is the placement of dredged material in large interior pools to fill them to an elevation that it is similar to the surrounding marsh platform. The third technique is the concentrated placement of dredged material over a small area of marsh platform to create elevated nesting habitat for black skimmer, a state-listed endangered water bird.

The project includes a series of four trial enhancement projects incorporating these various placement techniques to enhance salt marshes. The enhancement objective of each trial project is to increase the elevation of the marsh platform such that the elevation increase improves local coastal community resiliency, provides ecological uplift and does not have any harmful impacts on the marsh. Salt marshes in NJ that are suffering from a loss in elevation could benefit from the increases in elevation provided by the placement of clean dredged material. This loss in elevation is caused by decreased local sediment budgets, regional subsidence and hydrologic alteration, and is exacerbated by sea level rise. Increases in elevation will increase the resiliency of marsh ecosystems in the face of these stressors.

These trial enhancement projects will provide the opportunity for analysis of the effects of this practice on the ecosystem. NJDEP and its project partners intend to determine whether or not this practice increases marsh elevation and enhances a marsh's ability to provide valuable ecosystem services such as habitat provision, wave attenuation and flood reduction. Project partners also intend to document the technical capabilities and cost-effectiveness of this type of work which is relatively new to New Jersey. These summary reports will help inform future projects of this kind and help to determine the feasibility of scaling up this work within the state. As such, all project work is being carefully documented and project sites are being monitored.

2. Trial Enhancement Projects

The four trial enhancement projects are located in Middle Township (Ring Island) (thin layer placement and elevated nesting habitat creation), Avalon (in two phases; pool filling and thin layer placement), and Fortescue (thin layer placement). Each enhancement project is different in many respects including: the beneficial reuse techniques trialed, timeline, location, scale, vegetative cover, topography, tides, textural composition of dredged material available for enhancement, access points for dredge pipeline, etc. Two of the four projects are demonstration projects established during the first year of the grant period (Ring Island and Avalon demo projects) and the other two are full-scale pilot projects established during the second year (Fortescue and Avalon pilot projects). In total, approximately 61 acres of state-owned salt marsh received placement of dredged material.

Preliminary Site Selection: Prior to the start of the grant period, federal and state dredging projects were identified by U.S. Army Corps of Engineers and NJ Department of Transportation. Those dredging projects that were proximal to state-owned salt marshes in need of enhancement and to coastal communities that rely on the ecosystem services provided by healthy marshes were selected for the grant project. This general need for salt marsh enhancement was evaluated on a large scale using LiDAR datasets and aerial photographs, and in this way large areas of low elevation marshes that contained relatively large unvegetated areas and pools were identified.

Project Site Selection: Once these general areas were identified, the monitoring team conducted a series of site visits from fall 2013 through summer 2014 to narrow project site selection. Site visits provided the opportunity to perform on-the-ground visual assessments. Team members looked for signs of stress including: eroding marsh edge, stunted and sparse vegetation, patches of vegetation die-off and ostensibly unhealthy and expanding pools. Wildlife use was also assessed and sites where placement activities would coincide with bird nesting were avoided. Lastly, the constructability of sites was assessed. All project locations can be seen in Figure 1 and details of each project location are included in Figures 2-5.

Control Site Selection: Once project sites were selected, team members scouted out appropriate control sites. As with project site selection, a series of site visits and visual assessments were conducted to choose control sites. Control sites are no further than 3,000 feet away from project sites, but not close enough to be impacted by the dredged material placement activities.

Baseline Site Characterization for Project Design: Survey work to inform project design is the first step towards a successful project. Results of baseline survey activities enabled the project team to decide specific areas for placement of dredged material, to determine target elevations to be reached by placement in specific areas (which in turn determined target depths of placement), to determine the siting and configuration of containment measures, and to inform project monitoring work plans. To these ends, survey work included: literature review, site investigations, topographic surveys, identification of bio benchmarks, surface water elevation surveys, wave energy modelling, and chemical and textural analysis of dredged material and marsh sediment. Much of this survey work doubled as pre-placement baseline monitoring. The baseline survey work is not described at length in this document. This document presents the plans for ecological monitoring.

Project Monitoring: Once project and control sites were selected and the survey work was completed, monitoring activities could be planned and undertaken. These are explained in detail in the next section.

3. Monitoring Activities

Monitoring Leads: The Nature Conservancy; GreenVest, LLC; Princeton Hydro, LLC; Rutgers University; The Wetlands Institute; NJDEP, Division of Fish and Wildlife

The project monitoring program has been designed to assess the project objectives above. Since little is known of the effects of this practice in New Jersey, the monitoring is purposefully broad and is designed to detect positive, negative, and neutral impacts of placement on select salt marsh ecosystem features and services. The monitoring will also serve to evaluate project performance. The program is comprised of a host of monitoring activities including surveys of topography, surface elevation tables, bearing capacity, sediment/dredged material properties, surface water elevation, tide range, water chemistry, vegetation, epifaunal macroinvertebrates, benthic infauna, nekton, avian wildlife, black skimmer habitat use, and wave energy modeling. Reductions in local coastal community vulnerability to coastal storms, sea level rise, flooding and erosion will be modeled. In addition, a separate economic analysis modeling avoided flood damage costs will be conducted using the HAZUS model (not described in this document). Monitoring activities follow widely-accepted, scientifically sound methods. It is the intent that monitoring activities will take place before and after placement of dredged material and will utilize a BACI (Before-After Control-Impact) design. However, where this is not possible due to the difference between the grant funding timeline and the construction timeline, projects include a control site (see Figures 2-5 in the *Appendix* for maps and timelines of monitoring). Where possible, the monitoring that took place before placement was used to inform project design. The following list provides the summaries of each monitoring activity. Associated monitoring plans with detailed methods can be found in the *Appendix*.

Topography: The primary objective of the placement of dredged material on a salt marsh is to increase marsh surface elevation. This increase can be an absolute increase in surface elevation that simply changes the position of the marsh platform within the tidal range; or this increase can be used to create desired changes to marsh topography to improve drainage in hydrologically impaired areas. Both the absolute elevation and the topography of a salt marsh influences the hydrology, which determines the floral and faunal communities that ultimately define the ecological functions of the marsh. The location, vertical magnitude and horizontal extent of dredged material placement and the resulting changes to elevation and marsh topography will primarily determine the ecological outcomes of dredged material placement. In order to attribute changes in other marsh ecosystem features to the addition of dredged material, it is imperative to accurately document the new elevation and topography of the project site.

Permanent survey transects will be established at placement and control sites. Permanent plots for monitoring vegetation will also be established at placement and control sites (see *Vegetation* below). The survey transects and vegetation plots will be monitored before placement to inform placement design. Topographic surveys and existing knowledge on local plant growth ranges (bio benchmarks) will be used to determine target elevations to be reached by placement. These surveys will also be conducted immediately after placement (as-built survey) and periodically after placement. This BACI design will allow for important analyses of the relationship between the change in elevation caused by placement and changes to other marsh features. Measurements of pre- and post-placement elevations can be compared with tide range, tidal

amplitude, hydroperiod and key biotic factors to measure the efficacy of placement as a salt marsh enhancement technique.

One-time surveys of elevation will also be taken at tide gauge stations, bio-benchmarks, and surface elevation tables. Lastly the horizontal extent of placement will be surveyed. This will be done immediately after placement (as-built) and annually following the anniversary of periodically after placement. Monitoring horizontal extent of placement over time will provide information on how placed dredged material of different grain size shift and migrate. Elevation data will be collected using RTK-GPS technology.

It is likely that the initial increases to marsh surface elevation will change over time. Dredged material may consolidate or shift across the placement site. Movement of dredged material should lessen as vegetation recolonizes placement sites and stabilizes the added dredged material. Surface elevation can be impacted by surface processes such as erosion and accretion, and subsurface processes like compaction and subsidence. While these topographic surveys will only capture absolute change in surface elevation, which is the cumulative effect of these processes, coordinated monitoring of elevation and accretion with surface elevation tables will allow the measurement of these processes separately (see *Surface Elevation Tables* below).

Surface Elevation Tables (SETs): Marsh surface elevation is determined by a collection of physical processes including sea level rise, erosion, accretion, root growth, compaction and subsidence. Elevation, in turn, is the primary determinant of many important marsh ecosystem features. Since the placement of dredged material will necessarily change elevation, then it is critical to get high resolution measures of surface elevation. Surface elevation tables (SETs) are capable of taking such high resolution (mm) measurements. The initial gain in elevation from placement can be diminished over time; placed dredged material can be lost to erosion or redistribution across the marsh platform, and elevation can be gained by accretion. Surface elevation can be lost to compaction, subsidence or surcharging. Marker horizons (MHs) can provide measurements of accretion. Together, SETs and MHs can measure shallow subsidence (calculated as net accretion minus net surface elevation change).

Shallow and deep SETs and MHs will be installed after the placement of dredged material. SETs/MHs will be monitored in the late spring and early fall for the first two years, and annually after that. Long-term monitoring will allow us to track retention of any initial elevation increases and explain reasons for elevation losses over time at placement sites. It is expected that the dredged material will settle or compact for a period of time after placement leading to measured losses in surface elevation, but then eventually stabilize. It is also expected that increases to elevation achieved by placement will at first be affected by the erosion and dispersion of unstabilized dredged material. MHs can help to detect resuspension/redistribution of unstabilized dredged material. Once vegetative cover is established, dredged material will be less susceptible to these processes and the resulting net gain elevation should stabilize. SET/MHs will also detect the effects of marsh subsidence on surface elevation. Another possible outcome of placement is increased shallow subsidence due to compaction of marsh sediment under the weight of newly placed dredged material.

Bearing Capacity: Bearing capacity is the ability of soil to support the loads applied to the ground as measured by initial loading response and penetration depth/resistance. A 2" diameter capped PVC tube is placed onto the wetland soil surface and then standard force is applied with

a slide hammer. Bearing capacity in xeric use assesses soil compaction and the ability of light, water, and roots to penetrate the substrate. In hydric soils, bearing capacity assesses below-ground stability including the assumption that below-ground biomass and soil bearing capacity are directly correlated. In typical salt marshes, declines in below-ground biomass tend to occur prior to declines in above-ground biomass. Because of the diversity of dredged material types within a thin-layer placement site, both xeric and hydric bearing capacity uses are taken into consideration to assess below-ground stability and penetration resistance as it relates to vegetative re-growth.

In addition to bearing capacity, water depth and depth of dredged material are measured at each 1 m² permanent vegetation monitoring plot (see *Vegetation* below). Water depth is recorded as it may influence vegetative recovery and pore water or inundation may significantly alter bearing capacity. Depths of placed dredged material are measured in all four corners and in the center of the quadrat and then are averaged for the plot. Finally, after depths and bearing capacity have been measured, observations are made of the sediment/dredged material including general sediment/dredged material type, grain size, any distinctive coloring, differences in the visible soil layers, and anything else that seems pertinent.

Sediment Monitoring: Sediment/dredged material characteristics will be monitored in 2017 as a one-year addition. Sediment samples will be collected at the Avalon site to (a) generally characterize the distribution, and (b) evaluate the potential importance on vegetation (particularly *Spartina alterniflora*) survival and growth, of dredged material placement elevation, physical characteristics, and chemical characteristics (metals, nutrients, and sulfates).

Sediment samples will be located to provide for the analysis of the data in relation to the following factors in Avalon Placement Areas A, D, E, and F:

- Elevation within the placement areas
- Vegetation die-off areas adjacent to Placement Areas A and D
- Areas of natural vegetation recovery vs. no recovery within a selected placement area(s)

The collected data will be compared to baseline (pre-placement) marsh sediment characteristics and the Long et al. (1995) ER-L and ER-M sediment quality guidelines and other literature (see Monitoring Plan in the Appendix for citation) in order to evaluate correlations (and thus potential causes) between these characteristics and vegetation growth/survival. Data analysis will also include an evaluation of correlations between site elevation and physical and chemical sediment characteristics to develop a better understanding of the general distribution of these parameters in the placed dredged material.

Surface Water Elevation and Tide Range: Surface elevation and marsh topography determine the depth and duration of tidal flooding at a site. Tidal flooding, in turn, dictates what vegetation grows in different areas of the marsh. Since placement of dredged material will change marsh elevation, it is crucial to monitor changes to tidal flooding. Water surface elevations will be measured in the field and converted into NAVD 1988 by correlation with on-the-ground topographic surveys. Tide range (physical maximum) plus mean high, mean low, and mid tide elevations will all be calculated using real time data collected, validated by and compared to long term data collected by NOAA and others. Hydroperiod, or depth and duration of inundation, will be calculated using tide range data collected for each project and control site.

Surface water data will be continuously measured at placement and control sites for the two larger scale projects in Avalon and Fortescue for the entire project length—from baseline data collection before placement, and throughout the monitoring period after placement—by installing remote data logging equipment at semi-permanent tide gauge stations. This BACI design will allow for important analyses of the relationship between changes to elevation and tidal flooding caused by placement and changes to other marsh features.

Surface and Ground Water Chemistry: Placement of dredged material over a salt marsh platform and pools resulted in changes to surface elevation and marsh topography that has altered the depth and duration of tidal flooding at the Avalon site. Additionally, compaction and dewatering of dredged material may have created pooled water areas and altered water chemistry. Observations of unusual salinity and pH of pooled water and observations of acidic soils resulted in the addition of monitoring of water chemistry in 2017.

The approach taken was to characterize surface water chemistry in salt marsh pools following placement of dredged material. Sampling site selection occurred prior to containment removal and was based on an initial study design. Site selection aimed to test the effect of containment and to understand die off areas so sites were located both inside and outside containment and also in die-off areas. Sites were also selected to capture surface water pools that had a high likelihood of persisting through the summer and fall so that comparative analyses could be conducted. The sampling frequency and timing was designed to capture the range of conditions present post-placement to understand the role of surface water chemistry on vegetation recovery, survival of plantings and/or the relationship to die-off areas. To determine the potential cause of surface water chemistry being documented, the monitoring program also documented the water chemistry in perched water tables within the placed dredged material. Groundwater wells and piezometers installed by the US Army Corp of Engineers ERDC were utilized for monitoring. The study design included sampling control sites that did not have any dredged material emplaced. For comparative purposes, the monitoring also measured water chemistry on nearby salt marsh at The Wetlands Institute in natural pools and depressions created during a construction project that resulted in marsh compaction without any dredged material addition. In total, 9 surface water sites were located in placement areas, 3 surface water sites were located in control areas at the Avalon site, and 5 surface water sites were located at The Wetlands Institute during the monitoring period (April – August). Groundwater was sampled from three well clusters located in placement areas and 2 located in control areas.

Water chemistry data will be compared between sampling sites with varying thickness of emplaced dredged material, duration, and frequency of tidal inundation (via base elevation data), and relative to pre-emplacement condition (marsh platform vs pool). Comparisons will be made between surface water and groundwater in the same areas, and to control sites and comparison sites without dredged material emplacement.

Wave Energy Modeling: The purpose of the wave energy modeling effort is essentially two-fold:

1. Guide optimization of proposed design of edge enhancement and dredged material placement to maximize benefits of wave energy reduction across a range of storm events, as feasible.
2. Evaluate benefits in terms of wave height/energy and potential flood damage reduction of constructed enhancement, utilizing as-built surveys.

Modeling methodology will utilize existing available FEMA CHAMP modeling, and will modify topographic and roughness (vegetation) parameters to account for as-built conditions. Results will inform design and provide post-placement results through incorporation of as-built surveys, as well as inform future site selection and design at other sites. Both wave height (in feet) and overall flood elevation (referenced to NAVD88, feet) will be analyzed and reported. The modeling effort will look at a multitude of scenarios, utilizing a combination of multiple variables to inform project goals and impacts as shown in Table 1 below.

It is anticipated that results will indicate that wave height/energy, storm surge and overall flood elevation will be reduced pre- to post-placement, most significantly for smaller, more frequent events. Additionally, results of the wave energy and flood level modeling will be utilized in subsequent HAZUS modeling to determine flood damage reduction benefits.

Table 1 Combination of variables to determine multiple modeling scenarios

Scenario Variables					
Storm Event	Topography	Sea Level Rise	Stacking	Vegetation Density	Vegetation Type
2	Existing Conditions - Post Sandy	Existing	Single Event	No Vegetation	Spartina alterniflora - stunted
10	Existing + 6 inches	2050	Additional 6 inches x 5yrs	50% Coverage	Spartina alterniflora
100	Existing + 12 inches	2100	Additional 6 inches x 10yrs	100% Coverage	Phragmites

Vegetation: The placement of dredged material on a salt marsh can have a variety of impacts on the vegetation. Elevation and tidal flooding are important determinants of vegetation, and placement will result in immediate increases in marsh elevation and changes to depth and duration of flooding. Dredged material composition can also affect the response of vegetation to placement. Dredged material can differ from marsh sediment in texture, nutrient content, pH, and organic matter content. Additionally, the depth of dredged material placed may affect the rate at which vegetation recovers. All of these factors make it hard to predict the exact response of marsh vegetation to placement. Several metrics of abundance and primary productivity will be used to detect the response of vegetation to placement. Metrics include: species richness, percent cover by species, average stem height of dominant plant species, above-ground biomass, and below-ground biomass.

Permanent sampling plots will be established at placement and control sites for this monitoring which will occur during peak growing season (mid July-mid September). At these permanent plots, elevation and depth of placed dredged material will be measured. Monitoring vegetation metrics at the placement sites and control sites before placement, immediately after placement,

and annually for several years after placement—along with the other parameters described in the monitoring plan—will help us to document changes in vegetation in response to placement. Vegetation will also be photo-documented to provide qualitative information on the visible changes in plant communities over time.

At the time of placement, dredged material may bury, flatten, or settle around existing vegetation. It is anticipated that in the first growing season after placement, percent cover and biomass metrics will decrease, but over time vegetation will recover and improve from baseline conditions. Other possible outcomes include: 1) shifts in plant community may occur if the new elevation is within the range of a different habitat type (e.g. conversion from low marsh to high marsh); 2) low-lying unvegetated areas of marsh that have received dredged material may become vegetated over time as marsh plants colonize the area or, in some cases, are planted with native plants; 3) the ratio of above-ground to below-ground biomass may be altered, particularly if the dredged material is rich in nutrients shifting the ratio in favor of above-ground biomass initially.

Monitoring vegetation will help provide information such as: 1) the range of time it takes for marsh vegetation to recover after placement; 2) the relationship between the composition of dredged material and vegetation recovery; 3) the relationship between depth of dredged material placed and vegetation recovery; 4) the potential for colonization by invasive plant species, particularly *Phragmites australis*; 5) the relationship between changes in elevation and tidal flooding and changes in plant health.

Epifaunal Macroinvertebrates: Epifaunal macroinvertebrates (EMI) provide important trophic linkages within salt marsh ecosystems. They are prey for a variety of avian and aquatic species, grazers of vegetation, and contribute to the structure of the marsh substrate by digging burrows (crabs) or attaching to the base of vegetation (ribbed mussels). EMI are vulnerable to sudden changes in microhabitats within the marsh because of their relatively small size, and in some cases, limited mobility. Placement of dredged material will result in changes in marsh elevation, depth and duration of flooding, surface sediment composition of the marsh, and marsh vegetation. While it is difficult to predict how the EMI community will respond to these changes, monitoring EMI is necessary to determine both overall impact to the EMI community and to be able to consider indirect effects of the EMI community on other monitoring parameters, including the avian and nekton communities.

Monitoring to detect changes in EMI communities is very time intensive, and since the project sites are relatively small when compared to the surrounding marsh complex, the likelihood of losing significant EMI communities overall in response to placement, either for long periods or permanently, is relatively low. However, it is still important to perform this monitoring and track responses before beneficial reuse projects are approved and scaled up in NJ. Monitoring of EMI species richness and abundances of snails, crabs, and ribbed mussels will occur in conjunction with vegetation monitoring. This will allow the detection of significant changes to EMI within microhabitats and allow for comparison with changes in the vegetation (see *Vegetation* above).

At the time of placement, dredged material may bury or otherwise displace EMI. It is anticipated that in the first season after placement, EMI species richness may decrease, but over time the EMI community will recover and may even improve from baseline conditions. Additionally, shifts in EMI community may occur if elevation is increased to fall within the range of a different

habitat type (e.g. conversion from low marsh to high marsh). Monitoring EMI will help provide information such as: 1) the relationship between the composition of dredged material and EMI richness; 2) the relationship between depth of dredged material placed and EMI recovery; 3) the relationship between changes in elevation/tidal flooding and changes in EMI community; 4) which vegetation plots are impacted by herbivorous macroinvertebrates.

Benthic Infauna: Benthic infauna are prey for fish and macroinvertebrates and also play a key role in organic matter cycling in salt marshes. Due to the intimate association of benthic infauna with the sediment they live in, the placement of dredged material can potentially affect the abundance and composition of the benthic community. Dredged material is likely to differ from natural marsh sediment in particle size, concentrations of key nutrients (C, N, S and P) and organic matter content, properties which fundamentally affect benthic infauna. The potential effects of dredged material placement on vegetation that are described noted above (e.g. elevation, depth and duration of tidal flooding), are also likely to affect benthic infauna. The abundance and taxonomic composition of benthic infauna and sediment/dredged material properties will be monitored over time at placement and control sites to detect effects of dredged material placement on the benthic community.

Permanent sampling plots will be established at all placement and control sites, in conjunction with the other monitoring efforts. Sampling will be conducted monthly from May through October, the period of recruitment and growth of benthic taxa typical of mid-Atlantic salt marshes. Marsh sediment cores will be taken and analyzed for benthic infauna abundance, species composition and for sediment/dredged material properties. Monthly sampling will commence prior to placement (when possible given grant funding timelines), and will resume monthly one year later, post-placement, and potentially beyond that if additional funding can be secured.

Based on previous studies of enhanced marshes along Delaware Bay and elsewhere, placement of dredged material is likely to result in an immediate decline in abundance of resident benthic infauna, due to burial and mortality. The extent of any decline may be related to the depth of dredged material. Within several months after placement, abundances of opportunistic taxa (those well adapted to colonizing disturbed environments) will likely increase. Further changes in the benthic community will likely be driven by how the properties of the dredged material change over time. The food of benthic infauna consists largely of microalgae growing on the marsh surface and detritus from marsh vegetation. Thus, changes in marsh vegetation over time are likely to correlate with changes in benthic infauna.

Monitoring benthic infauna will provide information on how differences among placement sites (size of site, time of construction, location and composition of dredged material) affect the magnitude and trajectory of the response of benthic infauna. This information can be used to inform future projects. Monitoring sediment/dredged material properties will also provide information related to other monitoring parameters at placement and control sites including nekton, EMI, and vegetation outcomes.

Nekton: Nekton includes motile macroinvertebrates and fish. Their movements and use of the marsh platform and adjacent surroundings are typically controlled by tidal dynamics, specifically the movement of water through tidal channels and the movement of water onto and off of the marsh platform. As such, increases to elevation of the marsh surface and infilling of ditches and

marsh pools related to dredged material placement may have an effect on nekton utilization through alteration or elimination of habitat features. Changes to other marsh features, including vegetation and carbon cycling, could also change nekton use patterns. Given the anticipated small magnitudes of vertical deposition of placed dredged material and the expected recovery of vegetation, generalized use of the marsh platform on flood tides is likely to be little changed. The infilling of marsh pools will have a greater impact to nekton. Wider use and inhabitation patterns of these features may be lost or reduced.

This monitoring exercise will therefore focus on describing nekton in pre- and post-placement settings. Nekton will be sampled during the growing season ensuring full activity levels. Sampling will occur at one-year intervals to replicate seasonality. This approach provides a baseline to measure subsequent changes to nekton communities. Monitoring resolution will be on the sub-habitat level and will examine nekton usage within marsh pools, ditches, tidal creeks and the marsh edge. Sampling methods and metrics are adapted from Neckles et al., 2013. Relatively simple sampling parameters will be used including nekton assemblage, areal density, and *Fundulus* (killifish) length; however, these are deemed in the monitoring guidance cited above to be the most important metrics. Each sub-habitat will be sampled at five randomly selected discrete points during each event. Sampling equipment will include throw traps and ditch nets. In-situ water quality will be measured concurrently.

Ultimately, the data will be compiled and applied statistics will indicate whether there has been significant change to nekton usage at the examined sites over time on a site and sub-habitat basis. Because mobility and tidal hydrology are important aspects of nekton ecology and site use, little impact to the overall use of the site is expected especially with the passage of time. Documenting use patterns will be important in determining wider applicability of beneficial reuse projects and the potential impact to secondary producers as measured by the nekton.

Avian: Placement of dredged material over a marsh platform will likely result in a stepwise shift in both the composition of the avian community and the utilization of the dredged material placement areas subsequent to placement. Initial placement of dredged material will likely create suitable conditions for loafing and foraging activities, primarily by gulls, shorebirds and wading species, depending upon the season. The dredged material will likely contain food items for these species as well. Over time, as vegetation begins establishing, use of these areas will continue to provide loafing and foraging opportunities, but will also introduce refuge/sheltering opportunities as the vegetation becomes established. The refuge/sheltering opportunities will provide smaller passerines, such as sparrows and wrens a place to seek refuge/shelter. As the vegetation becomes taller, nesting/breeding opportunities for sparrows, wrens and rail species will avail themselves while also providing roosting opportunities for larger avian birds, including owls and raptors.

The purpose of these surveys is to identify which avian species utilize dredged material placement sites. Metrics will include avian abundance, avian richness and avian diversity. These metrics will enable analysis of avian community composition over the length of the surveys. The protocols implemented will be taken from *Standardized North American Marsh Bird Monitoring Protocols* (Courtney Conway, 2012). Surveys are proposed within dredged material placement locations, low marsh and high marsh, to document the differences in use between these specific habitat types during the course of the surveys. The potential for the creation of pools, depressions, and/or die off-areas due to the placement of dredged material will be monitored and documented if they develop. Eight (8) to ten (10) permanent survey locations will be established within both impact and control sites, each possessing a 100m survey area

surrounding the permanent locations. Twenty (20) minutes will be spent at each location identifying all species observed within the 100m survey area as well as the habitat type (e.g. high marsh, low marsh, open water, etc.) that each species was observed in. If the monitoring locations have suitable habitat for more secretive marsh birds, a specific broadcast sequence for each particular species will be conducted with a 30-second call series followed by 30-seconds of silence for each callback.

Subsequent to survey efforts, results will be analyzed to determine the differences between abundance, richness and diversity between and across the dredged material placement areas, low marsh, and high marsh portions of the site over time.

Black Skimmer Habitat Use: Dredged material composed largely of fine sand (96%) were placed on the northeast quadrant of Ring Island to establish elevated nesting habitat for black skimmers, a state-endangered species, and other species. Monitoring will occur to document use of the habitat site by skimmers and other species and to evaluate suitability of the site. Metrics will include species richness, species abundance, and reproductive success of skimmers. Together these metrics will provide an assessment of the response of skimmers and other species to the created habitat.

All monitoring activities will occur at the habitat site following creation. To facilitate monitoring, a grid will be established using stakes driven into the sand within 2-4" of surface elevation. Bird surveys will be conducted April to August of each project year following habitat creation. Species, age class and behavior will be recorded during surveys. A combination of direct counts (i.e. walk-through census), remote observation, and digital photography will be employed to meet monitoring needs depending on conditions such as species present, group size and disturbance or predation risks. A random sample of skimmer nests or all nests, depending on number, will be monitored to determine reproductive success. Observations and signs of use by other species, including diamondback terrapin, will be recorded using a combination of direct observations and remote surveillance (e.g. trap cameras). Habitat use will be photo-documented. Vegetation and elevation surveys will be conducted at the habitat site to inform results of habitat use monitoring.

Use of the habitat site by black skimmers, American oystercatchers, tern, and gull species for nesting and roosting is anticipated within the first breeding season following creation. The number of birds using the habitat is expected to increase within and between project years. Reproductive success of skimmers will vary spatially with factors such as elevation and vegetation. Diamondback terrapins are also expected to utilize the site for nesting. Outcomes from monitoring of the constructed habitat on Ring Island will provide insight on 1) response time for skimmers and other species to utilize the site for nesting; 2) relationships between habitat features such as elevation and vegetation; 3) bird use and reproductive success; and 4) overall habitat quality.

4. Appendix of Figures

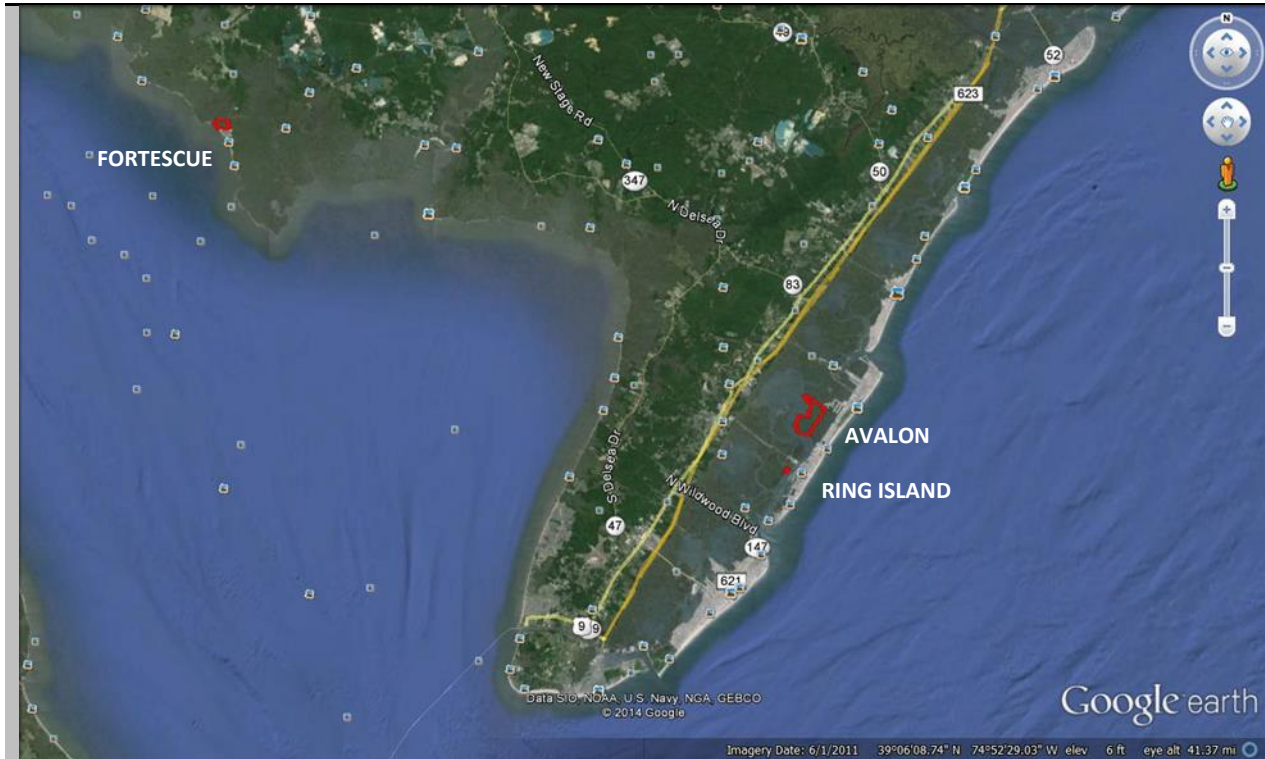
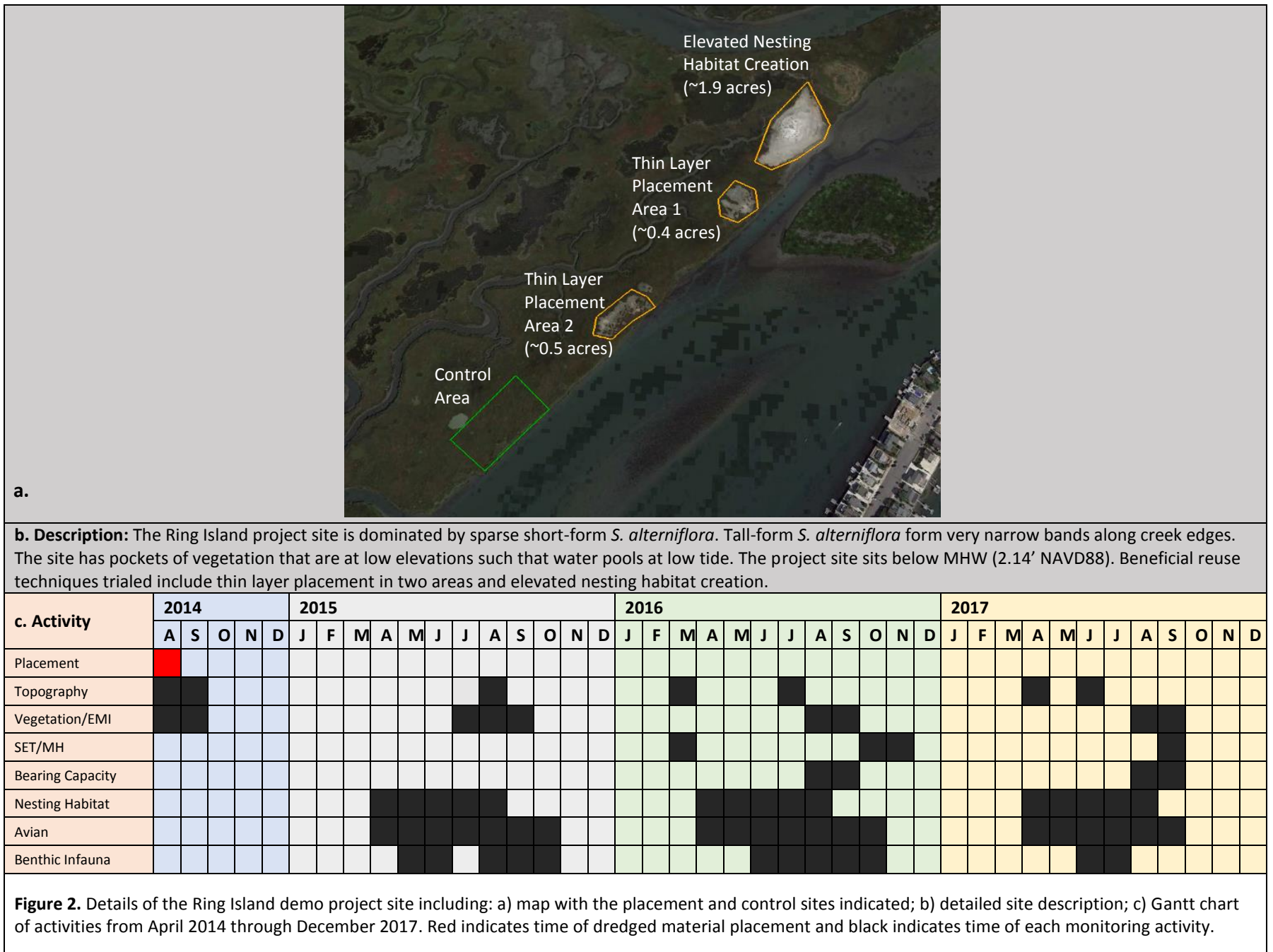


Figure 1. General Project Locations

Ring Island- Cape May Coastal Wetlands Management Area, Middle Township, Cape May County, NJ

Avalon- Cape May Coastal Wetlands Management Area, Avalon, Cape May County, NJ

Fortescue- Fortescue Fish and Wildlife Management Area, Fortescue, Cumberland County, NJ

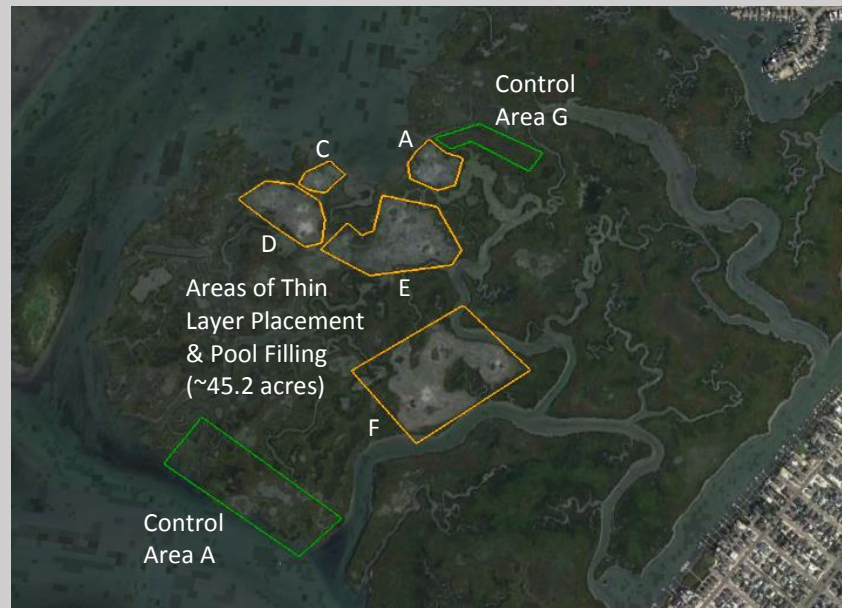




b. Description: The Avalon demo project site is dominated by short-form *S. alterniflora*. The site has large, expanding pool complexes. Edge erosion is severe. Beneficial reuse techniques trialed include thin layer placement of dredged material and pool filling in two areas.

c. Activity	2014					2015												2016												2017												
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Placement																																										
Topography																																										
Vegetation/EMI																																										
SET/MH																																										
Bearing Capacity																																										
Surface Water/Tide																																										
Benthic Infauna																																										
Nekton																																										
Avian																																										
Sediments																																										
Site Inspections																																										

Figure 3. Details of the Avalon demo project site, including: a) map with the placement and control sites indicated; b) detailed site description; c) Gantt chart of monitoring activities from April 2014 through December 2017. Red indicates time of material placement and black indicates time of each monitoring activity.



a.

b. Description: This site is predominantly low marsh habitat, dominated by short-form *S. alterniflora*. The site has large, expanding pool complexes. Edge erosion is severe. Beneficial reuse techniques trialed include thin layer placement and pool filling in 5 areas.

c. Activity	2014					2015												2016												2017														
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D			
Placement																																												
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SET/MH																																												
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Surface Water/Tide																																												
Benthic Infauna																																												
Nekton																																												
Avian																																												
Sediments																																												
Water Chemistry																																												
Site Inspections																																												

Figure 4. Details of the Avalon full-scale pilot project site including: a) map with the placement and control sites indicated; b) detailed site description; c) Gantt chart of monitoring activities from April 2014 through December 2017. Red indicates time of material placement and black indicates time of each monitoring activity.



b. Description: The Fortescue site is predominantly low marsh habitat, dominated by short-form *S. alterniflora*. Several areas of this site contain vegetated hummocks that are separated by low elevation bare ground that is often covered in water. There are large patches of bare ground and several pools. The site has been ditched for mosquito control and these ditches are still present. Tall-form *S. alterniflora* form very narrow bands along creek edges. There are scattered patches of high marsh (*Spartina patens* and *Distichlis spicata*). *Phragmites australis* exists at the site on a berm on the bay side. Beneficial reuse techniques trialed include thin layer placement of dredged material in two areas (Area 1 split into 2 sections) and construction of a dune along the marsh edge of Placement Area 1.

c. Activity	2014					2015												2016												2017													
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		
Placement																																											
Topography																																											
Vegetation/EMI																																											
SET/MH																																											
Bearing Capacity																																											
Surface Water/Tide																																											
Benthic Infauna																																											
Nekton																																											
Avian																																											
Site Inspections																																											

Figure 5. Details of the Fortescue full-scale pilot project site including: a) map with the placement and control sites indicated; b) detailed site description; c) Gantt chart of monitoring activities from April 2014 through December 2017. Red indicates time of material placement and black indicates time of each monitoring activity.

5. Appendix of Monitoring Plans

Monitoring Plan Title: Topography and Elevation Monitoring

Monitor: GreenVest, LLC

A. List of metrics

1. Topography/Elevation (NAVD 88)
2. Horizontal extent of placement¹ (NAD 83)

B. Monitoring design

1. Spatial design: Topography/Elevations shall be monitored along permanently established transects placed at 50 foot intervals across at placement and control sites. Elevations will be taken at 10 foot intervals along each of the permanently established transects using a Real Time Kinematic (RTK) Global Positioning System (GPS) survey equipment. Each elevation point will have a permanent defined coordinate to facilitate repeated surveying. In addition to these transects, other locations will be surveyed including but not limited to bio-benchmarks, tide gauge stations, permanent vegetation monitoring plots and surface elevation tables.

Horizontal extent of placement will be monitored at each placement site to document the limits of placement and migration of dredged material. Limits shall be documented as possible using a GPS or aerial imagery.

2. Temporal design: The topographic survey/elevation monitoring will follow a BACI design. Elevation/topographic surveys will be conducted at placement and control sites during low tide and at the following times:
 - prior to placement to document pre-placement marsh elevations (baseline),
 - immediately following placement of dredged material (as-built). In order to allow for adequate dewatering and settlement this survey shall be completed no sooner than 5 days following placement and otherwise as soon as possible. This will be compared to the pre-placement condition to document the change in elevation and configuration, and
 - periodically after the placement of dredged material to document changes in elevation and configuration over time.

C. Detailed methods

1. Methods for topography/elevation surveys:
 - Equipment/Supplies:
 - RTK GPS backpack unit
 - Procedures:
 - Locate permanent transects (established in the office prior to fieldwork).
 - Record marsh surface/substrate elevations at 10 foot intervals along the prescribed transect.

¹ "Placement" refers to the placement of dredged material on the project site. The word placement is consistently used to mean this throughout this document.

- Record marsh surface/substrate elevations at other locations of interest (bio-benchmarks, permanent vegetation monitoring plots, tide gauge stations, surface elevation tables, etc.).
- 2. Methods for survey of extent of placement:
 - Equipment/Supplies:
 - GPS unit
 - Aerial imagery
 - Procedures:
 - Track the limits of the placement sites using GPS survey equipment

D. Data management and quality analysis/quality control

1. Data collection: All field work will be processed in NAD 83/NAVD88 horizontal and vertical datums within the NJ State Plane Coordinate System. RTK-GPS survey will be completed in order to ensure accuracy to 0.1 feet. Survey sub-contractors will complete topographic/elevation surveys in accordance with standard practices and mapping will be produced by a Licensed NJ professional land surveyor.
2. Data storage: Elevation data will be in excel worksheets and GIS shapefiles. Horizontal extent data will be stored as GIS shapefiles. The resulting Excel worksheets and GIS shapefiles, will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: GreenVest will review the digital data/work product to identify data gaps, if any, that must be filled by the surveyor. Elevation data for survey points along each of the permanent established transects will be interpolated across the survey areas to allow for comparison of pre- and post-placement conditions. Summary reports describing means/methods and results will be produced. The resulting reports will be stored in a cloud storage location that is shared by the project team (Box).

Monitoring Plan Title: Surface Elevation Table (SET)/Marker Horizon (MH) Monitoring Plan
Monitor: The Nature Conservancy

A. List of metrics

1. Elevation (NAVD 88)
2. Elevation (mm)
3. Net accretion (mm)
4. Shallow subsidence (mm)

B. Monitoring design

1. Spatial design: Shallow and deep Surface Elevation Tables (SETs) were located within placement and control areas at Fortescue, Ring Island, and Avalon: three shallow/deep pairs (stations) were established within control areas and three stations within placement areas for each site. Each SET station was also paired with at least three Marker Horizons (MHs). SET station locations were identified after placement was completed at each site to ensure placement areas received placement. SETs were deliberately associated (within 2m) with TNC's permanent vegetation plots to allow cross metric comparisons. Baseline conditions at permanent vegetation plots were used in SET site selection. Parameters for SET site selection included:
 - Within 2 m of a permanent vegetation plot with available baseline vegetation data
 - Distance of >30 m from channels and creeks
 - Other marsh surface features (i.e., mosquito ditches; interior ponds, etc.) will be avoided whenever possible when locating each SET
 - SET locations were selected within a specific elevation range below MHHW
 - Placement area plots must have received placement
 - Starting vegetation community in permanent vegetation plot had at least 46% cover of *Spartina patens* or *Spartina alterniflora*
 - SETs must be at least 15m apart.
2. Temporal design: SETs were installed post-placement and therefore installation times varied by site (see Table 1). The SETs were given at least two weeks to settle, after which an initial reading was taken and marker horizons established. At all subsequent readings of the SETs, each of the marker horizons established around each SET were sampled to estimate net accretion. Data were collected once every season post-installation during the grant period. Care should be taken to replicate monitoring conditions (same tidal stage, tidal amplitude, and time within the season) whenever possible in subsequent years. Additionally, sampling of an entire site or pair of sites (i.e. control-placement pairs) should be completed as closely together as possible. SETs are a long-term monitoring tool, and monitoring will continue annually between August 25th and September 15th after the end of the grant period.

Table 1: Installation and reading dates for SETs and Marker Horizons

Site	Deep SET Installation	Shallow SET Installation	Marker Horizons Laid	Baseline SET Readings	SET Readings to Date
Ring Island	Mar 2016	Oct 2016	Nov 2016	Nov 2016	Sep 2017
Avalon	Oct 2016	Oct 2016	Nov 2016	Nov 2016	May/June 2017, Sep 2017
Fortescue	Mar 2017	March 2017	May 2017	May 2017	Aug 2017

C. Detailed methods

1. Field methods for SET installation:

- General equipment:
 - map/aerial photo showing SET locations
 - GPS with location points (extra batteries for GPS)
 - waterproof data book + pencils
 - portable platforms
 - gorilla carts or sled to transport materials
 - demolition hammer + driving attachment
 - driving heads (2) + extra screw locks
 - generator
 - angle grinder with charged battery + discs
 - narrow planting (sharpshooter) shovel
 - post hole digger
 - gloves, eye protection, hearing protection, hard hats
 - knife
 - five-gallon buckets (3)
 - small plastic cups (3)
 - concrete trowels (2)
 - small hand sledge hammer
 - rubber hand sledge
 - trash bag
 - tool box with various tools
 - vise grip pliers (2)
 - wrench (9/16 inch)
- Supplies (per group of 3 SETs):
 - driving points/tips (3)
 - rods (60)
 - 6" PVC pipe ~18" in length (3)
 - white PVC marker (3)
 - 60 lb bag of concrete (3)
 - receiver heads (3)
 - extra lock screws
- Procedures:
 1. Load coordinates of SETs into GPS.
 2. Navigate to the point vicinity, being careful not to step on the marsh within a 2 m radius of the SET point.
 3. Erect portable platforms over the SET point.

4. Standing on the platform, cut an 8 inch hole in the marsh turf, about 18 inches deep using the post hole digger.
5. Place the driving tip on the first steel rod and tighten with vice-grip pliers.
6. Drive the stainless steel rod into the marsh, keeping it as straight (vertical) as possible.
7. Connect successive rods, ensuring the screw is tightened into the rod with vice grips.
8. Insert rods until the point of refusal, using a jack hammer. Guide the rod into the hole to prevent bending or breaking. For each point record:
 - Name and/or number of point
 - Latitude & Longitude
 - Number of rods
 - Was last rod cut?
9. When no more rods can be driven (the point of refusal), cut off the last rod at marsh level.
10. Place a 6-inch PVC pipe into the hole so that it rests just above marsh level.
11. Fill the PVC pipe with cement to about 6-inches below the top.
 - Bail water out of the pipe
 - Pour in dry cement
 - Mix with a narrow shovel
12. Place the receiver at the top of the stainless steel rod. Be sure the longer screws are at the bottom. Tighten with a wrench.
13. Overfill the PVC pipe, smoothing the top so that it sheds water.
14. Place a 1.5 inch PVC pipe near the SET point to aid locating it in the future.

2. Field methods for MH installation:

- Equipment:
 - map/aerial photo showing SET locations
 - GPS with location points (extra batteries for GPS)
 - waterproof data book + pencils
 - portable platforms
 - gorilla carts
 - gloves, eye protection, masks
 - five-gallon buckets (3)
 - small plastic cups (3)
 - knife
 - trash bag
 - tape measure
 - meter stick
 - small hand sledge hammer
- Supplies (per group of 3 SETs)
 - (3) 5-gallon buckets + lids, each with 25# of G200 feldspar
 - ½ inch white schedule 40 PVC marker stakes 2 ½ ft long (42): 14 stakes are used at each SET
- Procedures:
 1. Safety Note: Feldspar dust should not be inhaled, consider wind direction when applying feldspar or use an appropriate mask.
 2. Navigate to the SET keeping 2 m away from the monument itself.

3. Place a stake ~2 m from the SET monument in line with the notch (If the direction of the notch is unknown then erect a platform to access the SET to unscrew the cap).
4. First, extend a measuring tape to three meters adjacent to the SET area. Second, without disturbing the area within 1 m of either the monument or the to-be-established feldspar plots, walk the tape over to the SET area such that the 1.5 m mark is over top of the SET monument. Third, place a temporary stake at each end of the meter tape (0 m mark and 3 m mark).
5. First, measure 1.5 m at a 90° angle from one of the temporary marker stakes to place a stake marking the outside corner of the first feldspar plot. Second, measure 1.5 m in the opposite direction from the temporary marker stake used previously. This forms the outside corner of the second feldspar plot.
6. Repeat step 4 for the opposite side of the SET area. You can now remove the two temporary marker stakes.
7. Ensure the 4 corner stakes form a square that measures 3 m on each side.
8. Stake out the first feldspar plot with each side measuring 0.5 m. Using a meter stick is recommended.
9. Stake out the final two feldspar plots.
10. Place 1/3 of the 25 lbs feldspar in each of the three plots (approx. 8 lbs for each plot). Take care to not inhale the dust by considering wind direction when applying. Ensure feldspar contacts marsh surface by gently brushing any that lies on top of vegetation.

3. Field methods for SET reading:

- Equipment/Supplies:
 - map/aerial photo showing SET locations
 - GPS with location points (extra batteries for GPS)
 - waterproof data book + pencils
 - portable platforms
 - SET reader arm + 9 pins
 - coupler
 - two clamps
 - mm ruler (2)
- Procedures:
 1. Navigate to the SET keeping 2 m away from the monument itself.
 2. First erect a platform next to the SET (in line with the SET marker stake) using the aluminum plank and the two stools. Next, insert the coupler into the SET. Ensure that the button on the coupler recesses all the down into the slot on the SET monument. Finally, screw down the grey plastic piece on the bottom of the coupler.
 3. Affix the reader arm to the coupler with the pin side of the reader arm in line with the “1” on the round disk top of the coupler. You are now reading quadrant 1.
 4. Clamp the reader arm to the coupler using the two clamps.
 5. Using the two adjustment wheels, ensure that the reader arm is level. On top of the reader arm is a bubble.

6. Insert the numbered pins into their corresponding holes on the top of the reader arm. Using the clamps on each rod, do not allow pins to approach the marsh surface at this time.
7. Before lowering pins to the marsh surface, recheck the bubble level indicator at the top of the reader arm. Ensure it is level. Next, carefully lower each pin to the marsh surface by first unclipping the pin. Do not let it fall on its own. Once the pin encounters the proper resistance, clip it in place at the top edge of the bar.
8. Using the ruler, measure (in mm) the height of the pins above the top surface of the reader arm. When reading the height, be sure to view the ruler at a 90° angle for each measurement.
9. Record each measurement in a data book/data sheet. If the pin does not encounter the proper resistance before going below the top surface of the reader arm, record a zero.
10. First, raise the pins back to their starting positions and clip into place. Second, remove the two clamps holding the reader arm to the coupler. Next, rotate the reader arm 90° in a clockwise fashion. The arm should hold in place initially because there are built-in grooves every 45°. Finally, carefully reposition the bench and reclamp the reader arm to the coupler. You are now reading in Quadrant 2.
11. Repeat steps 5, 7, 8, 9 and 10 to perform readings in Quadrant 3.
12. Repeat steps 5, 7, 8, 9 and 10 to perform readings in Quadrant 4.
13. Repeat Steps 2-12 to read the shallow SET.

4. Field methods for MH sampling:

- Equipment/Supplies:
 - GPS or paper map
 - Sharp knife (at least 6cm long)
 - Ruler (mm)
 - Datasheet or field notebook
- Procedures:
 1. At the time of each reading, a core is collected from each marker horizon.
 2. Cut a small four-sided plug (about 3 cm x 3 cm) from within the marker horizon plot. If there are extensive roots, it helps to have a sharp knife. A long serrated kitchen knife works well.
 3. Pry the plug out of the ground from one of the sides. The plug will be about 3 cm x 3 cm x 6 cm in size. You need to make sure the core is deep enough to include the marker horizon. The depth is also related to the length of your knife blade.
 4. You should be able to see a marker layer right away. It's difficult to scrape a core that's not frozen, but you can give it a try to improve the visibility of the layer.
 5. Try to get 4 readings from a single plug, one representative reading from each side of the plug.
 6. Put the plug back into the ground.
 7. Move on to your next marker horizon plot and repeat the above steps.

D. Data management and quality assurance/quality control

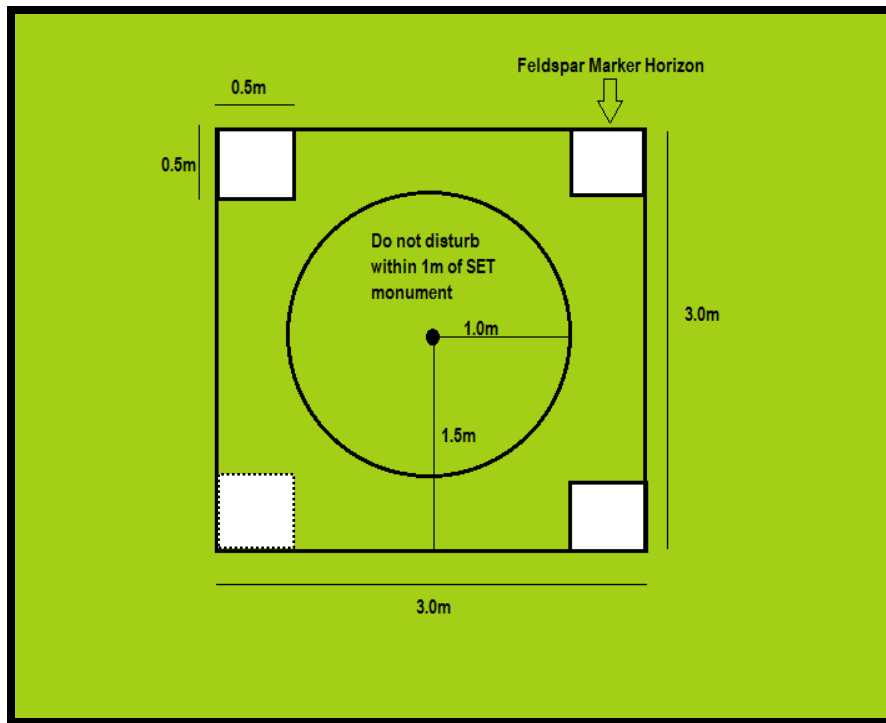
1. Data collection: Final coordinates of each SET will be taken with a GPS in the field at the time of installation. SET/MH readings will be performed by a limited number of trained individuals to ensure accuracy of assessments. Data from readings will be recorded in a dedicated field notebook.
2. Data storage: Final coordinates of each SET will be uploaded from the GPS unit and converted into shapefiles using the DNRGarmin application. Field datasheets will be scanned. Data will be transferred from the datasheets into Excel worksheets. QA/QC for data entry is accomplished by random checks by the principal investigator, comparing datasheet entries with electronic file entries. Any photos will be uploaded and labelled. The resulting digital copies of field datasheets, Excel worksheets, shapefiles and photos will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis:
 - Elevation (NAVD88): The one-time measure of elevation in NAVD88 using RTK-GPS at each SET will be used to convert all SET readings from mm to NAVD88.
 - Surface elevation (mm): All 36 readings (9 pins x 4 positions) from each SET will be averaged for each reading to give one measure of surface elevation. The change in surface elevation (mm) will also be calculated every time a SET is read using the current averaged elevation reading and the initial averaged elevation reading.
 - Net accretion (mm): Readings from the three marker horizons at each SET will be averaged for each reading.
 - Shallow subsidence (mm): Shallow subsidence will be calculated every time a SET is read by subtracting the change in surface elevation (mm) from net accretion (mm). Positive values represent shallow subsidence. The answer should never be negative.
 - All metrics will be analyzed for significant differences between placement sites and control sites within and between years and within distance strata between placement sites and control sites within and between years. Independent measures and matched-pair t-tests will be used where datasets are normal and homogeneous, otherwise non-parametric equivalents will be used.
 - Accretion will be analyzed for relationships to elevation between placement sites and control sites within and between years, and within distance strata between placement sites and control sites within and between years. One-way independent measures ANOVA and one-way paired measures ANOVA tests will be used where datasets are normal and homogeneous, otherwise non-parametric equivalents will be used.

E. References

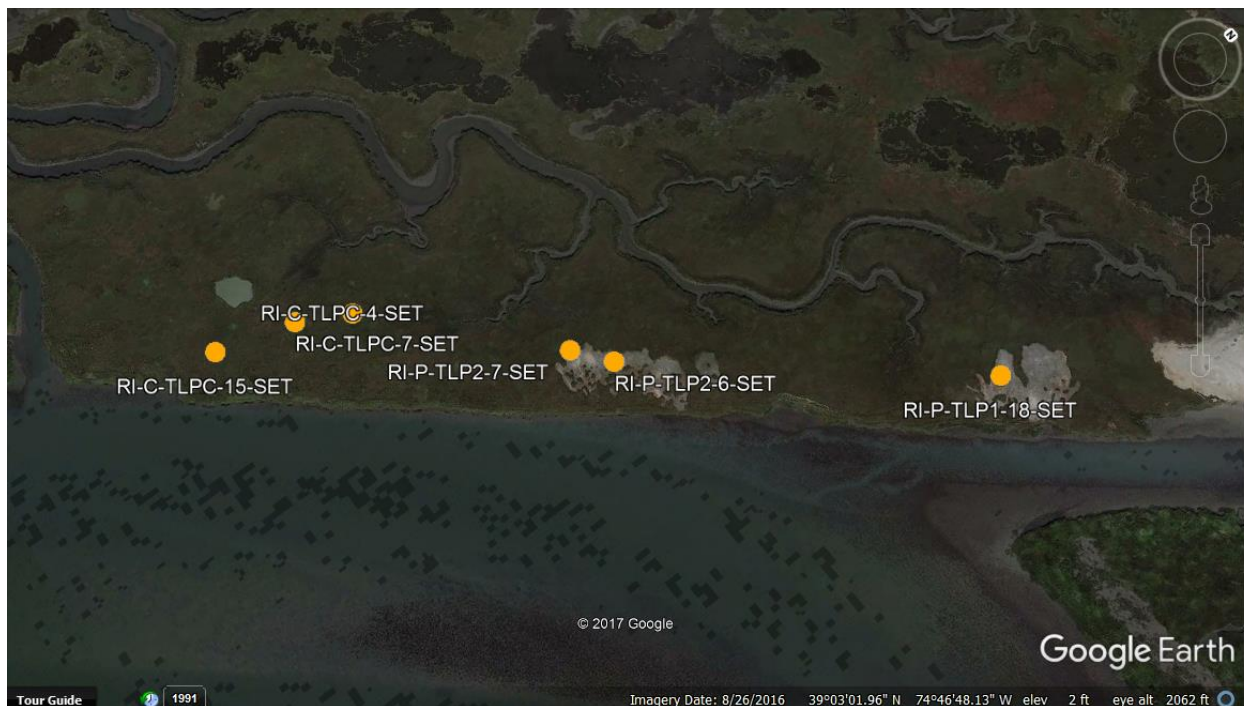
1. Plans developed based on The Salt Marsh Integrity Index monitoring plans developed for Forsythe National Wildlife Reserve
2. USGS Surface Elevation Table website: <http://www.pwrc.usgs.gov/set/>

F. Appendix

1. Visual representation of the layout of an individual SET and marker horizon sampling station



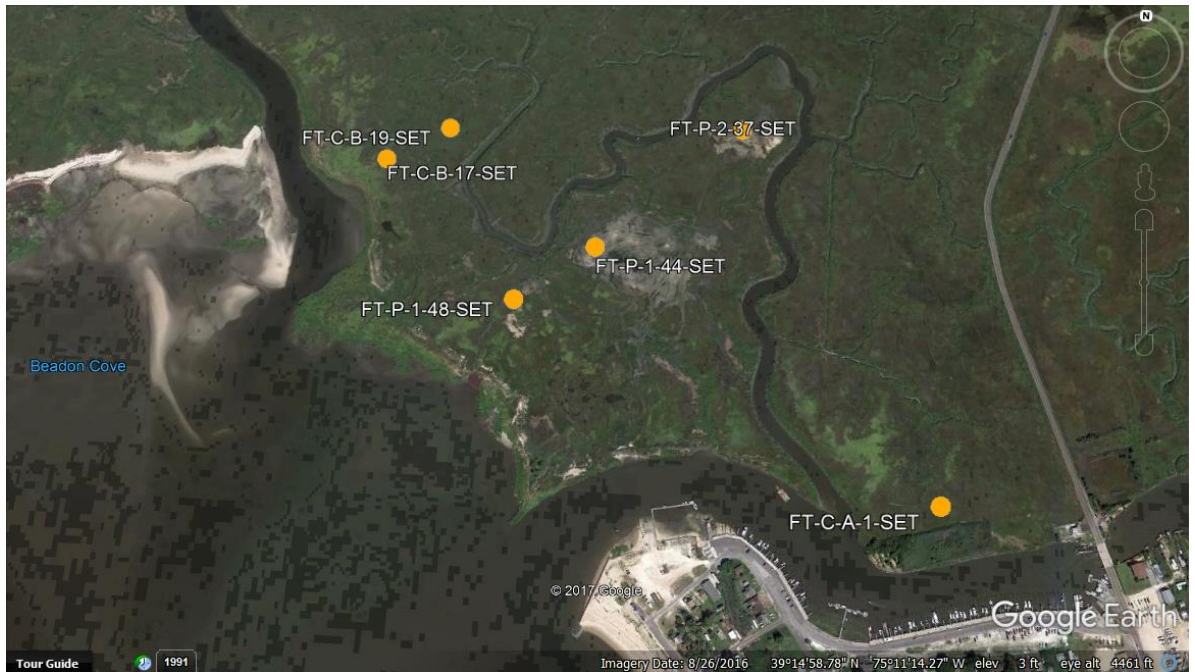
2. Map of placement and control SET stations at Ring Island



3. Map of placement and control SET station locations at Avalon



4. Map of placement and control SET stations at Fortescue.



5. Field data sheet for SET readings and Marker Horizons

Site:						Date:			
Control/ Placement:						SET ID:			
Area/Polygon:						Reader	1.		
SET – measurements (mm)							2.		
Benchmark	Deep				Shallow				
Direction									3.
Bearing									4.
Pin	Height	Height	Height	Height	Height	Height	Height	Height	Notes:
1									
2									
3									
4									
5									
6									
7									
8									
9									
Marker Horizon – measurements (mm)					<input type="checkbox"/> Cryo <input type="checkbox"/> Cut Plugs				
A									
B									
C									
D									
Additional Notes: (weather, dominant plant species, Map of site, etc.):									

Data QA/QC	Color	Date	Initials
Field Review	N/A		
Entered in DB			
DB Review			

- Slide Hammer with PVC cap
 - The slide hammer is the top, weighs eighteen pounds and is attached to a PVC ring with a 5/8th inch bolt
 - The base of the instrument is a 2-inch capped PVC tube with a centimeter scale marked on its side. The PVC pipe is one-meter-long and has a flat cap on the bottom (makes total diameter 2.5").
- **Procedure:**
 1. Fill out datasheet
 2. At each permanent vegetation 1 m² quadrat, use a compass to find the southeast corner (or given corner for that year). Take the bearing capacity within a 25 cm radius outside of that corner of the permanent quadrat. (In subsequent monitoring bearing capacity will be measured clockwise around the quadrat)
 - i. If plot does not seem suitable in best judgement (bird nest, containment, previous biomass samples taken etc.) or is drastically different from conditions within the vegetation plot, move the subplot to another corner. Make note of why the subplot was moved.
 - ii. If vegetation is present, move it gently out of the way so that the PVC cap is resting on as much bare ground as possible.
 3. Measure and record the depth of surface water at each sub-plot in centimeters.
 4. Measure bearing capacity:
 - i. Assemble the PVC tube and the slide hammer together first and then place gently on wetland surface at determined location.
 - ii. Measure initial compaction by recording how deep the PVC penetrates into the ground without exerting any force, using the centimeter scale on the PVC pipe. Record this as 'Initial Depth'. Note: if there is water on the marsh, take readings at the surface of the water, not at the surface of the marsh.
 - iii. Lift and extend the slide hammer fully. Release the hammer and allow it to fall freely with gravity.
 - iv. Without moving the slide hammer, measure compaction by reading where the marsh or water surface aligns with the centimeter scale on the PVC pipe. Record the depth as 'Blow 1'.
 - v. Repeat steps c and d for Blows 2-5.
 - vi. In the office, subtract initial depth from final depth to calculate penetration depth.
 5. Measure placement depths:
 - i. In each corner and in the center of the permanent quadrat, gently but firmly insert the meter stick until it meets a point of resistance which can be hard soil beneath placement or plant matter.
 - ii. Record the placement depth in centimeters.
 6. Record sediment observations:
 - i. Make a note of surface sediment grain size/texture (i.e., sand, fine sediment, or organic material), color, and presence of roots, algal mats, anoxic sediment, iron, etc. If the substrate or vegetation cover are different between plot and subplot, make a note.

D. Data management and quality analysis/quality control

1. Data collection: Data will be collected manually on datasheets or a rugged field tablet (as of 2017) in the field.

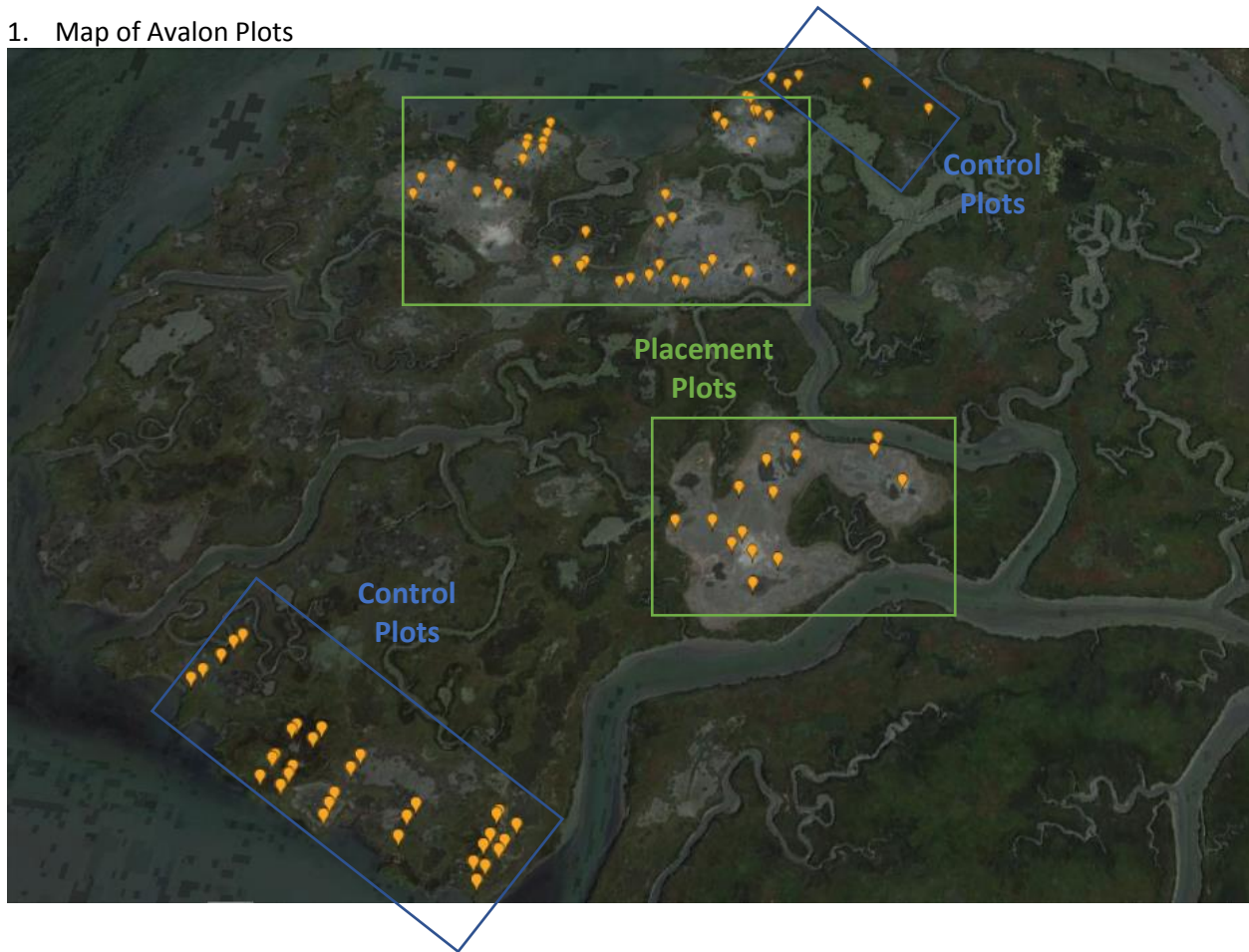
2. Data storage: Data will be transferred to Excel spread sheets and then quality assured by a secondary person. The digital data workbooks and scanned field datasheets will be stored on the TNC server.
3. Data analysis: Average placement depths will be calculated for each plot. ANOVAs will be used where datasets are normal and homogeneous; otherwise non-parametric equivalents will be used to relate Bearing Capacity and placement depths to other metrics including vegetation cover (see Vegetation, Biomass, and Epifaunal Macroinvertebrate Monitoring Plan)

A. References

1. Bertness MD, Miller T (1984) The distribution and dynamics of *Uca pugnax* burrows in a New England salt marsh. *Journal of Experimental Marine Biology and Ecology* 83:211–237
2. Mid-Atlantic Tidal Wetland Rapid Assessment Method Version 3.0
([http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Documents/Tidal%20Rapid Protocol%203.0%20Jun10.pdf](http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Documents/Tidal%20Rapid%20Protocol%203.0%20Jun10.pdf))

B. Appendix (next page)

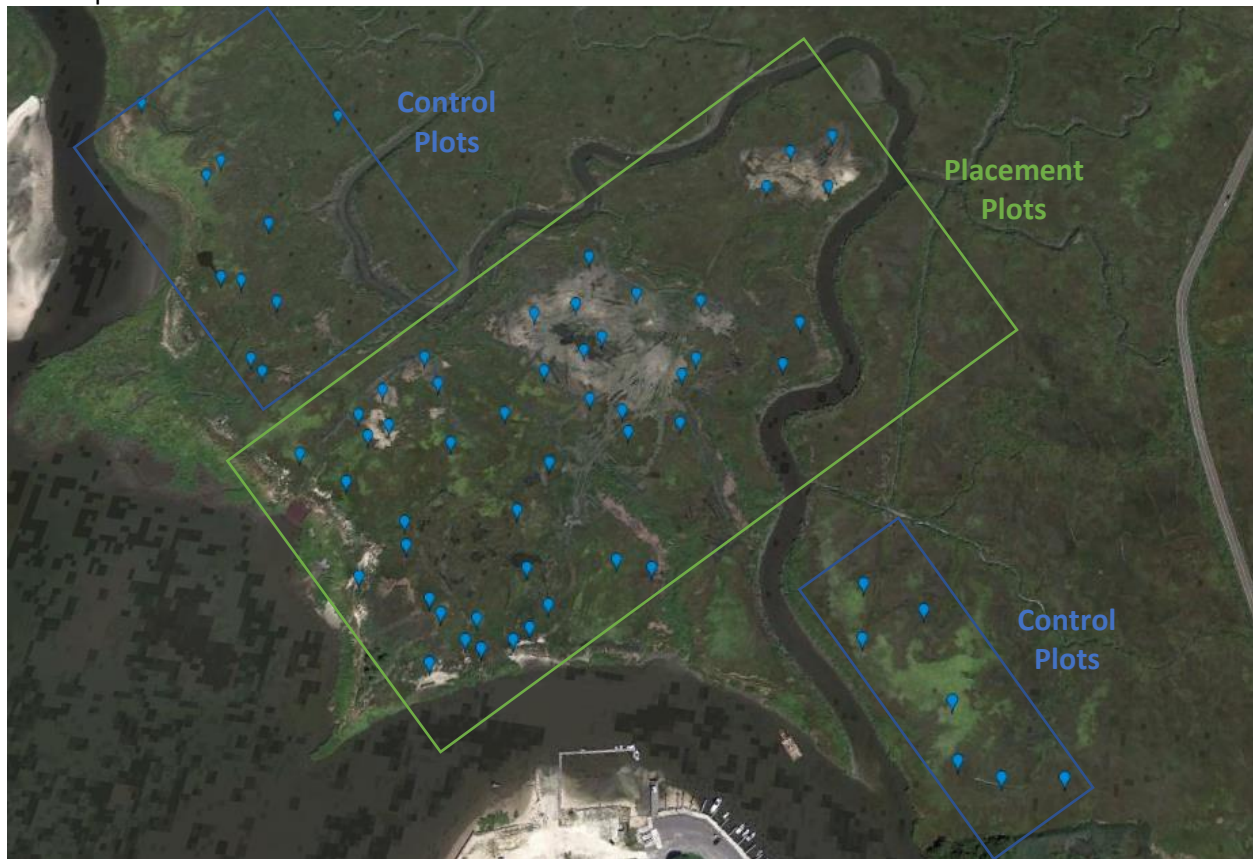
1. Map of Avalon Plots



2. Map of Ring Island Plots



3. Map of Fortescue Plots



4. Data Sheet Template:

Date: _____
Field Crew: _____
Site: _____
Control/Placement (circle) Polygon/Area: _____
Tide: L-----H

Cover type/Species: Bare (Includes wash/placement), wrack/litter, water, rock, trash, large macroalgae, dredge material	
Spa alt	<i>Spartina alterniflora</i>
Spa pat	<i>Spartina patens</i>
Sal spp	<i>Salicornia</i> species
Dia spi	<i>Distichlis spicata</i>
Lim car	<i>Limonium carolinianum</i>

Braun-Blanquet cover scheme:

- 0: Less than 1% (only 1 specimen in plot)
- 1: 1% to 5% cover
- 2: 6% to 10% cover
- 3: 11% to 25% cover
- 4: 26% to 50% cover
- 5: 51% to 75% cover
- 6: 76% to 100% cover

Crab Burrows	
None	0
Low	1-10
Medium	11-20
High	21+

Expected EMI Species	
Mel bid	<i>Melempus bidentatus</i>
Ily obs	<i>Ilyanassa obsoleta</i>
Ova myo	<i>Ovatella myosotis</i>
Lit lit	<i>Littorina littorea</i>
Ses ret	<i>Sesarma reticulatum</i>
Uca pug	<i>Uca pugnax</i>
Geu Dem	<i>Geukensia demissa</i>

[illegible]

Monitoring Plan Title: Sediment Monitoring

Monitor: Princeton Hydro, LLC

A. List of metrics

1. Physical Characteristics:
 - Particle Size
 - Organic Content
 - pH
 - Unit Weight
 - Porosity
2. Sulfates
3. Sediment Metals:
 - Target Analyte List (TAL) of 23 metals
4. Sediment Nutrients:
 - Nitrate
 - Total Phosphorus

B. Monitoring design

1. Spatial design: 40 sediment samples will be collected and analyzed from within and adjacent to Avalon Placement Area A, Placement Area D, Placement Area E, and Placement Area F. Placement Area C was not included in this study due to the fragmented distribution of placed sediment/dredged material within this area, and its relatively large percentage of marsh pool area. Each placement area contains multiple zones, which are generally defined by elevation. Salt marsh elevation is critically important because it is the primary characteristic that affects the growth of vegetation. In addition, based on qualitative observations, it appears that sediment/dredged material physical characteristics may vary with elevation. The attached Sample Location Map for each placement area identifies the proposed sampling locations and their approximate elevation range. In general, the sample locations are distributed as follows:
 - 31 samples within the four (4) placement areas
 - 6 samples in vegetation die-off areas adjacent to Placement Areas A and D
 - 3 additional samples (locations to be determined in the field) in locations of vegetation recovery within a placement area, to be paired with a nearby sample location with no vegetation recovery. Ideally these sample locations will be collocated with TNC monitoring plots.

The baseline for sampling locations was established using a grid format that varied with the size of the placement/die-off area. Placement Areas A and D utilized a 100 x 100 ft grid format, and Placement Areas E and F utilized a 125 x 125 ft grid format. Differences in grid size in the placement areas were a result of the total acreage within each area. At least one (1) sample is proposed within each elevation range in each placement area. In the vegetation die-off areas (Placement Areas A and D), seven (7) samples will be collected, three (3) in Placement Area A and four (4) in Placement Area D. We have co-located our proposed samples so as to coincide with The Nature Conservancy's (TNC) monitoring of vegetation plots throughout the placement areas. These vegetation plots will be monitored for an additional 5 years (by others) and results from the monitoring may prove to be valuable in the future. We have also reserved three (3) sample locations for selection in the field based on observed conditions. These locations will be selected in the field with the goal of sampling adjacent areas of natural vegetation recovery vs. no recovery within a selected

placement area(s). The preference is to locate these samples adjacent to TNC monitoring plots.

2. Temporal Design: Sediment monitoring was added in 2017, conducted at Avalon two years post-placement.

C. Detailed methods

1. The attached Sample Location Maps show the approximate locations of the samples. Each sample location (x, y, and z coordinates) will be documented in the field using a Leica survey grade GPS unit.
2. To obtain the samples required for method ASTM D 7263, in situ sediment/dredged material core samples will be collected using ASTM D2937 (Density of Soil in Place by the Drive-Cylinder Method). This method utilizes thin-walled “Shelby” tubes which are progressed through the sediment and extracted while minimizing sample disturbance. Samples will be collected to the depth of the underlying pre-placement marsh surface (typically 4 to 8 inches). Samples of sediment/dredged material placed in pooled areas of the marsh will not exceed 12 inches in length. Immediately adjacent to the core sample locations (within 1 meter), manual excavation techniques will be used to collect sediment/dredged material grab samples for the remaining physical and chemical analyses. Samples will be collected to the same depths as those of the “Shelby” tube samples noted above, and will be representative of the entire depth of collection.
3. Subsequent to sample collection, the collected sample will be examined and logged by a Princeton Hydro geologist using USDA classification and description techniques. The methods of examination and logging will be documented in accordance with Version 3 of the Natural Resource Conservation Service field classification manual. At each sampling location, soil textures will be estimated using the Thin Soil Texture by Feel analysis. Laboratory grain size results (discussed below) will be utilized to cross-reference or update the field USDA classifications.
4. The sediment/dredged material grab samples will be completely homogenized, and then sub-sampled to provide the volume/mass required for each of the physical and chemical analyses. Each sub-sample will be placed in a pre-labeled container suitable for each specific analysis.
5. A digital photograph of each sampling location and sample will be taken. The photo log will include, but may not be limited to, pictures of immediately adjacent areas, close-up shots of the sediment surface before sampling, and photos of the exposed soil profile (if intact) with a reference scale. It is noted that water seepage and excessive soil slough may prevent a detailed examination of the soil profile. Each photograph will include a “sign” identifying the sample location.

D. Data management and quality assurance/quality control

1. Sample Handling: Sample handling, storage, and preservation procedures will follow the requirements in the relevant analytical test methods. Holding times for each analysis, as specified in the analytical methods, will be adhered to. All sampling utensils and containers will be appropriately cleaned, and solvent-rinsed (acetone is preferred; however other approved solvents such as methanol or hexane can be used as well) to minimize any sample contamination. Samples will completely fill the storage container, leaving no head space, except for the expansion volume required for potential freezing. Samples will be placed in a cooler on ice, refrigerated, or frozen with dry ice immediately after sample collection. Chain of custody documentation for each individual sample for laboratory analysis will be

maintained. The samples will be stored in laboratory provided coolers at 4°C and will be delivered or picked up by IAL (Environmental Testing Laboratory) or Princeton Hydro, LLC Soil Laboratory proceeding each day or every other day of sampling.

2. Data analysis:

- Physical Characteristics:
 - The collected sediment/dredged material samples will be analyzed for physical characteristics that may influence vegetative growth and survival on the marsh. The physical parameters of concern include bulk density, porosity, organic matter content, pH, and grain size distribution. The following test methods will be used to measure these physical characteristics:
 - ASTM D 7263 – Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
 - ASTM D 2974 – Standard Test methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
 - ASTM D 422 – Standard Test Method for Particle-Size Analysis of Soils (with Hydrometer)
 - ASTM D 4972 – Standard Test Method for pH of Soils
 - Note: The results of the unit weight (ASTM D7263) and an estimated specific gravity value will be used to calculate the porosity of each specimen. The specific gravity estimation will be based on an examination of the parent material and the results of the grain size analysis.
 - The analyses identified above will be performed at Princeton Hydro's in-house AASHTO and USACE certified soils testing laboratory.
- Sulfates:
 - One of the most important results of the loss of tidal flow over a marsh is the absence of reducing sulfidic conditions in the marsh sediment. Hydric soil formations are developed through anaerobic (anoxic) conditions, which result from prolonged periods of soil saturation. These anaerobic environments make sulfide materials readily available for sulfur adaptive bacteria that convert sulfate to sulfide (hydrogen sulfide) and pyrite. Often these processes are accelerated through an increased concentration of organic material. While sulfidic soils do not cause an issue under natural tidal regimes, when these soils are left to dry, the sulfides in the soil begin to oxidize producing sulfuric acid and eventually jarosite, which significantly lowers the soil pH (<4.0)⁸. These processes create elevated acidic conditions that could negatively impact marsh vegetation and aquatic organisms.
 - In order to determine the sediment/dredged material's potential to oxidize sulfate and produce sulfuric acid, samples will be subjected to a sulfate test (SM 4500 SO₄-E/EPA 9038).
- Sediment Nutrients:
 - Nitrogen and phosphorus in soils are the primary nutrients needed for plant growth. Although nutrients can be beneficial for the revitalization of plant growth, excess nutrients may also result in a decline of the recovery of the marsh. Differences in nutrient concentrations in pre-placement salt marsh sediment and the placed dredged material could impact vegetation growth/survival, and alter the vegetation species composition. Laboratory

testing will include analytical methods for sediment/dredged material nitrate (SM 4500 NO3-F) and total phosphorous (SM 4500P-E) concentrations.

- Sediment Metals:
 - Healthy salt marshes can be a sink for trace metals. These metals are often bound to organic matter and sulfides that result from anaerobic sediment conditions. Tidal flow into the dredged material placement areas would cause oxidized conditions, solubilizing sediment-bound metals into pore water and the overlying water column. Acidic sediment could also further increase the solubility of metals. These metals may indirectly or directly affect the growth/survival of marsh vegetation.
 - The following metals will be analyzed using methods SW-846 6020A and SW-846 7471B (for Hg):

Name	Name Symbol	CAS	Units: mg/kg (ppm)
Aluminum	Al	7429-90-5	0.5
Antimony	Sb	7440-36-0	0.5
Arsenic	As	7440-38-2	0.5
Barium	Ba	7440-39-3	0.5
Beryllium	Be	7440-41-7	0.5
Cadmium	Cd	7440-43-9	0.5
Calcium	Ca	7440-70-2	5
Chromium	Cr	7440-47-3	0.5
Cobalt	Co	7440-48-4	0.5
Copper	Cu	7440-50-8	0.5
Iron	Fe	7439-89-6	5
Lead	Pb	7439-92-1	0.5
Magnesium	Mg	7439-95-4	5
Manganese	Mn	7439-96-5	0.5
Mercury	Hg	7439-97-6	0.0125
Nickel	Ni	7440-02-0	0.5
Potassium	K	7440-09-7	5
Selenium	Se	7782-49-2	0.5
Silver	Ag	7440-22-4	0.5
Sodium	Na	7440-23-5	5
Thallium	Tl	7440-28-0	0.5
Vanadium	V	7440-62-2	0.5
Zinc	Zn	7440-66-6	0.5

Detection limits for TALs

- All analytical procedures will be conducted by a laboratory certified by the New Jersey Department of Environmental Protection or NELAC.

E. References

1. Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19(1):81-97.
2. Rabenhorst, M.C., D.S. Fanning, and S.N. Burch 2002. Acid Sulfate Soils, Formation. In: R. Lal (ed.). *Encyclopedia of Soil Science*. Marcel Dekker, New York. 14-18.
3. Reddy, K.R., and R.D. DeLaune. 2008. *Biogeochemistry of Wetlands: Science and Applications*. CRC Press, Taylor & Francis Group, Boca Raton, FL.
4. Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. *Field book for describing and sampling soils*, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.
5. Thein, S. "A flow diagram for teaching texture-by-feel analysis," *Journal of Agronomic Education*, 1979, vol. 8, pp. 54-55.

F. Appendix

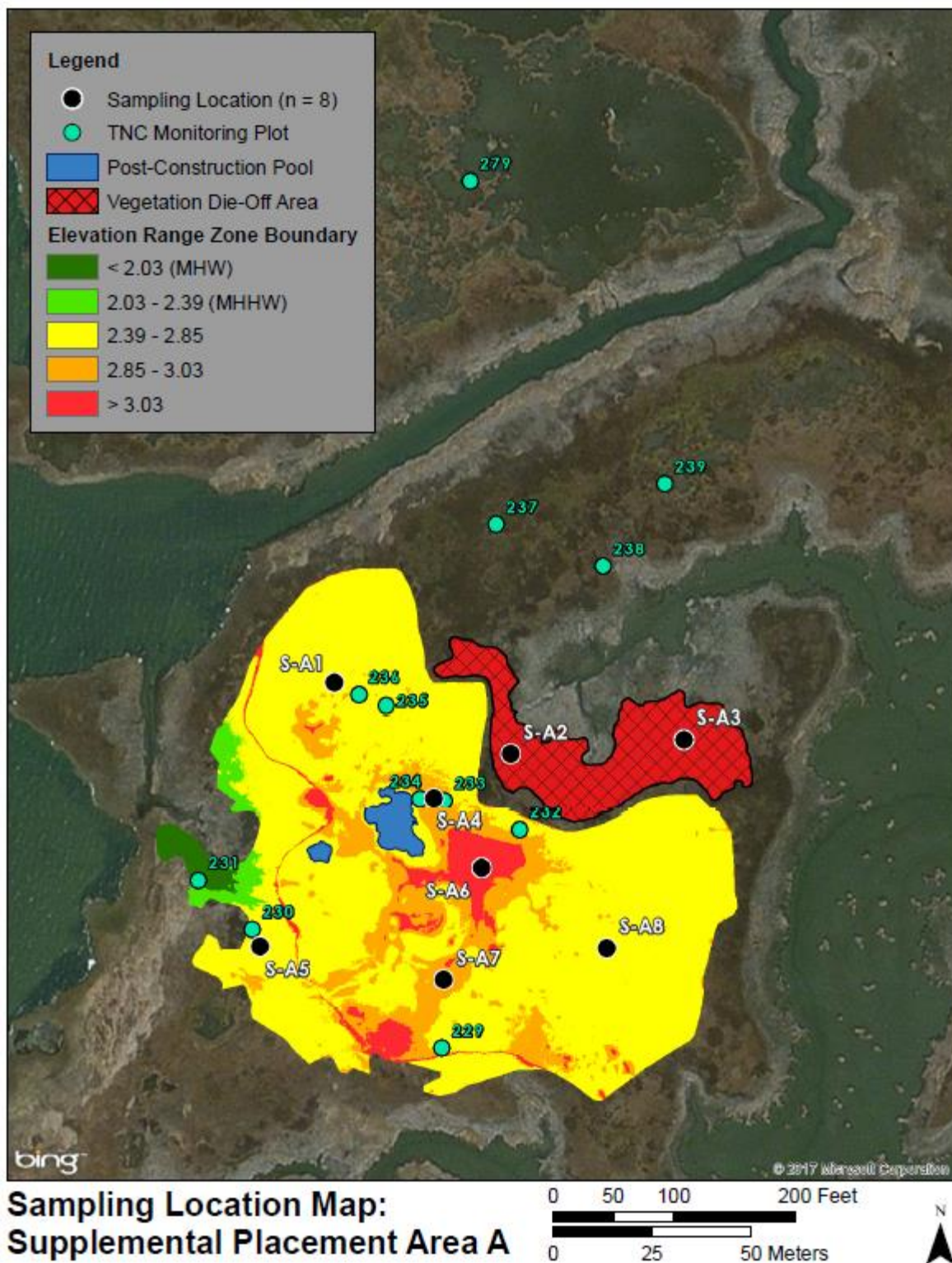
Table 1 (below) displays the sampling and testing Details.

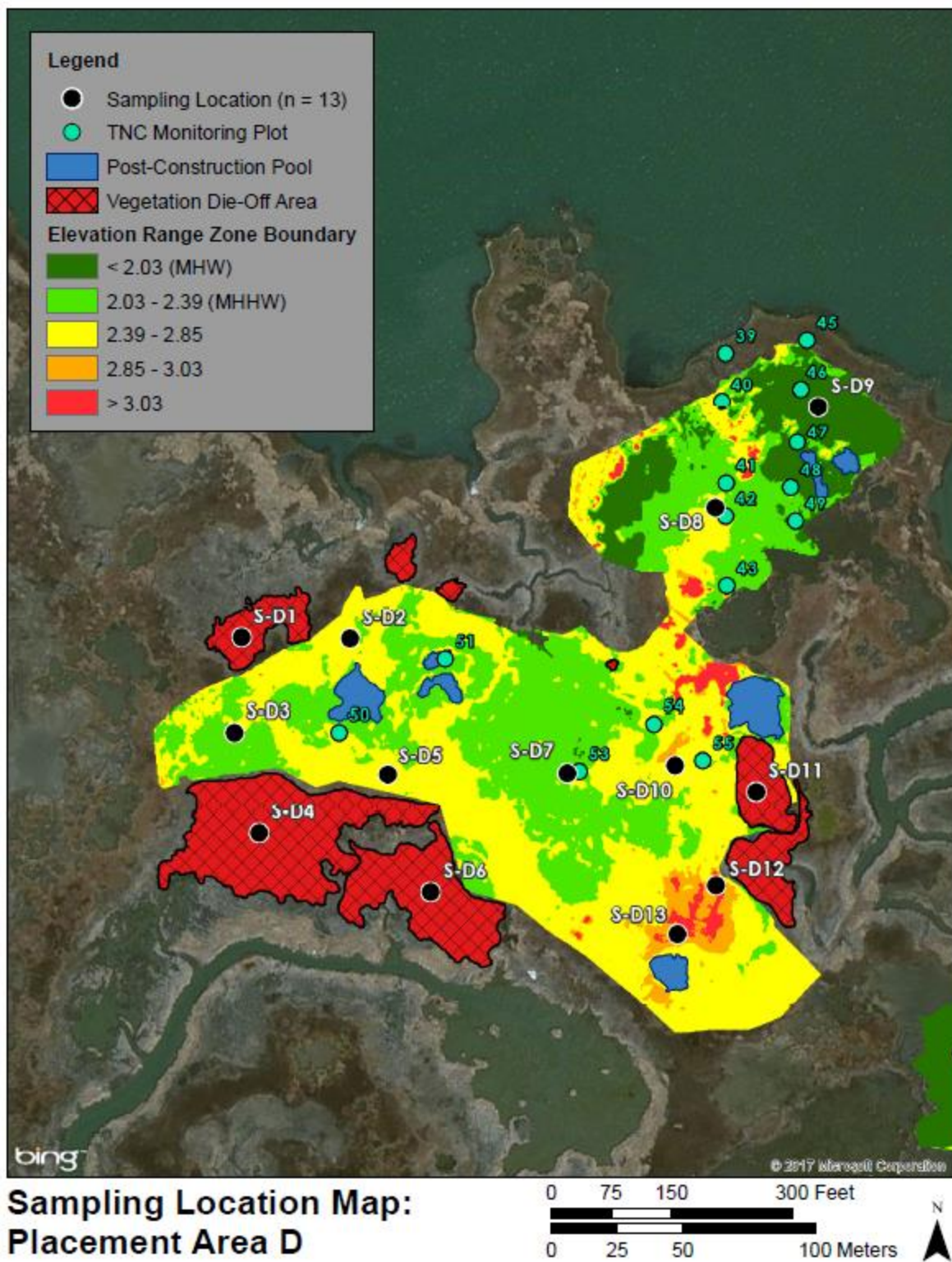
Table 1: Sampling Location and Testing Details

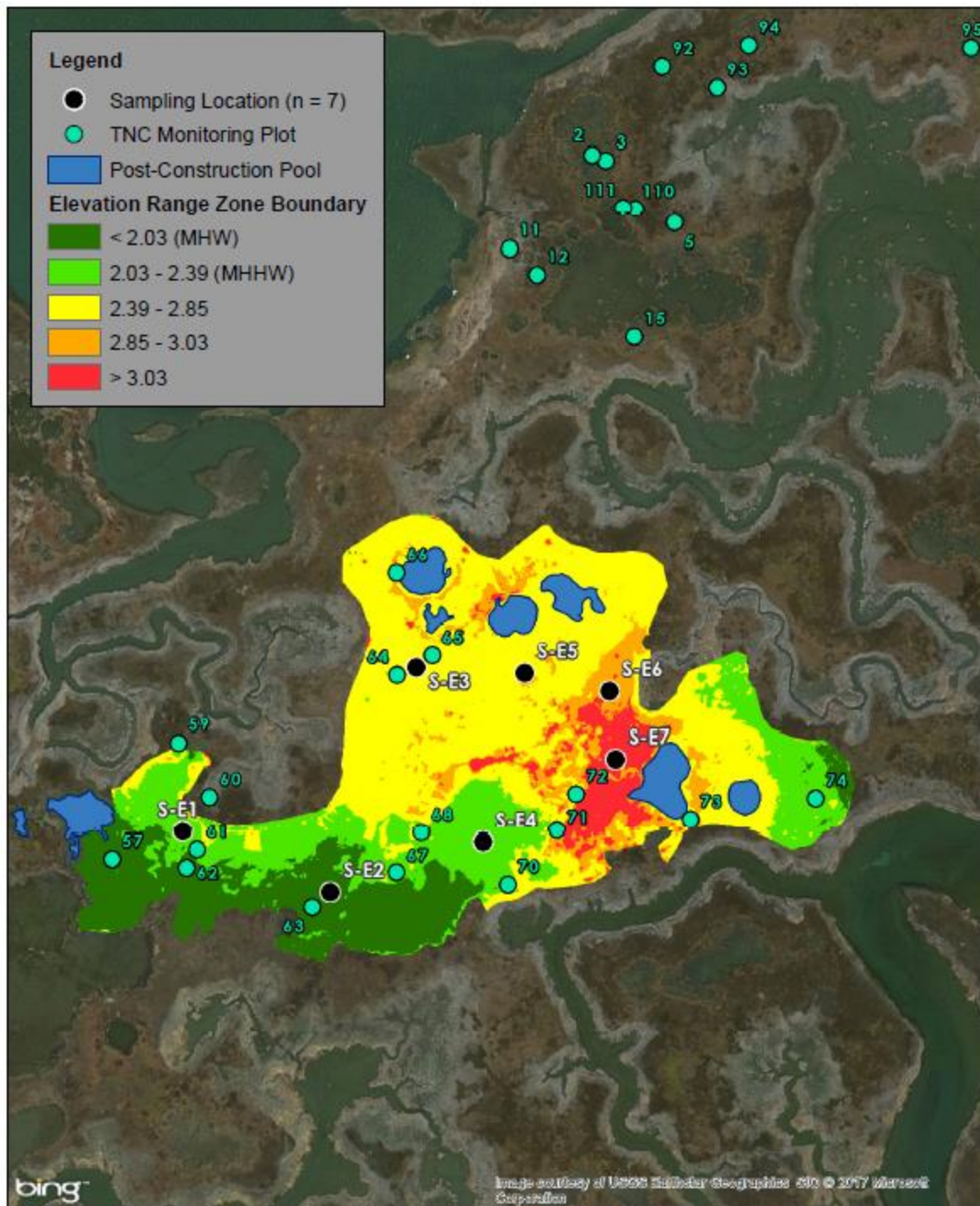
Placement Area	Number of Samples	Testing	Samples Tested
A	8 (2 in die off areas)	Physical Analysis	All
		Metals	All
		Nutrients	All
		Sulfate	All
D	13 (4 in die off areas)	Physical Analysis	All
		Metals	All
		Nutrients	All
		Sulfate	All
E	7	Physical Analysis	All
		Metals	All
		Nutrients	All
		Sulfate	All
F	9	Physical Analysis	All
		Metals	All
		Nutrients	All
		Sulfate	All
TBD	3	All	All

Table 2 Sample Coordinate and Elevation Zone Details

Sample ID	Placement Area	Northing	Easting	Elevation	Elevation Zone
S-A1	A	91486.46	419268.24	2.71	2.39 - 2.85
S-A2		91428.94	419413.97	Die-Off Area	Die-Off Area
S-A3		91440.44	419557.78	Die-Off Area	Die-Off Area
S-A4		91392.04	419350.72	2.89	2.85 - 3.03
S-A5		91268.93	419206.52	2.73	2.39 - 2.85
S-A6		91334.02	419390.00	3.25	> 3.03
S-A7		91241.53	419358.80	2.93	2.85 - 3.03
S-A8		91267.87	419493.54	2.54	2.39 - 2.85
S-D1	D	90858.83	417616.88	Die-Off Area	Die-Off Area
S-D2		90857.54	417752.32	2.50	2.39 - 2.85
S-D3		90741.45	417607.85	2.38	2.03 - 2.39 (MHHW)
S-D4		90616.33	417638.81	Die-Off Area	Die-Off Area
S-D5		90690.04	417799.56	2.63	2.39 - 2.85
S-D6		90542.81	417852.93	Die-Off Area	Die-Off Area
S-D7		90691.46	418023.13	2.43	2.39 - 2.85
S-D8		91021.06	418207.57	2.52	2.39 - 2.85
S-D9		91146.41	418335.60	1.64	< 2.03 (MHW)
S-D10		90701.46	418157.34	2.89	2.85 - 3.03
S-D11		90667.93	418257.96	Die-Off Area	Die-Off Area
S-D12		90551.34	418208.17	2.97	2.85 - 3.03
S-D13		90490.33	418160.29	3.19	> 3.03
S-E1	E	90385.44	418628.25	2.14	2.03 - 2.39 (MHHW)
S-E2		90286.95	418866.36	1.93	< 2.03 (MHW)
S-E3		90647.60	419004.49	2.76	2.39 - 2.85
S-E4		90367.47	419112.70	2.20	2.03 - 2.39 (MHHW)
S-E5		90638.42	419179.89	2.81	2.39 - 2.85
S-E6		90610.05	419316.48	2.96	2.85 - 3.03
S-E7		90501.86	419327.29	3.20	> 3.03
S-F1	F	89258.16	419690.79	2.52	2.39 - 2.85
S-F2		88982.44	419609.86	3.40	> 3.03
S-F3		88780.23	419516.02	2.26	2.03 - 2.39 (MHHW)
S-F4		88905.38	419934.02	2.94	2.85 - 3.03
S-F5		88953.74	419733.88	3.26	> 3.03
S-F6		88995.30	419989.18	2.72	2.39 - 2.85
S-F7		89532.04	419964.86	2.34	2.03 - 2.39 (MHHW)
S-F8		89406.74	420084.56	2.49	2.39 - 2.85
S-F9		89534.04	420171.22	2.65	2.39 - 2.85
TBD	-	-	-	-	-
TBD	-	-	-	-	-
TBD	-	-	-	-	-



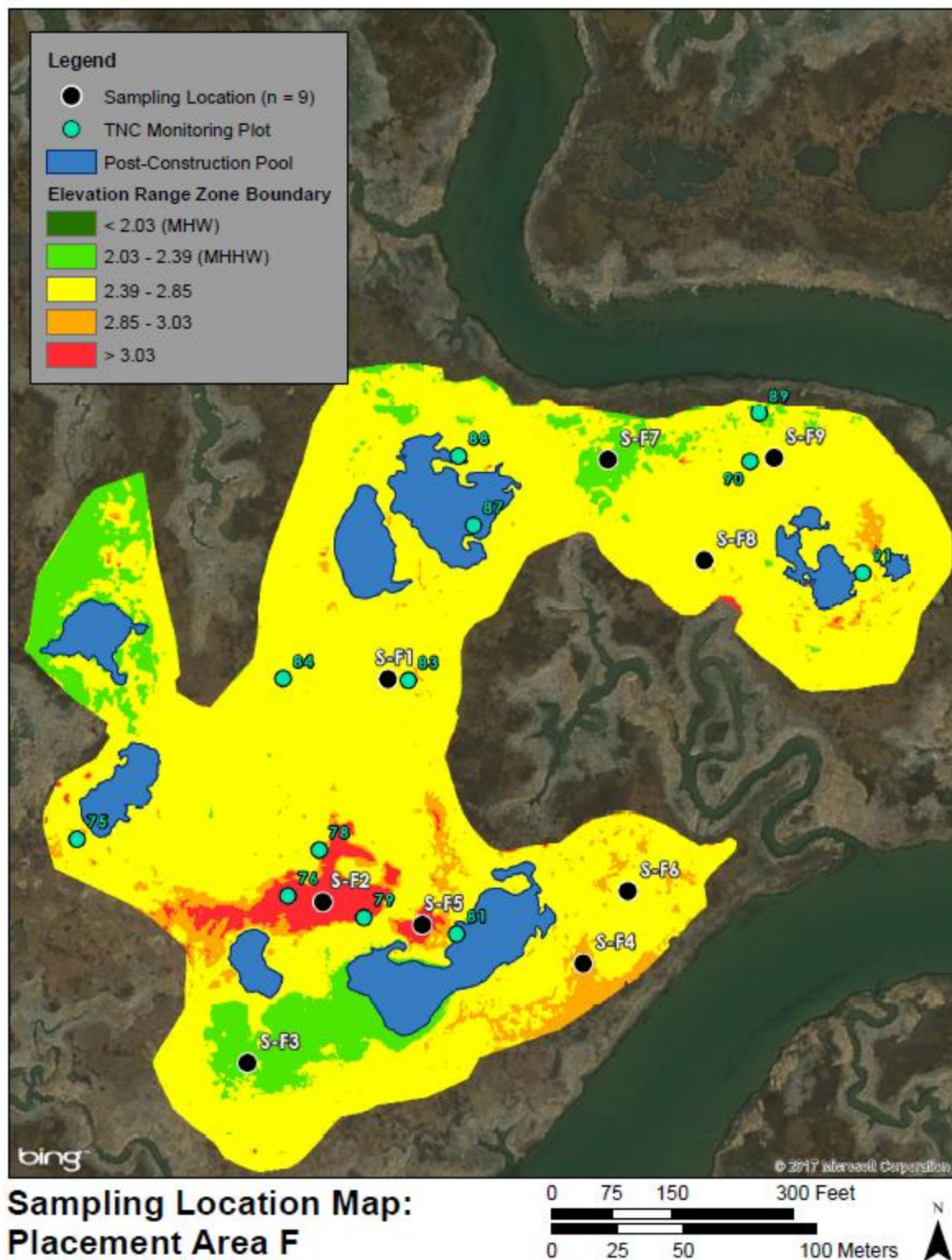




**Sampling Location Map:
Placement Area E**

0 100 200 400 Feet
0 25 50 100 Meters





Data Sheet Template:

MARSH SEDIMENT FIELD SHEET									
Date:		Placement Area:			Coordinates				
Time:		TBD Location Note:			X: Y: Z:				
Site: Avalon		Sampling Team:			Elevation:				
Photos Taken:		Before:		Exposed Soil Profile:			Photo Comments:		
		After:		Seepage:					
				Excessive soil slough:					
Sample Location ID:		S-A		Linked with TNC or ERDC Plots:					
		S-E							
		S-D							
		S-F							
Surface Cover:		Vegetative: No		Bare: Yes		Percent Cover (m x m): 0%			
Existing Vegetation:		Veg Species							
Boring Structure Material:		Sand		Peat					
		Silt		Clay					
Soil Texture:				Water State Class:					
		Sand		Dry					
		Loamy Sand		Moist					
		Sandy Loam		Wet					
		Silt Loam		Freshwater					
		Loam		Saltwater					
		Sandy Clay Loam							
		Silty Clay Loam							
		Clay Loam							
		Sandy Clay							
		Silty Clay							
		Clay							
Soil Matrix Color:		Depth (zone of occurrence):							
Hue		Top Depth		ft.					
Value		Bottom Depth		ft.					
Chroma									

Monitoring Plan Title: Surface Water Elevation and Tide Range Monitoring
Monitor: GreenVest, LLC

A. List of metrics

1. Hydroperiod or Tidal Inundation Depth/Duration
2. Tide Range
 - Mean Higher High Water (MHHW) Elevation
 - Mean High Water (MHW) Elevation
 - Mid Tide Line (MTL) Elevation
 - Mean Low Water (MLW) Elevation
 - Mean Lower Low Water (MLLW) Elevation

B. Monitoring design

1. Spatial design: Semi-permanent tide gauging stations (number and distribution to be determined on a site-by-site basis) will be installed at placement and control sites. These stations will be outfitted with remote, continuous data logging equipment. Gauging stations/wells will be placed in a variety of settings based on the specific objectives of the enhancement project, including deeper open water, on the marsh platform or within internal tidal creeks or ditches. Remote data logging equipment shall be surveyed using Real Time Kinematic (RTK) Global Positioning System (GPS) survey equipment and calibrated to collect data in the same vertical datum as the topographic survey that will be completed for each site.
2. Temporal design: The surface water monitoring will follow BACI design. Surface water data will be continuously measured for the entire project length (from baseline data collection before placement, through placement and throughout the monitoring period after placement) by installing remote data logging equipment at semi-permanent tide gauge stations. The only time data will not be collected is during the winter when loss of equipment by ice shear is highly probable. Remote data loggers will be removed prior to marsh and watercourse freezing and replaced after the spring thaw. Data will be collected at 15-minute intervals to ensure that high and low tide elevations are captured. Stations will be visited to download data and assess condition of remote data loggers on a quarterly basis at a minimum and after major storm events.

C. Detailed methods

1. Field Methods for installation of semi-permanent tide gauging stations:
 - Equipment/Supplies:
 - Boat/canoe/kayak
 - 4x4 timber stand post & 2x4 supports (to support the gauging station)
 - Slotted (0.10 astm) schedule 40 PVC pipe (2" diameter)
 - Mounting Hardware (Strapping, Nails, screws, etc.)
 - Sledge Hammer, Framing Hammer, Wood Saw, Hack saw, etc.
 - Cordless Drill & Driver
 - Remote data loggers (In-Situ Level Troll 500)
 - Procedures:
 1. Calibrate remote data loggers to collect surface/ground water elevations in the same vertical datum as the topographic/elevation survey.
 2. Install gauging stations in positions identified prior to fieldwork. Install open water gauging stations at low tide to ensure that the automated data

- loggers are positioned to capture the full tidal fluctuation in that area.
3. Install remote data loggers within the PVC pipe housing attached to the tide gauging station in accordance with manufacturer recommendations. The top of the PVC housing shall be a minimum of two feet above the MHHW line to avoid inundation of the data logger connection ports.
 4. Measure the well and record well installation measurements.
 5. Survey tide gauge elevations and locations using RTK-GPS survey (GreenVest will accompany the survey sub-contractor in the field to ensure proper survey of the tide gauges).
2. Field Methods for data collection at semi-permanent tide gauging stations:
- Equipment/Supplies:
 - Boat/canoe/kayak
 - Handheld water level monitoring device
 - Laptop and connection cable
 - Procedures:
 - Assess the condition of remote data logger (assess battery life, determine if data is being collected properly, assess data file capacity)
 - Download data to the laptop
 - Measure and record water level using handheld water level monitoring device (this is done to verify remote data logger calibration and accuracy).

D. Data management and quality assurance/quality control

1. Data collection: All water surface elevation data will be processed in NAD 83/NAVD88 horizontal and vertical datums within the NJ State Plane Coordinate System. Remote data loggers take measurements with an accuracy of less than 0.1 feet.
2. Data storage: Surface water elevation data shall be stored in excel spreadsheets and tide gauge locations will be stored in Excel and converted to GIS shapefiles. The resulting Excel worksheets and GIS shapefiles will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: GreenVest will review the digital data/work product identifying data gaps, if any. Tide range and tidal amplitude will be calculated from the data collected. Hydrographs and histograms will be produced to summarize all data collected over the period of record. These data will be used to analyze pre- and post-placement conditions including any measurable delta in hydroperiod. Data will be analyzed and used to calculate key tidal elevations (MHHW, MHW, MTL, MLW, MLLW). Tide range, physical maximum, minimum, mean high, mean low and mid tide elevations will all be calculated using real time data collected. These will then be validated by and compared to long term data collected by NOAA and others. Summary reports describing means/methods and results will be produced. The resulting reports will be stored in a cloud storage location that is shared by the project team (Box).

Monitoring Plan Title: Surface and Groundwater Chemistry at the Avalon Site
Monitor: The Wetlands Institute, Lenore P. Tedesco, PhD

A. List of Metrics

1. Temperature (°C)
2. Conductivity (µs/cm)
3. Specific Conductivity (µs/cm)
4. Total Dissolved Solids (mg/L)
5. Salinity (ppt)
6. Dissolved Oxygen (% saturation and mg/L)
7. pH
8. Oxidation Reduction Potential (mV)
9. Sampling Depth (m)

B. Monitoring Design

1. **Spatial Design:** Surface water and groundwater chemistry in salt marsh pools and shallow groundwater wells and piezometers will be measured following placement of dredged material at the Avalon, NJ project site. The sampling strategy focused on documenting the range of water chemistry that occurs during spring and late summer conditions to understand if water chemistry is controlling vegetation recovery and / or survival of vegetation plantings at the Avalon Beneficial Reuse site. This monitoring program was added in 2017 in response to observations of vegetation die off and surface water chemical conditions that may be stressful to vegetation. Sites were selected to capture surface water pools that had a high likelihood of persisting through the summer and fall so that comparative analyses could be conducted. There are no pre-treatment measurements available thus a BACI design is not possible.

The water chemistry of perched water tables accessible through ACOE ERDC piezometers and groundwater wells was included in the monitoring program following initial surface water monitoring. The groundwater monitoring effort was implemented in response to very high salinities measured on site in early spring 2017 especially in pools within emplaced dredged material.

Four surface water sites were selected in placement area D, four were in area E, and 1 was in area A. The study design included monitoring a control pool and marsh and pool wells that did not have any dredged material emplaced (Area G). For comparative purposes, the monitoring program utilized water chemistry in natural pools as well as marsh depressions created on The Wetlands Institute property during a construction project that resulted in marsh compaction without any dredged material addition. Comparison marsh wells at The Wetlands Institute are also included. Surface water chemistry of two estuary control sites at the Avalon site and one at The Wetlands Institute was also monitored.

2. **Temporal Design:** Sampling will be following periods of repetitive tidal flushing associated with astronomic high tides or storm events and following periods of stagnation associated with neap tides and to capture variability associated with seasonality. Sampling following a fresh water rain event is also planned. Sampling is scheduled for early spring (March – June) and late summer (August – September).

C. Detailed Methods

1. Field Methods for Surface Water Chemistry

- Equipment/Supplies:
 - EXO1 Multiparameter Sonde
 - Digital Camera
 - Data Sheets and Pens
 - Garmin GPS Unit
 - Site Location Map
- Procedures:

Surface water chemistry monitoring of pools is scheduled to coincide with either periods of repetitive tidal flushing or following periods of stagnation. Confirming tidal conditions at the site is done by reference to the USGS tidal station 01411360 at Great Channel in Stone Harbor (https://waterdata.usgs.gov/nj/nwis/uv/?site_no=01411360&PARAMeter_cd=00065.72279). Prior to site testing, the instrument is calibrated following manufacturer protocols. Use the site location map and GPS coordinates to occupy sampling site locations. Record the GPS coordinates of the sampling location. A calibrated EXO1 Multiparameter sonde is used to measure water chemistry. Remove the sonde storage cup from the sensor unit leaving the sonde sensor guard in place. Rest the sonde within the water column or when water depths are too shallow on the bottom of the pool taking care to have all sensors in the water and not submerged in sediment. Allow the sensors to reach equilibrium and record each parameter on the data sheets including the sampling time. For surface water measurements, 2 to 3 measurements will be taken in each the pool, and the mean value will be reported. Remove the sonde and replace sonde head into storage cup for transport to next station. Use a digital camera to photograph site conditions or and cyanobacterial or algal mats.

2. Field Methods for Well and Piezometer Water Chemistry

- Equipment/Supplies:
 - EXO1 Multiparameter Sonde
 - EXO1 Flowcell and Tubing Connectors
 - Tygon Flexible Tubing
 - Peristaltic Pump
 - 12 Volt Battery
 - Solinist Water Meter
 - 10 m Tape Measure
 - Digital Camera
 - Data Sheets and Pens
 - Garmin GPS Unit
 - Site Location Map
- Procedures:

Shallow groundwater at stations established by ERDC in a suite of pools and in the marsh platform at the Avalon project site will be monitored. Locate well cluster and confirm via a Garmin GPS and site map then record coordinates on the data sheets for each well cluster or individual well. Wells and piezometers are labelled inside the cap. If the water level sensor is attached to the well cap, take care to remove the sensor prior to sampling. The depth to the water surface within the piezometer or well is measured with a Solinist water meter by removing the well caps and lowering

the water meter sensor until the water surface is reached as indicated by the meter. Surface water position is then read from the calibrated meter tape. The water level relative to ground surface is determined by subtracting the well casing height above ground from the length of water meter tape until water is reached in the piezometer or well. Water chemistry is measured using an EXO1 Multiparameter Sonde. Water will be pumped from the piezometers and wells into a flow cell using a peristaltic pump powered with a 12v battery. ¼" Tygon tubing is lowered into the well or piezometer to within 2 cm of the bottom of the well or piezometer. The EXO1 Sonde is screwed into the top of the flow cells. Water is pumped from the well/piezometer into the bottom of the flow cell. Once the flow cell is filled and overflowing out of the top of the cell, measurements are recorded on the data sheets when the parameters stabilize. Remove the sonde and replace sonde sensor guard and replace head into storage cup for transport to next station. Drain Tygon tubing and flow cell. Use a digital camera to photograph site conditions or and cyanobacterial or algal mats. Surface water measurements will also be taken if there is surface water at or near the piezometer locations following the procedures noted for surface water monitoring.

D. Data Management and Quality Assurance/Quality Control

1. Data Collection: Data from monitoring will be collected in real-time on-site in a field notebook or on datasheets. Once survey locations are finalized in the field, coordinates of the survey locations will be recorded with a GPS unit to facilitate repeated surveying. Sampling location coordinates will be uploaded from the GPS unit and converted into shapefiles.
2. Data Storage: Field notes will be scanned and data will be transferred from the field notebook or datasheets into Excel worksheets. QA/QC for data entry will be accomplished by random checks by the principal investigator, comparing datasheet entries with electronic file entries. Photos will be uploaded and labelled.
3. Data analysis: Due to limited amount of data collection, it is not possible or reasonable to apply statistics that are typically used to identify significant differences. Water chemistry will be analyzed against parameters including base elevation, thickness of emplaced dredged material, prior site type (pool or marsh). Comparisons will be made between control sites and comparison sites.

E. Appendix (next page)

1. Map of Avalon water chemistry sampling points



2. Gantt chart showing the months that various activities were completed

Year	2016				2017											
Month	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Site Reconnaissance	X						X									
Surface Water Monitoring	X						X			X	X	X				
Groundwater Monitoring										X	X	X				
Data Analysis													X	X		
Reporting														X		

3. Data Sheet Template

Water Quality Monitoring Avalon Beneficial Reuse Site

LP Tedesco Triplicate per site

Equipment: YSI Exo 1 Multiparameter Sonde

Air T _____

Date _____

Assistants _____

Tide Stage/Time _____

Weather Current/Prior Notable _____

Site	Lat	Long	T (°C)	Conductivity ($\mu\text{S}/\text{cm}$)	Specific Conductivity ($\mu\text{S}/\text{cm}$)	Total Dissolved Solids (mg/L)	Salinity (ppt)	Dissolved Oxygen (% Sat)	Dissolved Oxygen (mg/L)	pH	ORP (mV)	Depth (m)	Time/Comment

Monitoring Plan Title: Wave Energy Modeling
Monitor: Princeton Hydro, LLC

A. List of metrics

1. Wave Height (ft)
2. Flood Elevation (ft, referenced to NAVD88)
3. Potential Flood Damages, measured in USD
4. Topographic Elevation (ft, referenced to NAVD88)
5. Vegetation Type/Density; data used to modify roughness variables.

B. Monitoring design

The experimental design utilizes existing FEMA modeling data available from the recent Coastal Flood Study along the NJ coast, modified as necessary to account for proposed/as-built conditions such as topographic and roughness (vegetation) parameters. Incorporation of proposed conditions will provide results that will guide project design. Incorporation of as-built conditions will provide actual results of placement. Additionally, FEMA modeling data will be modified for projected sea level rise in 2030. Subsequently, results of the wave height analysis will be utilized in the potential flood damage reduction analysis. Below is a matrix of the modeling scenarios.

Table 1 Modeling Scenarios

Storm Event	Topography	Sea Level Rise	Vegetation Community*	Vegetation Biometrics*
10%	Pre-Construction (Existing Conditions)	Existing	1. No Vegetation 2. Low Marsh 3. High Marsh 4. Scrub Shrub	1. Plant Species 2. Stem Height 3. Percent Cover
10%	Pre-Construction (Existing Conditions)	2030		
10%	Post-Construction	Existing		
10%	Post-Construction	2030		

*Plant Community and Biometrics are dependent on topography, tidal stage, and field observations.

C. Detailed methods:

1. Obtain FEMA modeling from Region II.
2. Obtain necessary GIS data layers (critical facilities, building locations/attributes (First Floor Elevation, occupancy type, building material, # of floors, etc.), from NJDEP, NJGIN, and local municipalities, for flood damage reduction modeling.
3. Obtain data collected by monitoring team, including topographic/bathymetric data, water level monitoring data, and vegetative community data.
4. Identify transects for use in the modeling effort.

5. Calculate model parameters for the 10-yr event including stillwater elevation, significant wave height, deepwater wave period, Wind IF, and Wind OF.
6. Run modeling of existing conditions for the 10-yr determined by FEMA.
7. Modify topographic and roughness (vegetation) parameters to account for proposed/as-built conditions.
8. Run modeling of proposed/as-built conditions for the 10-yr determined by FEMA.
9. Iterate as necessary to optimize design features.
10. Utilize wave modeling results to complete potential flood damage reduction modeling.

D. Data management and quality assurance/quality control

1. Data collection: Results from modeling effort will be compiled for various scenarios.
2. Data storage: The resulting datasets will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: Results will be analyzed to determine optimization of placement efforts during design, as well as determination of long-term efficacy of treatments on flood reduction and habitat improvement.

E. References

1. USACE EM 1110-2-1100 "Coastal Engineering Manual"
(<http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;101>)
2. FEMA Coastal Hazard Analysis Modeling Program (CHAMP) User's Manual
(<http://www.fema.gov/media-library-data/20130726-1615-20490-3409/champ2um.pdf>)
Version 2.0
3. FEMA HAZUS-MH 2.1 Technical and User's Manuals (<https://www.fema.gov/protecting-our-communities/hazus/hazus-user-technical-manuals>).

Monitoring Plan Title: Vegetation, Biomass, and Epifaunal Macroinvertebrate Monitoring
Monitor: The Nature Conservancy (TNC)

A. List of metrics

1. Vegetation metrics:
 - Species richness
 - Percent cover by species
 - Average stem height of dominant plant species
 - Above-ground biomass
 - Below-ground biomass
2. Epifaunal macroinvertebrates (EMI) metrics:
 - Species richness
 - Species abundance
 - Species density
3. Physical metrics:
 - Elevation (taken during a separate topographic survey)

B. Monitoring design

1. Spatial design: Vegetation, EMI, and physical metrics will be monitored at permanent 1 m² plots located within placement and control areas at each of the three sites. Biomass metrics and EMI species density will be monitored in 0.25 m² plots adjacent to a subset of these permanent monitoring plots. All plots will be marked in the field and all project team members and contractors will be told about the markers and asked to avoid disturbing these plots. Locations of the permanent monitoring plots depend on individual site characteristics and enhancement project design. At some areas of Avalon and Ring Island, plots were established along transects that run perpendicular to channel banks and into the marsh interior following a systematic random approach. At other areas of Avalon and Ring Island, and at all sites at Fortescue, plots were established so they were distributed proportionally among habitat types and elevation zones following a stratified random approach. Habitat types include low marsh, high marsh, and pools. Important site-specific spatial design considerations include variation in habitat types, marsh condition, and elevation. Plots were initially established prior to placement. After placement, plots that were in “Placement” areas that did not receive any placement were removed from subsequent monitoring, and some additional plots were established to replace them.
2. Temporal design: Monitoring will follow a BACI design. Monitoring will be conducted during peak biomass (mid-July to mid-September) prior to placement and once per year post-placement, continuing as funding allows. Monitoring will be conducted when there is little to no water on the marsh surface and monitoring at each site will occur during the same approximate time of the season.

C. Detailed methods

1. Field methods per permanent 1 m² plot (annual non-destructive sampling):
 - Metrics:
 - Vegetation metrics: Species richness, percent cover by species, average stem height of dominant plant species
 - EMI metrics: Species richness, relative abundance, and species density
 - Physical metrics: Pre-placement and post-placement elevation (taken during a separate topographic survey)

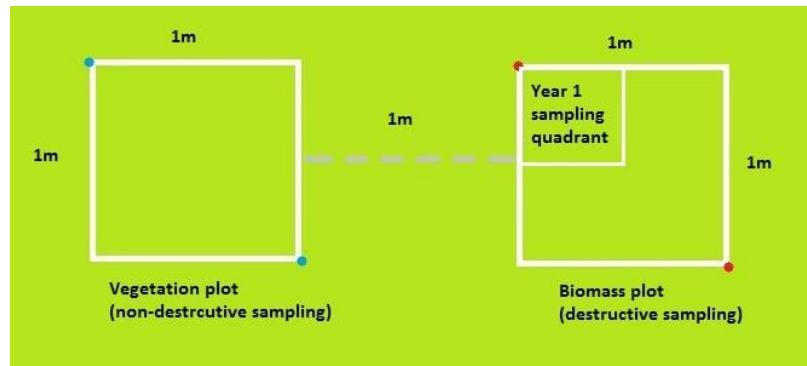
- Equipment/Supplies:
 - Garmin GPS unit
 - Maps of plot locations
 - 1m² quadrat
 - PVC quadrat markers
 - Digital camera
 - Meter stick (mm)
 - Ruler (mm)
 - Flashlight
 - Compass
 - Stopwatch
 - Data sheets and pencils
 - Rugged field tablet (beginning 2017)
 - Procedures:
 - Locate plot; record start time.
 - Carefully slide a 1mx1m PVC quadrat down over vegetation as far as possible; place ½" PVC markers in two corners of quadrat; mark a waypoint at center of plot.
 - Beginning from one corner of the quadrat (corner will be rotated on a yearly basis), conduct a 3-minute timed systematic search from a crouched position for EMI species within that ¼ m² subset of the quadrat, gently moving aside vegetation and probing the sediment/dredged material for mussels. Record the number of snails (by species), ribbed mussels, and crabs (by species) within a ¼ m² subset of the quadrat. As of 2017, categorical abundances will be used when there are > 11 individuals of a given species, and crab burrows will be used to quantify crab abundances rather than actual crabs.
 - Take a photo from above the marsh surface to capture entire quadrat and record photo number. As of 2017, photos will be taken with the NE corner of the plot in the bottom left corner of the photo.
 - Record the presence of each distinct plant species (*Genus species*).
 - Estimate percent cover of each plant species and other cover types (i.e. litter, dead standing vegetation, water, etc.) using Braun-Blanquet (BB) cover classes.
 - Beginning from the same corner of the quadrat as the EMI count, measure the heights of the first 15 stems of the dominant plant species you encounter.
 - If unable to identify a species (EMI or vegetation) in the field, collect a single specimen in a labeled zip locked bag for identification upon return to the office.
 - Note: Elevations of these plots will be taken during separate topographic surveys. Coordinates of the permanent 1m² plots will be given to the surveyors, who will report back to TNC with the elevation data.
2. Field methods per 0.25m² plot (annual destructive sampling):
- Metrics:
 - Biomass metrics: aboveground and belowground biomass
 - EMI metrics: EMI density by species (at a minimum ribbed mussel counts but ideally density of all distinct species will be taken)

▪ Equipment/Supplies:

- Garmin GPS unit
- 0.25m² quadrat
- PVC quadrat markers
- Digital camera
- Data sheets and pencils
- Garden shears
- Gallon size Ziploc bags
- Sharpies
- 15 cm length of 15 cm diameter PVC pipe
- Sledge hammer
- Clear garbage bags
- Rite-in-the-rain labels
- Cooler with crushed ice
- Timekeeping device

▪ Procedures:

- Flip the 1 m² quadrat two times away from the non-destructive plot so that there is 1m between the non-destructive plot and biomass sampling area; place ½" PVC markers in two corners of the 1 m² quadrat; place the 0.25 m² quadrat in the designated quadrant of the 1m² quadrat (designated quadrants will be rotated on a yearly basis); mark a waypoint at center of plot.



- Take a photo of the plot; record photo number.
- Remove EMI species from standing marsh vegetation by systematically brushing hands through vegetation within the plot prior to harvest.
- Harvest above-ground biomass within the 0.25m² quadrat taking care to clip the vegetation flush with the marsh surface (include living, dead-standing and decaying plant material); place all plant material into a labeled gallon-size Ziploc bag, remove any EMI species encountered and return to surface of plot.
- Conduct a timed (3 minute) search for all EMI species, counting all individuals of each distinct EMI species seen or felt when probing the surface of the plot. Count and record densities by species.
- Pound in the below-ground biomass core (15 cm length of 15 cm diameter PVC pipe) using a sledge hammer until it is flush with the surface; remove by

- digging around the core to free it; keep sample inside PVC core and place in a clear labeled garbage bag
 - Place biomass samples in a cooler with ice
- 3. Laboratory methods for biomass sample processing (see Appendix)
- 4. Field methods for as-built vegetation plot survey (one-time sampling within 2 weeks of placement):
 - Metrics:
 - Vegetation metrics: Species richness, percent cover by species
 - Equipment/Supplies:
 - Garmin GPS unit
 - 1m² quadrat
 - Digital camera
 - Soil augur
 - Meter stick (with mm markings)
 - Data sheets and pencils
 - Timekeeping device
 - Procedures:
 - Locate plot and place the 1 m² PVC quadrat over vegetation within plot.
 - Take a photo from above the marsh surface to capture entire quadrat and record photo number.
 - Record the presence of each distinct plant species (*Genus species*).
 - Estimate percent cover of each plant species and other cover types using the BB cover classes.
 - Record all other observations and take any necessary photos.

D. Data management and quality assurance/quality control

1. Data collection: Data from vegetation metrics and EMI metrics measurements will be recorded on standardized datasheets (see Appendix) or on a rugged field tablet (as of 2017). Coordinates of the locations of sampling plots will be recorded in a GPS unit in the field. The number of all photos taken in the field will be recorded on data sheets.
2. Data storage: Field datasheets will be scanned. Data will be transferred from the datasheets or tablet into Excel worksheets. QA/QC for data entry will be accomplished by random checks by the principal investigator, comparing datasheet entries with electronic file entries. Sampling plot coordinates will be uploaded from the GPS unit and converted into shapefiles using a free program from Minnesota DNR (DNRGPS). Photos will be uploaded and labelled. The resulting digital copies of field datasheets, Excel worksheets, shapefiles and photos will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis:
 - Vegetation metrics: Vegetative species richness will be calculated for each permanent plot and on each site as the total number of native species occurring in that space. A mean of the number of species found per plot per site will also be calculated. Vegetative percent cover by species, per plot, per habitat type (e.g. high marsh, low marsh, pool), and per site will be evaluated using the midpoint of the BB cover classes. The average stem height of dominant plant species will be calculated for each permanent monitoring plot and means will be calculated for each site.
 - EMI metrics: EMI species richness will be calculated for each permanent plot and on each site as the total number of native species occurring in that space. Relative

abundance of EMI by species will be calculated for each permanent plot using exact counts (when ≤ 11 individuals) or the midpoints of the categorical abundance classes (when > 11 individuals).

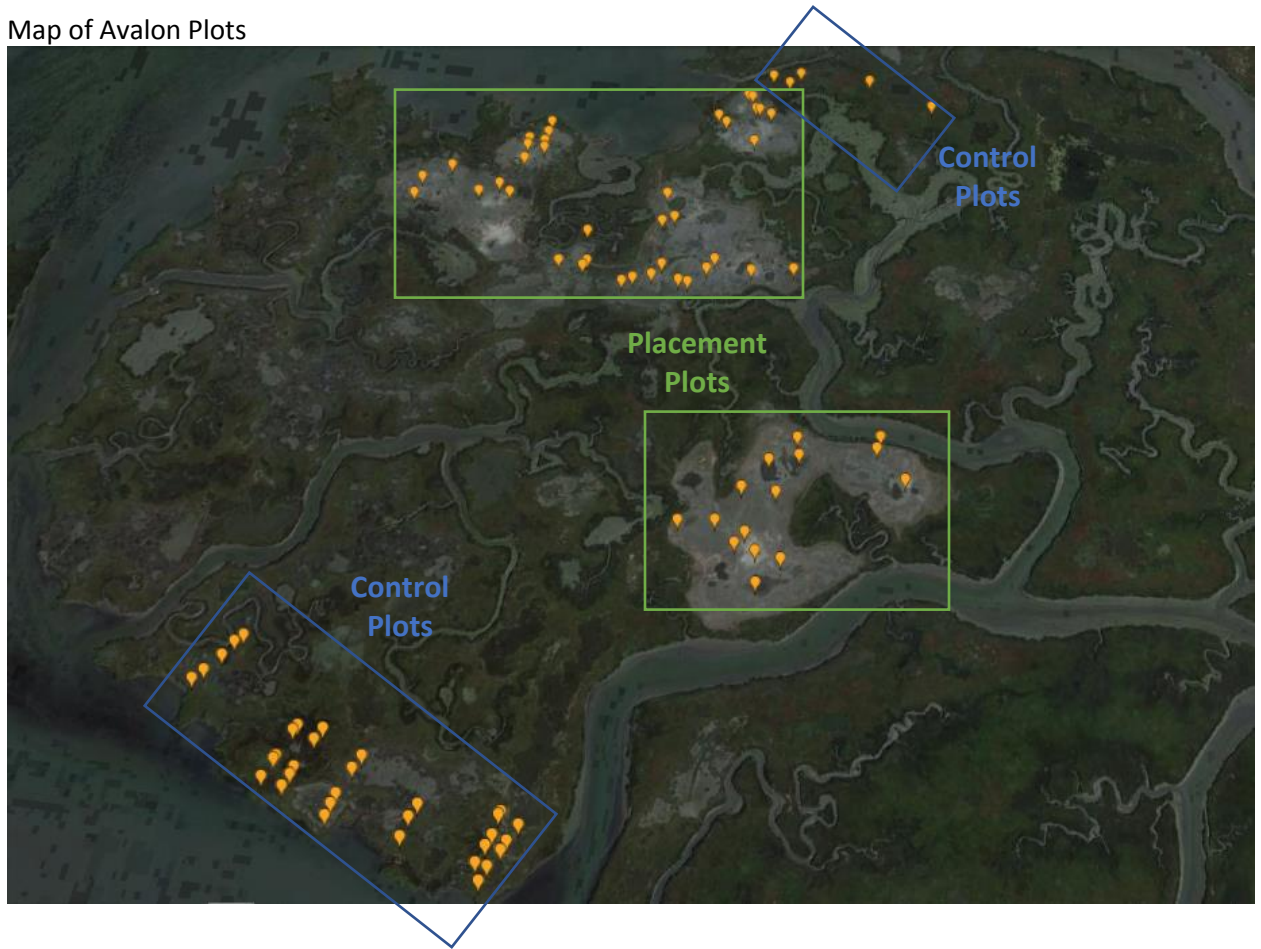
- Biomass metrics: Above-ground biomass and below-ground mass will be first assessed independently and will be calculated for each plot. Then a mean will be derived for each site. Ratios of above-ground to below-ground biomass will also be calculated for each plot and means derived for each site.
- All individual metrics (including elevation) will be analyzed for significant differences between placement sites and control sites within years, and within placement/control sites between years. ANOVAs and t-tests will be used where datasets are normal and homogeneous; otherwise non-parametric equivalents will be used.
- Individual metrics will be analyzed for relationships to depth of placement for each site (see Bearing Capacity and Sediment Observations Monitoring Plan. ANOVAs will be used where datasets are normal and homogeneous; otherwise non-parametric equivalents will be used.
- Individual metrics will be analyzed for relationships to elevation for each site. ANOVAs will be used where datasets are normal and homogeneous; otherwise non-parametric equivalents will be used.
- TNC will also explore the potential effects of dredged material composition (texture and chemical properties) on the response of vegetation to placement (data on dredged material composition will be obtained from project partners).

E. References

1. Braun-Blanquet, J. 1932. Plant sociology. The study of plant communities. McGraw-Hill, New York, NY, US.
2. Vegetation monitoring adapted from Diers, T. and Roman, C. 2000. Ecosystem indicator: vegetation. p 12-14 in H.A. Neckles and M.Dionne Editors. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME.

F. Appendix (see next page)

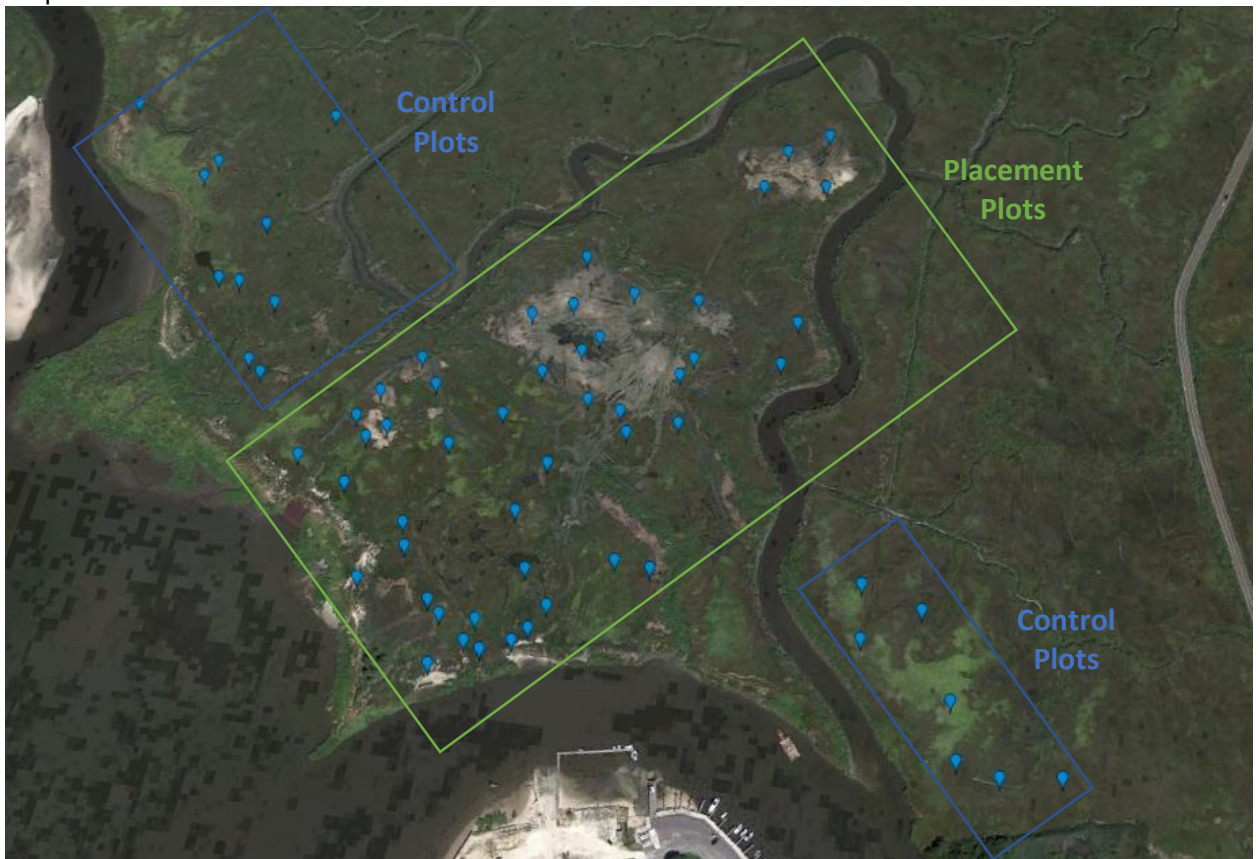
1. Map of Avalon Plots



2. Map of Ring Island Plots



3. Map of Fortescue Plots



4. Data Sheet Template:

Date: _____
 Field Crew: _____
 Site: _____
 Control/Placement (circle) Polygon/Area: _____
 Tide: L- - - - - H

Cover type/Species: Bare (includes wash/placement),
 wrack/litter, water, rock, trash, large macroalgae, dredge
 material
 Spa alt *Spartina alterniflora*
 Spa pat *Spartina patens*
 Sal spp *Salicornia* species
 Diu spi *Distichlis spicata*
 Lim car *Limonium carolinianum*

Braun-Blanquet cover scheme:
 • 1: Less than 1% (only 1 specimen in plot)
 • 2: 1% to 5% cover
 • 3: 6% to 10% cover
 • 4: 11% to 25% cover
 • 5: 26% to 50% cover
 • 6: 51% to 75% cover
 • 7: 76% to 100% cover

Quadrat #			
Latitude/ Longitude (dd)			
Photo #			
Waypoint			
Biomass (y/n)			

Crab Burrows
 None 0
 Low 1-10
 Medium 11-20
 High 21+

Expected EMI Species
 Mel bid *Melampus bidentatus*
 Ily obs *Ilyanassa obsoleta*
 Ova myo *Ovatella myosotis*
 Litt lit *Littorina littorea*
 Ses ret *Sesarma reticulatum*
 Uca pag *Uca pugnax*
 Geuk Dem *Geukensia demissa*

Q#	EMI		Ribbed Mussel Lip Count	Quadrat Observations/Salinity	Percent Cover		1st 15 Stem Heights of Dominant Species (cm)	Bearing Capacity							
	Species	Count or Presence			Cover Type/Species	BB Class		Mark Depth (cm)							
								Water Depth	Initial Depth	Blow 1	Blow 2	Blow 3	Blow 4	Blow 5	Blow 5-Initial
					TOTAL Veg Cover				Sediment Depths (cm)						
					TOTAL Veg Cover				Sediment Depths (cm)						
					TOTAL Veg Cover				Sediment Depths (cm)						

5. Laboratory Methods for Biomass Sample Processing

Determination of Belowground Biomass of Wetland Macrophytes

Partnership for the Delaware Estuary (PDE) Standard Operating Procedure No. 39

Equipment:

Refrigerator, 5°C
Paper bags
Drying oven, 60°C
Desiccator and fresh desiccant, or low humidity chamber
Analytical balance, ± 0.1 g

39.2. Belowground Biomass Determination

- 39.2.1. In the laboratory, place cores in refrigerator at 5° C until processed.
- 39.2.2. Remove cores from labeled plastic bags and extrude core from PVC pipe.
- 39.2.3. Place core on a large sieve with 2 mm mesh size and wash soil and sediment from root material. Sort biomass according to species-specific live and dead material.
- 39.2.4. Place biomass in labeled paper bag for drying.
- 39.2.5. Place bags in drying oven set at 60° C until it reaches a constant weight and biomass can be considered dry.
- 39.2.6. Weigh samples to a tenth of a gram.
- 39.2.7. See PDE-SOP-33 for Determination of Ash in Biomass for LOI determination.
- 39.2.8. Multiply the dry weight of the biomass by the percent organic matter determined by the LOI procedure.
- 39.2.9. Calculate the resulting ash-free dry weight to be on a meter-square basis.

Determination of Aboveground Biomass of Wetland Macrophytes

Partnership for the Delaware Estuary (PDE) Standard Operating Procedure No. 38

Equipment:

Distilled water
Plastic weigh pans for larger samples
Analytical balance(s) for measuring weights (to nearest 0.1 g)
Drying oven, 60°C

38.2. Aboveground Biomass Determination

- 38.2.1. In the laboratory, place material in refrigerator at 5° C until processed.
- 38.2.2. Remove biomass from labeled plastic bags.
- 38.2.3. Sort biomass according to species-specific live and dead material.
- 38.2.4. Wash material with tap water, removing obvious soil and sediment.
- 38.2.5. Place biomass in labeled paper bag for drying.
- 38.2.6. Place bags in drying oven set at 60° C until it reaches a constant weight and biomass can be considered dry.
- 38.2.7. Place dried samples in a dessicator with fresh desiccant to cool prior to mass determination, or allow to cool in a dry location at low relative humidity if dessicator not large enough.
- 38.2.8. Weigh samples to a tenth of a gram.

- 38.2.9. See PDE-SOP-33 for Determination of Ash in Biomass. A subsample of dried ground plant material is often used for LOI.
- 38.2.10. Multiply the dry weight of the biomass by the percent organic matter determined by the LOI procedure (and correct for subsample dry weight of total sample dry weight if appropriate).
- 38.2.11. Calculate the resulting ash-free dry weight of aboveground biomass on a per meter-square basis, separately by species, live vs dead, and total.

Monitoring Plan Title: Benthic Infauna and Sediment Properties Monitoring
Monitor: Rutgers University

A. List of metrics

1. Benthic infauna metric:
 - Density of macrofauna
2. Sediment properties metrics:
 - Total organic matter concentration
 - Total carbon, nitrogen, sulfur, and phosphorus concentrations
 - Grain size

B. Monitoring design

1. Spatial design: Sampling sites will be co-located with the permanent monitoring plots established by the Vegetation Monitoring component of the project. Plot coordinates will be obtained from The Nature Conservancy. During each sampling event, samples will be taken within a 1m² area located at a randomly determined heading, and 2m from the center of each permanent monitoring plot. These 1m² areas will be photographed prior to sampling. Ten random samples for benthic infauna and two random samples for sediment properties will be taken at each control site and each placement site. Since sediment sampling is a destructive sampling process, each area sampled will be marked to prevent re-sampling the same area at a later sampling event, and a new heading used to locate each subsequent sampling area. Locations of sampling areas will be adjusted, if needed, to match elevation of previous sampling areas.
2. Temporal design: Sampling will be conducted five times per year, monthly from May through September, at each project site and control site. Sampling will be conducted at this time prior to the placement of dredged material and at the same time in the year after placement. Sampling will be conducted at low tide.

C. Detailed methods

1. Field methods for benthic infauna metric:
 - Equipment/Supplies:
 - 1m² quadrat
 - PVC cylinder, 3.8cm inner diameter, 20cm length, beveled bottom edge
 - Hand trowel
 - Metric ruler
 - Core extruder
 - 16 ounce capacity screw cap jars
 - Labels
 - 10% formalin solution in seawater, with Rose Bengal dye added
 - Vinyl electrical tape (Scotch Super 88)
 - Data sheets and pencils
 - Procedures:
 - Locate sampling quadrat relative to permanent vegetation monitoring plot.
 - Press PVC cylinder into sediment to a depth of 7-8cm.
 - Using trowel, remove cylinder with intact sediment core.
 - Using core extruder, slice off top 5cm of sediment core, place into jar, add formalin solution, label identifying sample location and date. Beginning with August 2015 sampling and thereafter, changed to slicing off top 3 cm of

- sediment cores due to large amounts of marsh grass stems, roots, etc. in control samples that resulted in excessive time needed to sort samples.
 - Tighten cap, seal edge of cap with electrical tape, invert jar as needed to disperse sediment.
- 2. Field methods for sediment properties metrics:
 - Equipment/Supplies:
 - 1m² quadrat
 - Stainless steel cylinder, 7.6 cm inner diameter, 30cm length, beveled bottom edge
 - Hand trowel
 - Metric ruler
 - Core extruder
 - Whirl-Pak bags
 - Waterproof markers
 - Cooler with crushed ice
 - Procedures:
 - Press stainless steel cylinder into sediment to a depth of 4-5cm.
 - Using trowel, remove cylinder with intact sediment core.
 - Using core extruder, slice off top 2cm of sediment core, place into Whirl-Pak bag, label with sample identity and date.
 - Place bag in cooler on ice.
- 3. Laboratory methods for benthic infauna:
 - Equipment/Supplies:
 - 8-cm-diameter metal sieve, 300µm mesh opening
 - 70% ethanol
 - Stereomicroscopes with fiber optic illuminators
 - Procedures:
 - Decant fixed sediment onto a 300-µm-mesh screen.
 - Use gentle stream of tap water to remove fixative and all material smaller than 300µm.
 - Transfer the >300µm fraction to 70% ethanol.
 - Under low-power magnification (12–25×), sort through retained material and remove all animals.
 - Count and identify all polychaetes to lowest practical taxonomic level.
 - Count and identify all crustaceans and mollusks to lowest practical taxonomic level.
 - Count all oligochaetes.
- 4. Laboratory methods for sediment properties:
 - Equipment/Supplies:
 - 8-cm-diameter metal sieves: 63µm, 125µm, 250µm, 500µm, 1000µm mesh openings
 - Model RX-24 Portable Sieve Shaker (W. S. Tyler, Inc.)
 - Drying oven
 - High-temperature oven, Blue M Electric
 - Mettler AE-160 analytical balance
 - Carlo-Erba NA1500 Series 2 elemental analyzer
 - Beckman DU64 spectrophotometer
 - 50mL capacity beakers

- 1000mL graduated cylinders
- 20mL volumetric pipette
- Sodium hexametaphosphate
- Agate mortar and pestle
- Procedures:
 - Remove sediment core from bag, split into two equal halves vertically.
 - For particle size analysis:
 1. Wet-sieve sediment through a 63- μ m-mesh screen using distilled water with 10% sodium hexametaphosphate as dispersant.
 2. Transfer rinse water with sediment to 1000mL graduated cylinder, fill to mark with DI water
 3. Mix thoroughly, withdraw 50mL and transfer to pre-weighed 50mL beaker.
 4. Dry at 60°C, re-weigh to determine mass of silt/clay fraction (<63 μ m).
 5. Mix thoroughly, withdraw 20mL and transfer to vial for particle size analysis of <63 μ m fraction.
 6. Dry the >63 μ m fraction at 60°C, then separate with stacked graded sieves [63-125 μ m fraction (very fine sand), 125-250 μ m fraction (fine sand), 250-500 μ m fraction (medium sand), 500-1000 μ m fraction (coarse sand), and >1000 μ m fraction (very coarse sand)] for 10 minutes on sieve shaker. Weigh each size fraction.
 - For sediment chemical properties:
 1. Dry sediment at 60°.
 2. Grind in mortar and pestle to fine powder.
 3. Determine total organic matter content by weight loss after combustion at 500° for 5 hours.
 4. Determine total nitrogen, carbon, and sulfur content by flash combustion using a Carlo Erba NA1500 elemental analyzer (Verardo et al. 1990).
 5. Determine total phosphorus content by the ammonium molybdate-ascorbic acid method (Solórzano & Sharp 1980).

D. Data management and quality assurance/quality control

1. Data collection:

- Benthic infauna: A regimented process of quality control checks has been developed and widely adopted by most benthic ecology laboratories. Through a series of random checks of sorted samples (major taxon groups separated from debris), at least 10% of each sorter's work is verified by a senior taxonomist who again goes through (that is, re-sorts) a previously processed sample. The re-sorts will be conducted on a regular basis on batches of five samples. The quality criteria for the benthic sorting are that the re-sorts from a sorter's work be evaluated at ~90% efficiency; that is the minimum level of acceptability. In most instances without undue complicating factors (e.g., excessive amounts of debris from vegetation in the sample), the sorting efficiency should be $\geq 95\%$. Sorting efficiency (%) will be calculated using the following formula:

$$\frac{\text{number of organisms originally sorted}}{\text{number originally sorted} + \text{number found in re-sort}} \times 100$$

If the QCed work is substandard, all that sorter's samples subsequent to the last passed check must be re-sorted and the sorter will be offered further instruction to correct the deficiency. Only after the sorter demonstrates to a senior taxonomist that the problem has been rectified, will the sorter be allowed to process additional samples. Experience has shown that in most situations appropriate corrective measures are readily implemented and that the work continues with little delay. Standard data forms will be used to record the results for the original sorts and the QCed re-sorts. Species identification and enumerations will be performed by or under the close supervision of a senior taxonomist and only sorters with demonstrated ability will be allowed to assist in these tasks. As with the sorting process, at least 10% of each taxonomic technician's work will be checked by a senior taxonomist to verify accuracy of species identification and enumerations. The QC check will consist of confirming identifications and recounting individuals of each taxon composing the sample. The total number of errors (either misidentifications or miscounts) will be recorded and the overall percent accuracy will be computed using the following formula:

$$\frac{\text{number of organisms in QC recount} - \text{number of errors}}{\text{number of organisms in QC recount}} \times 100$$

The minimum acceptable taxonomic efficiency will be 90%. If the efficiency is greater than 95%, no corrective action is required. If taxonomic efficiency is 90-95%, the taxonomist will be consulted and problem areas will be identified. Taxonomic efficiencies below 90% will require re-identifying and enumerating all samples that comprised that batch. The taxonomist must demonstrate an understanding of the problematic areas before continuing with additional samples, and then his/her performance will be closely monitored for sustained improvement.

- Sediment chemical properties: Certified material obtained from NIST (Standard Reference Material 2702 - Inorganics in Marine Sediment) is included in the sample processing stream. A standard sample is run after every six environmental samples. Values for the standard must be within $\pm 10\%$ of the certified values for carbon, sulfur, and phosphorus; otherwise the source of the problem must be identified and corrected before continuing with the analyses of samples.
2. Data storage: Datasheets and notes will be scanned. Data will be transferred from field datasheets and lab notebooks into Excel worksheets. QA/QC for data entry is accomplished by random checks by the principal investigator, comparing notebook entries with electronic file entries. The resulting digital copies of datasheets and Excel worksheets will be stored in a cloud storage location that is shared by the project team (Box).
 3. Data analysis: For benthic infauna, density of the various taxa in the project site will be compared to density in the control site for each sampling time. If data meet the assumptions of normal distributions, 95% confidence intervals will be used to evaluate significant differences between sites. If assumption of normality is not met, nonparametric tests (e.g., Wilcoxon rank sum test) will be conducted. The results will be stored in a cloud storage location that is shared by the project team (Box).

E. References

1. Solórzano L, Sharp JH (1980) Determination of total dissolved phosphorus and particulate phosphorus in natural waters. *Limnol Oceanogr* 25:754-758 (Exact protocols are being used.)
2. Verardo DJ, Froelich PN, McIntyre A (1990) Determination of organic carbon and nitrogen in marine sediments using the Carlo Erba NA-1500 Analyzer. *Deep-Sea Res* 37:157-165 (Protocol is adapted with these changes: premanufactured silver foil sample cups are used rather than handmade aluminum cups; inorganic carbon is removed from sediment samples by fuming with concentrated HCl in closed chamber.)

F. Appendix (next page)

1. Data Sheet Templates

Monitoring Effects of Thin-Layer Placement on Marsh Benthic Infauna and Sediment Properties

Data Taker:			Date: (mm/dd/yy)			
Station ID:					Time Arrive on Station:	
Personnel:						
Weather:	Sunny	Partly Sunny	Overcast	Rainy	Windy	Foggy
Latitude:						
Longitude:						
Comments:						

Infaunal core #	Sediment Depth	Notes
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Sediment properties core #	Sediment Depth	Notes
1		
2		

NATURE CONSERVANCY PROJECT – BENTHIC INFAUNA DATA

SAMPLING DATE _____

SAMPLING SITE ☐ ☐ AVALON-CONTROL
 ☐ AVALON-PLACEMENT

 ☐ FORTESCUE CONTROL

 ☐ FORTESCUE PLACEMENT

 ☐ RING ISLAND CONTROL

 ☐ RING ISLAND PLACEMENT

CORE # _____

SORTER _____

DATE COMPLETED _____

TAXON	ABUNDANCE

Nature Conservancy Grain Size Analyses

Today's Date:

Sample ID:

Date of NC Sampling:

Station:

STONE HARBOR AVALON FORTESCUE

Site:

CONTROL IMPACT

Description:

Peroxide Treatment

YES / NO

3 ml total H2O2

Wet Subsample

Wt (grams)

Beaker#	beaker wt	final wt (beaker + sed)	Sediment wt
Total Sand Fraction			0
Total < 63 µm Fraction			0

shake for 6 minutes

<u>Pan #</u>	<u>Seive #</u>	<u>Wentworth Class</u>	<u>Phi</u>	<u>µm</u>	<u>grams</u>
1	10	gravel	-1	2000	
2	18	very coarse sand	0	1000	
3	35	coarse sand	1	500	
4	60	medium sand	2	250	
5	120	fine sand	3	125	
6	230	very fine sand	4	62.5	
7		total silt&clay		<62.5	
Total Sand Dry Weight (w/o debris)					0

50 ml

	tare (gr)	grams 63 µm subsample	grams total <63 fraction
< 63 µm Fraction	0	0	-0.005

Summary:

Seive #	Wentworth Class	Phi	µm	grams	%
	Debris				
10	gravel	-1	2000	0	0.00
	very coarse				
18	sand	0	1000	0	0.00
35	coarse sand	1	500	0	0.00
60	medium sand	2	250	0	0.00
120	fine sand	3	125	0	0.00
230	very fine sand	4	62.5	0	0.00
	silt&clay		<62.5	-0.005	100.00
Total (w/o debris)				-0.005	
				% total sand	0.00
				% silt & clay	100.00
					100.00

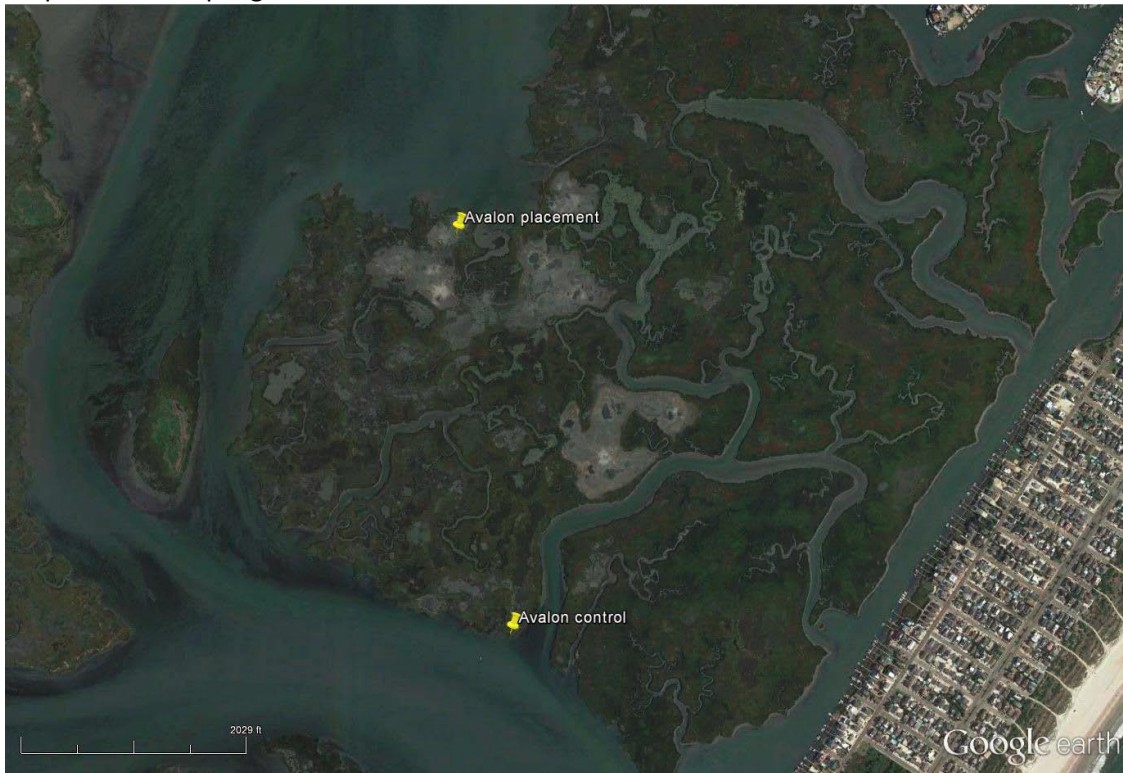
PO4	working stock	stock conc, mM	mL WS	mL 0.1 N HCl	mL mixed reagent	A880nm	final [P], mM
							0.00E+0
B		0.1947	0	4	0.6		0
B		0.1947	0.09	3.91	0.6		3.81E-03
B		0.1947	0.18	3.82	0.6		7.62E-03
B		0.1947	0.27	3.73	0.6		1.14E-02
B		0.1947	0.36	3.64	0.6		1.52E-02
B		0.1947	0.45	3.55	0.6		1.90E-02
B		0.1947	0.54	3.46	0.6		2.29E-02
							0.00E+0
C		0.2056	0	4	0.6		0
C		0.2056	0.09	3.91	0.6		4.02E-03
C		0.2056	0.18	3.82	0.6		8.05E-03
C		0.2056	0.27	3.73	0.6		1.21E-02
C		0.2056	0.36	3.64	0.6		1.61E-02
C		0.2056	0.45	3.55	0.6		2.01E-02
C		0.2056	0.54	3.46	0.6		2.41E-02

75

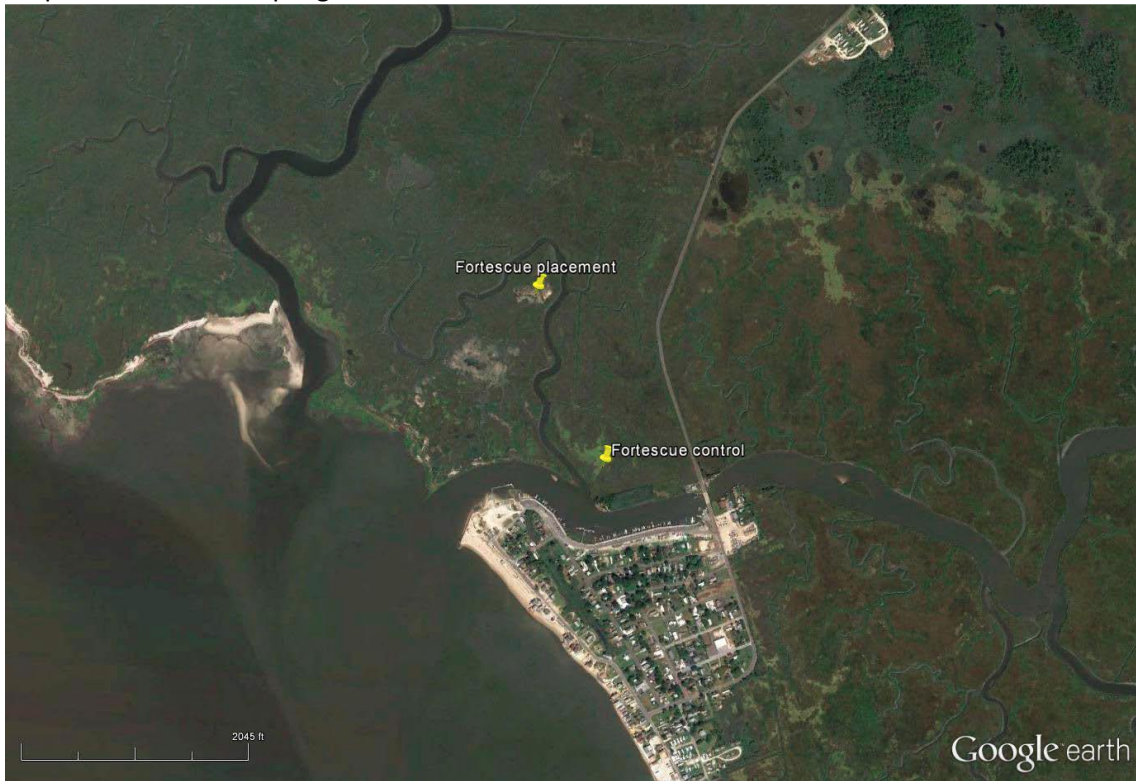
2. Map of Ring Island Sampling Locations



3. Map Avalon Sampling Locations



4. Map of Fortescue Sampling Locations



Monitoring Plan Title: Nekton Surveys

Monitor: Princeton Hydro, LLC

C. List of metrics

1. Nekton assemblage
 - Taxa richness
 - Composition
2. Areal density
3. *Fundulus spp.* length
4. In-situ water quality
 - Temperature
 - Salinity/Conductance
 - Dissolved oxygen (concentration and percent saturation)
 - pH
 - Clarity/turbidity

D. Monitoring design

1. Spatial design: This monitoring will follow a stratified random sampling design. Sampling will be conducted in four sub-habitats or strata at each of the placement sites. The sub-habitats include: 1) marsh pool, 2) tidal ditch, 3) larger tidal creek, and 4) marsh shoreline/edge. Twenty sample points will be surveyed in total per site per sampling event. Five sample points will be selected at random within each sub-habitat type. In the event that a particular sub-habitat is absent from a site, then sample points will be reassigned in order that there is still a total of twenty sample points per site. Sample point locations will be determined in the field. Sampling will be repeated at the same location in pre- and post-placement sampling events given that placement has not significantly altered the given feature. If the placement of dredged material alters extant sub-habitats, new sample points will be selected at random in the field within those affected sub-habitat strata for post-placement sampling events.
2. Temporal design: Sampling at each of the sites will be conducted prior to the placement of dredged material. Sampling will occur during late July and early August to ensure sampling is occurring during a period of active site use rather than during diapause or dormancy. Post-placement monitoring will occur approximately one year after the pre-placement monitoring to replicate seasonality. This will allow time for the placement site to stabilize and revegetate after the short term impacts of placement and will provide better data for medium and long-term site use. Each sampling event (i.e. 20 sample points) is expected to take approximately three days to complete given the number of sampling points and extent of processing as well as the logistics of accessing and moving around the project sites.

E. Detailed methods

1. Field methods per site: Identify five sampling locations in each of the four sub-habitats and record their positions with a GPS. Assign an ID to each sample point.
2. Field methods per sample point:
 - Metrics:
 - Taxa richness
 - Composition

- Areal density
- *Fundulus spp.* length
- In-Situ Water Quality metrics (see A.)
- Equipment/Supplies:
 - Ditch nets
 - Throw traps
 - Dip net
 - Ruler
 - Calibrated Water Quality Meter
 - Field Book
 - Field guides/keys
 - Holding vessel
 - Digital camera for ID photographs
 - GPS
- Procedures:
 1. Locate the sample point. Record sample point ID, date, time, weather conditions, lunar cycle and tide stage in field book.
 2. Record in-situ water quality including temperature, salinity/conductance, dissolved oxygen, pH, and turbidity/clarity.
 3. Conduct a qualitative characterization of sampling site (vegetation, sediment type, etc.).
 4. If sample point is within a tidal ditch sub-habitat:
 - i. Deploy ditch nets in ditches approximately a half hour in advance of high tide.
 - ii. Measure ditch geometry (for ditch net footprint including length and width) to accurately calculate area and consequently density.
 - iii. Allow at least 30 minutes prior to retrieving the nets to limit disturbance.
 - iv. Pull net and lay on marsh.
 - v. Collect nekton into a holding vessel.
 - vi. Process nekton identifying to species where appropriate and tallying abundance.
 - vii. Measure total length of 20 randomly selected *Fundulus spp.*
 5. If sample point is within a marsh pool, a larger tidal creek or at the marsh shoreline/edge:
 - i. Stealthily approach site to within 4 to 5 m.
 - ii. Wait 2 minutes and throw a 1m² throw trap into water.
 - iii. Run to trap and push into sediment.
 - iv. Scoop samples (including surficial sediment) from the trap with dip net until there is no capture or first four scoops are empty.
 - v. Transfer nekton to a holding vessel.
 - vi. Process nekton identifying to species where appropriate tallying abundance.
 - vii. Measure total length of 20 randomly selected *Fundulus spp.*

F. Data management and quality assurance/quality control

1. Data collection: Once survey locations are finalized in the field, coordinates of the survey locations will be recorded with a GPS unit. Field identification of the nekton will be

conducted by trained individuals. All data will be collected in field books. When a specimen cannot be identified in the field it may be retained for laboratory identification under microscopy; upon identification the data will be added to the field book. Digital photographs will also be taken.

2. Data storage: Field notes will be scanned. Data will be transferred from the field book or datasheets into Excel worksheets. Hard copies will be archived. QA/QC for data entry will be reviewed for transcription errors. Identification photographs will be verified against keys. Sample point coordinates will be uploaded from the GPS unit and converted into shapefiles. Photos will be uploaded and labelled. The resulting digital copies of field notes, Excel worksheets, shapefiles and photos will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: A variety of summary statistics will be prepared examining data across sites and before and after dredged material placement. Summary statistics will include means, medians, and other distributional data for the primary metrics. Summary statistics will be prepared for each site, event, and sub-habitat based on taxa richness, areal density, and *Fundulus spp.* length. Richness is simply a count of taxa encountered per sample; *Fundulus spp.* length will include total length measurements of *Fundulus spp.*; areal density will be nekton per unit area (to be expressed as m⁻²). T-tests will be used to test for significant differences in the community metrics (richness, *Fundulus spp.* length, areal density) between pre- to post-placement sampling events. A report will be written to summarize all sampling activities and analyses. This report will include summaries of the additional data collected at the time of the sampling including water quality and site characteristics. GIS prepared sampling figures will be included in the final reports. The report will be stored in a cloud storage location that is shared by the project team (Box).

G. References

1. Neckles, H.A., et al. 2013. Identification of Metrics to Monitor Salt Marsh Integrity on National Wildlife Refuges in Relation to Conservation and Management Objectives; Appendix 6. Nekton Monitoring in Salt Marshes. USGS Patuxent Wildlife Research Center. This is the primary document of interest and includes rationale for the selection of the monitoring metrics and more general sampling practices.
2. James-Pirri, M.J, C.T.Roman, E.L. Nicosia. 2012. Monitoring nekton in salt marshes: A protocol for the National Park Service's long-term monitoring program, Northeast Coastal and Barrier Network. Natural Resource Report NPS/NCBN/NRR – 2012/570. National Park Service, Fort Collins, Colorado. This document is attached as an appendix to the Neckles, 2013 document. This source provides the sampling methodology as well as the construction of the sampling equipment (ditch nets and throw traps).

Monitoring Plan Title: Avian Surveys

Monitor: Princeton Hydro, LLC and The Wetlands Institute

A. List of metrics

1. Species Richness: Number of different species represented in an ecological community
2. Species Abundance: Number of individuals per species

B. Monitoring design

1. Spatial design: Avian surveys will be performed at multiple survey locations at both placement and control sites. A survey location is a 100+ m radius circular area. Eight (8) to ten (10) such survey locations will be established at each site. Survey locations will be spaced at least 250 m apart to minimize double counting. These survey locations are permanent and will be revisited throughout the course of this project. Survey locations will occur within major habitat types including low marsh, high marsh, pools, and dredged material placement sites. If a sampling location has a unique habitat feature (e.g. pool, dense stand of *Baccharis*) this will be noted. Survey locations will be approximated from aerial maps prior to initiation of surveys, but final locations will be selected in the field based on accessibility and other factors.
2. Temporal design: In general, surveys will occur twice in the spring, summer and fall for a total of six (6) events at each placement and each control site. Each survey will occur at least 10 days apart. Survey windows will be coordinated among project sites for consistency of results. All locations at a site will be surveyed between 30 min before sunrise and 10 am on the same survey day, if possible, preferably during low to mid-tide. The frequency of surveys may increase if additional funding is available.

C. Detailed methods

1. Field methods per survey location:
 - Equipment/Supplies:
 - Field book or datasheets
 - Pencils
 - Binoculars
 - Bird ID field guide
 - Standard recordings for playback units, reflecting focal effort species of the region
 - Mp3 player and speakers
 - GPS
 - Extra batteries
 - Procedures:
 - Two people arrive at the survey location. One person will record while the other focuses on observations.
 - Record survey location ID, date, time, weather conditions and tide stage in field book or on datasheet. This will be done at the location, giving birds time to acclimate to observer presence.
 - During each survey, the observing surveyor will spend five minutes conducting a point count survey to document all bird species and the number of each species within the 100+m-radius survey area. Birds will be identified by sight and sound. Location (e.g. high marsh, low marsh, etc.), compass bearing and approximate distance of each sighting will be noted in

a field book or on a datasheet. During each survey, the surveyor will then conduct a standard 5 min passive/8 min play callback survey (SHARP, SMI protocols) to target secretive marsh-nesting birds. There is a five-minute passive period prior to the callbacks in order to record birds present by sight and sound without recorded vocalizations. During the second 8 minute period, each callback will be played for 30 seconds followed by 30 seconds of silence. For the duration of the mp3 file all birds will be recorded that are observed/heard. Location (e.g. high marsh, low marsh, etc.), compass bearing and approximate distance of each sighting will be noted in a field book or on a datasheet. Flyover birds will be a judgment call as to whether the bird was using the marsh/thin layer dredged material location(s) or not. Species included in the vocalization sequence include: Black Rail, Least Bittern, Sora, Virginia Rail, King Rail, Clapper Rail, American Bittern, and Common Gallinule.

- Survey procedures will be implemented at each survey location, following the same sampling order for each survey.

D. Data management and quality assurance/quality control

1. Data collection: Data from the surveys will be collected in real-time on-site in a field book or on datasheets. Trained biologists will perform the surveys. There will be 2 surveyors in the field assigned to roles of data recorder and observer. Once survey locations are finalized in the field, coordinates of the survey locations will be recorded with a GPS unit to facilitate repeated surveying.
2. Data storage: Field notes will be scanned. Data will be transferred from the field book or datasheets into Excel worksheets. QA/QC for data entry will be reviewed for transcription errors. Survey location coordinates will be uploaded from the GPS unit and converted into shapefiles. Photos will be uploaded and labeled. The resulting digital copies of field notes, Excel worksheets, shapefiles and photos will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: Due to the limited amount of data collection it is not possible or reasonable to apply statistics that are typically used to identify significant differences.
 - Species Richness: Species richness will be determined as the number of species present. For these surveys it is recommended that a Jaccard index (SC_j) is used to compare richness between control sites and placement sites, high marsh within control and high marsh within placement, before placement and after placement, etc.

$$SC_j = (c/A+B-c) * 100$$

A and B are the richness of the different sites and C is the number of species found within both sites. The higher the index is, the more similar the two sites/habitats being compared are. The lower the index, the greater the differences between compared sites.

- Species Abundance: the abundance of species observed within each habitat type will be used as a simple indicator of which species prefer which habitat types and as an indicator of difference between control and placement sites.

E. References

1. Standardized North American Marsh Bird Monitoring Protocols, Wildlife Research Report #2007-04, Courtney Conway and SMI Avian Point-Count/Callback Survey Protocol (revised November 2012).

Some deviations were necessary to capture the needs of this project. Deviations from this protocol include the addition of bird location, expansion of survey windows and number of visits, and the addition of a five-minute point count at the beginning of the survey.

Additionally, the point-selection methodology was changed due to the desire to include a non-random variation in surveyed habitat types.

F. Appendix (next page)

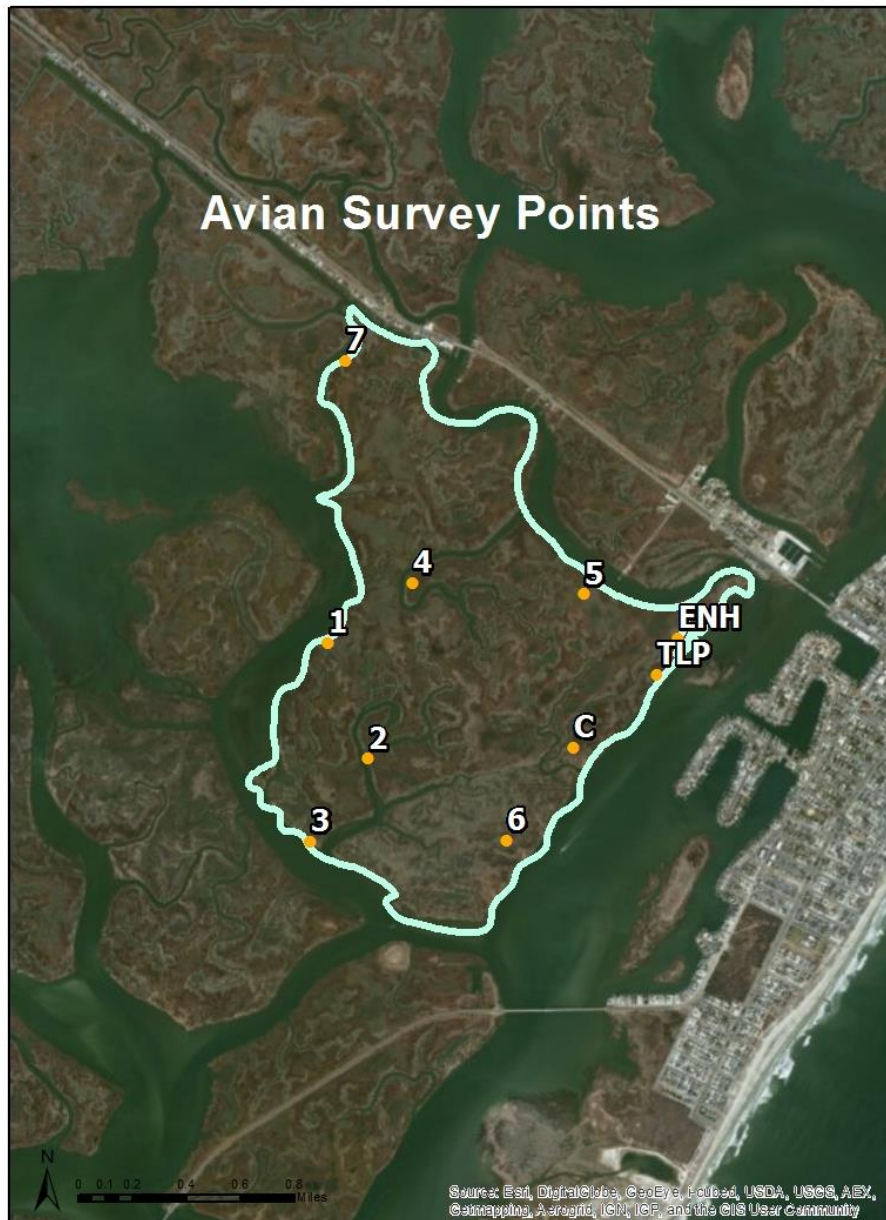
1. Map of Fortescue Sampling Locations:



2. Map of Avalon Sampling Locations:



3. Map of Ring Island Survey Locations (ENH is the location of the constructed elevated nesting habitat):



4. Data Sheet Template for Avian Monitoring

[illegible]

Monitoring Plan Title: Avian and Wildlife Use of Constructed Elevated Nesting Habitat on Ring Island

Monitor: The Wetlands Institute

A. List of metrics

1. Species richness for all bird species
2. Species abundance
 - Primary focal species: Black Skimmers
 - Secondary focal species: all avian and wildlife species present
3. Reproductive success for Black Skimmers and other breeding birds
 - Number of nests
 - Hatch success: proportion of nests that hatch at least one egg
 - Fledging success: proportion of nests that fledge at least one chick
 - Productivity: number of chicks fledged per nesting pair

B. Monitoring design

1. Spatial design: Survey location will coincide with ongoing monitoring projects at dredged material placement sites (i.e. two thin-layer placement sites and one constructed elevated nesting habitat) and control sites on Ring Island (see Vegetation Monitoring Plan for site locations). For species richness and abundance surveys, a 20m x 20m sample grid of the constructed habitat site will be established prior to the nesting season. Stakes will mark start, end, and corner points and will be driven within 2-4" of surface elevation. Stakes will be fitted with bird spikes to discourage perching by predatory avian species. The grid will be determined using ArcGIS prior to field implementation. Grid cells will coincide with vegetation monitoring transects on the site, where possible. For reproductive success surveys of colonial nesting birds, a simple-random or stratified-random survey design will be employed depending on the evenness of nest density and colony size. For this reason the spatial design for reproductive success surveys will be determined after the beginning of black skimmer nesting season (March 15-August 31). For solitary nesting birds, all nests will be monitored.
2. Temporal design: The study site was constructed in August 2014. All surveys will be conducted post-placement to examine change over time in use of the site by wildlife during the breeding season. Surveys will be conducted 1-2 times per week from April to August 2015, 2016, and 2017 during morning hours for birds and other wildlife using the site.

C. Detailed methods

1. A sample grid will be established prior to the nesting season. Stakes will mark start, end, and corner points and will be driven within 2-4" of surface elevation.
 - Supplies: stakes, mallet, GPS unit, bird spikes
2. Bird use surveys will be conducted 1-2 times per week using high quality optics (binoculars, scope) from a vantage point on the marsh, a boat, or other location beyond flight initiation distance of birds nesting on the constructed site and vicinity. The number of birds observed will be recorded by species, age class, and behavior (e.g. nesting, loafing, foraging). Two counts will be averaged for each count/estimate.
 - Supplies: Binoculars, spotting scope, Garmin GPS unit, rangefinder, compass, datasheets, field notebook, digital camera
3. Direct counts (i.e. walk-through census) or estimates of total number of nests of focal and secondary species will be made, depending on factors such as group size, spacing and

disturbance or predation levels, and recorded on the datasheet. These counts will be made at the same time as the above-mentioned bird use surveys and so will be conducted 1-2 times per week. If no skimmers use the site for nesting, social attraction measures (e.g. decoys, vocalization) may be utilized in the second year of the project to attract Black Skimmers to the site. A random sample of nests (or all nests, depending on number and species) will be monitored from a distance to determine reproductive metrics. Nest checks will be conducted from a distance with optics if approaching the nest would adversely affect nesting birds, or when predators are present. The grid system and a rangefinder will facilitate location and identification of nests within a colony from a distance. Observations of signs of disturbance or predation events (e.g. tracks, scat, egg shell, carcasses) and bird response will be recorded during bird use surveys and nest checks, and photo documented whenever possible. Disturbance or predation impacts (e.g. egg or chick loss) will be recorded during bird use surveys and nest checks.

- Supplies: Binoculars, spotting scope, Garmin GPS unit, rangefinder, compass, datasheets, field notebook, digital camera.
- 4. Observations of signs of use (e.g. tracks, scat, nests, etc.) by other species, particularly diamondback terrapins, will be recorded during bird use surveys and nest checks and may be supplemented with wildlife cameras if funding allows.
 - If used, required supplies include: camera, batteries, SD cards, deployment supplies.

D. Data management and quality assurance/quality control

1. Data collection: Trained biologists will perform the surveys. Data from bird use surveys and nest monitoring will be recorded on standardized datasheets (appendix) and in field notebooks. Coordinates of nests will be recorded in the field with a handheld GPS.
2. Data storage: Datasheets will be scanned. Data will be transferred from datasheets and field notebooks to Excel worksheets. QA/QC for data entry will include reviewing data for transcription errors. All GPS waypoints will be uploaded and saved as .csv and shapefiles. Photos will be uploaded and labeled. The resulting digital copies of datasheets, Excel worksheets, shapefiles and photos will be stored in a cloud storage location that is shared by the project team (Box).
3. Data analysis: Species richness will be calculated as the total number of bird species using the site. Species abundance will be calculated for all species recorded, and for each survey. Species richness and abundance will be compared between and within years to assess temporal changes in relative use of the site by wildlife. Number of nests, hatching success, fledging success and productivity will be calculated based on data collected during nest monitoring surveys.

E. References

1. Anotolos M., D.D. Roby, D.E. Lyons, S.K. Anderson, and K. Collis. 2006. Effects of nest density, location, and timing on breeding success of Caspian Terns. *Waterbirds* 29: 465-472. Methods from this study were incorporated into the proposed methods, specifically related to using a rangefinder for tracking and mapping tern nests from a distance.
2. Florida Fish and Wildlife Conservation Commission. 2012 (updated 2014). Breeding Bird Protocol for Florida's Seabirds and Shorebirds. General methods for surveying beach-nesting birds were incorporated from this document.
3. Steinkamp, M., B. Peterjohn, V. Byrd, H. Carter, and R. Lowe. 2003. Breeding season survey techniques for seabirds and colonial waterbirds throughout North America. Unpublished Final Report. Methods for surveying ground nesting colonial birds through visual and direct

count surveys were incorporated from this document.

F. Appendix (next page)

[illegible]

[illegible]

Species: LAGU (laughing gull) BLSK (black skimmer) COTE (common tern) LETE (least tern) FOTE (Forster's tern) GBTE (gull-billed tern)

2017-Ring Island- Solitary Species

Observers _____ Date _____

Date _____
 Start time _____
 Stop time _____

Species _____
 Pair # _____
 Nest # _____

Expected hatch date _____
 Expected fledge date _____
 Explored (PIP) Y ☐ N ☐

Nest location WP _____ Latitude _____ Longitude _____
 Description/notes: _____
 Restored Area Y ☐ N ☐
 Area _____ Cell _____
 View Location WP _____
 Photo # _____

Bird 1 L Band _____ Location, WP _____ Exact ☐ Est ☐ NA ☐
 M F U R Band _____ Distance, angle _____ Restored Area Y ☐ N ☐ Behavior _____
 Bird 2 L Band _____ Location, WP _____ Exact ☐ Est ☐ NA ☐
 M F U R Band _____ Distance, angle _____ Restored Area Y ☐ N ☐ Behavior _____

Nest status Discovered ☐ # e/c _____ Hatching ☐ # e/c _____ Unknown ☐
 Remote ☐ Laying ☐ # e _____ Brooding ☐ # c _____ Notes: _____
 Direct ☐ Incubating ☐ # e _____ Fledged ☐ # c _____

Nest fate Hatched ☐ # chicks obs _____ # eggs unhatched _____
 Failed ☐ Flooding ☐
 Predated ☐ Avian ☐ Mammal ☐ Undetermined ☐
 Abandoned ☐
 Undetermined ☐
 Other ☐
 Unknown ☐

Photo # _____
 Notes/signs of loss: _____

Brood obser # chicks obs _____ Location, WP _____ Exact ☐ Est ☐ NA ☐ Band _____
 Appearance D _____ F _____ FL _____ Restored Area Y ☐ N ☐ Behavior _____ Trans ☐
 Adult behav (AMOV): Location, WP _____ Exact ☐ Est ☐ NA ☐ Band _____
 Distance, angle _____ Restored Area Y ☐ N ☐ Behavior _____ Trans ☐
 Location, WP _____ Exact ☐ Est ☐ NA ☐ Band _____
 Distance, angle _____ Restored Area Y ☐ N ☐ Behavior _____ Trans ☐
 Location, WP _____ Exact ☐ Est ☐ NA ☐ Band _____
 Distance, angle _____ Restored Area Y ☐ N ☐ Behavior _____ Trans ☐
 Notes/signs of loss: Photo # _____

Behavior: In = incubating; Br = brooding; Ro = foraging; Ro = roosting; Pr = preening; Ot = other (what) Appearance: D = downy; F = feathered; FL = fledged
 Bands: b - Light blue; B - Dark blue; g - Light green; G - Dark green; l - Grey; L - Black; R - Red; O - Orange; Y - Yellow; W - White; X - Metal band; --- No band; T - other (describe)

Nest observations		Spp/type		Obs/signs		#	photo #
Mammal Pred (10 M)	Y <input type="checkbox"/> N <input type="checkbox"/>	Fo <input type="checkbox"/> Ra <input type="checkbox"/> Ca <input type="checkbox"/> Sk <input type="checkbox"/> Co <input type="checkbox"/> Other		Ob <input type="checkbox"/> Tr <input type="checkbox"/> Fu <input type="checkbox"/> Other			
Bird response	N <input type="checkbox"/> W <input type="checkbox"/> F <input type="checkbox"/> FR <input type="checkbox"/> FM <input type="checkbox"/> CH <input type="checkbox"/> BW <input type="checkbox"/> TD <input type="checkbox"/> AC <input type="checkbox"/> NA <input type="checkbox"/>						
Avian Pred (10 M)	Y <input type="checkbox"/> N <input type="checkbox"/>	LG <input type="checkbox"/> HG <input type="checkbox"/> GB <input type="checkbox"/> PF <input type="checkbox"/> Cr <input type="checkbox"/> Other		Ob <input type="checkbox"/> Tr <input type="checkbox"/> Fe <input type="checkbox"/> Other			
Bird response	N <input type="checkbox"/> W <input type="checkbox"/> F <input type="checkbox"/> FR <input type="checkbox"/> FM <input type="checkbox"/> CH <input type="checkbox"/> BW <input type="checkbox"/> TD <input type="checkbox"/> AC <input type="checkbox"/> NA <input type="checkbox"/>						
Flooding (10 M)	Y <input type="checkbox"/> N <input type="checkbox"/>						
Bird response	N <input type="checkbox"/> W <input type="checkbox"/> F <input type="checkbox"/> FR <input type="checkbox"/> FM <input type="checkbox"/> CH <input type="checkbox"/> BW <input type="checkbox"/> TD <input type="checkbox"/> AC <input type="checkbox"/> NA <input type="checkbox"/>						
Disturbance (50 M)	Y <input type="checkbox"/> N <input type="checkbox"/>	D <input type="checkbox"/> W <input type="checkbox"/> C <input type="checkbox"/> B <input type="checkbox"/> Bt <input type="checkbox"/> F <input type="checkbox"/> Other		Ob <input type="checkbox"/> Tr <input type="checkbox"/> Other			
Bird response	N <input type="checkbox"/> W <input type="checkbox"/> F <input type="checkbox"/> FR <input type="checkbox"/> FM <input type="checkbox"/> CH <input type="checkbox"/> BW <input type="checkbox"/> TD <input type="checkbox"/> AC <input type="checkbox"/> NA <input type="checkbox"/>						
Other	Y <input type="checkbox"/> N <input type="checkbox"/>						
Bird response	N <input type="checkbox"/> W <input type="checkbox"/> F <input type="checkbox"/> FR <input type="checkbox"/> FM <input type="checkbox"/> CH <input type="checkbox"/> BW <input type="checkbox"/> TD <input type="checkbox"/> AC <input type="checkbox"/> NA <input type="checkbox"/>						
Notes:							
<p>Predator type: Fo = fox; Ra = raccoon; Ca = cat; Sk = skunk; Co = coyote; LG = LAGU; HG = HERG; GB = GBBG; PF = PEFA; Cr = crow; American or Fish</p> <p>Obs/signs: Ob = direct observation; Tr = tracks; Fu = fur; Fe = feathers</p> <p>Disturbance: D = dog; W = walker; C = child; B = beehive; Bt = boat; F = fishing</p> <p>Bird response: N = none; W = walk away; F = fly and not return; FR = fly and return; FM = fly and move away; CH = chase; BW = broken wing; TD = threat display; AC = alarm call; NA = not applicable</p>							

Nest characteristics

% vegetation (1 m) _____ % vegetation type _____

Dist nearest veg _____ Dist vegetation type _____

Substrate type (1m) _____ % shell (1m) _____

Tern colony (15m) Y ☐ N ☐ Photo # _____ # Nests within 15m _____

Dist nearest nest _____ Dist nest species _____

If within plot: Dist to marsh edge _____ Dist to water _____

If outside plot: Dist to restoration plot _____ Dist to water _____

Notes:

Other activities:

Observers

Temperature _____

Wind _____

Sky _____

[illegible]

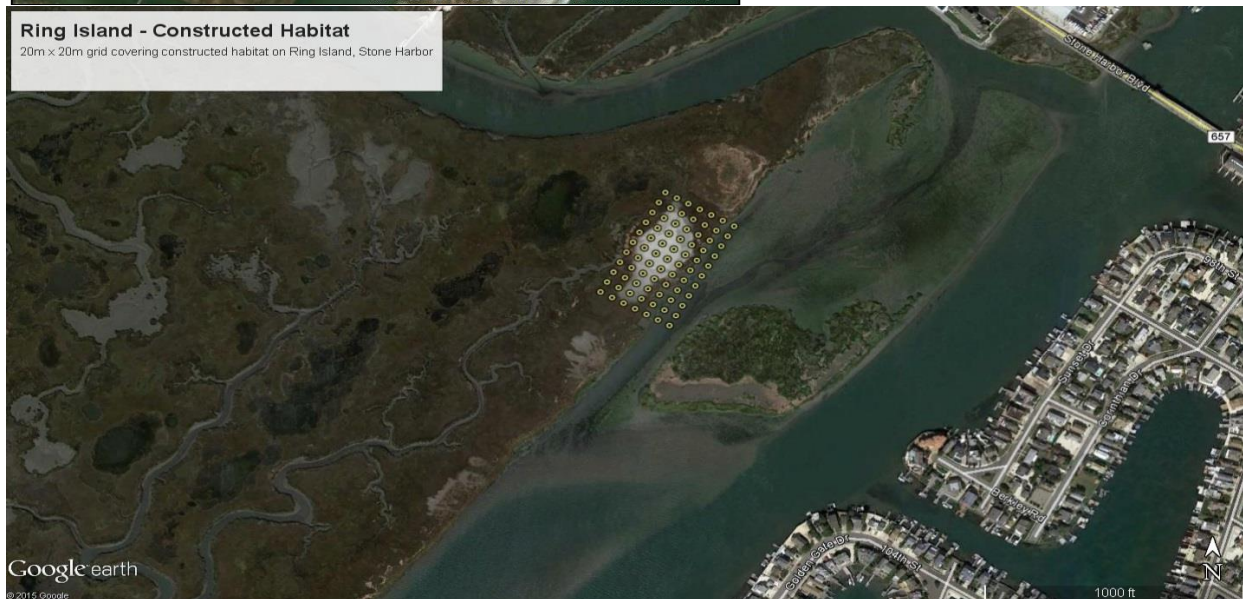
Age: Ad = birds in adult plumage, at least 1 year old; Juv = birds capable of sustained flight; Fledglings = birds capable of flight but still dependent on parents; chicks = pre-fledge young

Behavior: In = incubating; Br = brooding; Fo = foraging; Ro = roosting; Pr = preening; Ot = other (what)

Notes:

Marked birds:

2. Maps of the avian survey points throughout Ring Island (ENH is the location of the constructed nesting habitat), and the 20 m x 20 m grid covering the constructed habitat.



Monitoring Plan Title: Monthly Site Inspections

Monitor: NJDEP, Division of Fish and Wildlife

Please note: these are mostly anecdotal/qualitative observations. The data collected are meant only to inform adaptive management, not contribute to the statistical data set for the project.

A. List of metrics

1. Vegetation Recovery
 - Species Present
 - Method of Growth (recovery vs. recruitment)
 - Depth of Dredged Material (cm)
 - Sediment Characteristics (saturation, texture, color, grain size, etc.)
2. Vegetation Die-Off
 - Species Present
 - Sediment Characteristics (saturation, texture, color, grain size, etc.)
 - Depth of Dredged Material (cm)
 - Depth of Pooled water (cm)
3. Containment
 - Identify issue (blocking tidal flow, wildlife impingement, wrack deposition, etc.)
 - Size of containment (inches)
 - Difference in sediment elevation inside versus outside containment (cm)
4. Dredged Material
 - Characteristics (saturation, texture, color, grain size, etc.)
 - Depth of Dredged Material (cm)
 - Cracking/Drying of Surface (yes/no)
5. Pooling
 - Depth of water (cm)
 - Persistence (ephemeral or permanent)
6. Wildlife
 - Species Present
 - Activity (foraging, nesting, loafing, etc.)
7. Planting Success
 - Species Planted
 - Depth of Dredged Material (cm)
 - Sediment Characteristics (saturation, texture, color, grain size, etc.)
8. Planting Failure
 - Species Planted
 - Depth of Dredged Material (cm)
 - Sediment Characteristics (saturation, texture, color, grain size, etc.)

B. Monitoring design

1. Spatial design: Each impacted project site (Avalon areas A, C, D, E, F, and Fortescue Areas 1 & 2) will be inspected as a whole on a monthly basis to observe changes in the salt marsh and document recovery post-placement of dredged material. Team members will walk the perimeter and interior of each placement area at each site (excluding Ring Island) and make observations about enhancement progress using the metrics listed above. No permanent observation points will be established; however, during each visit the same areas will be observed and noted on blank site maps for comparison across different

months and years. Previous months' data sheets and maps should be reviewed prior to site inspections, or taken into the field during site inspections to provide a reference of which areas to revisit and observe.

2. Temporal design: Monthly site inspections will occur post-placement of dredged material, once per month during the growing season (June to September) for a total of four (4) inspections annually. Additional visits during the spring, fall, and winter will occur as needed. Site inspections will happen at various tidal stages to observe the fluctuating hydrology of the salt marsh and the interaction of the tide with the project site. Nightly observations are restricted to time-lapse cameras positioned in non-random locations with a limited view. Plantings will occur post-placement of dredged material and after dredged material has had significant time to de-water and stabilize. The time this takes is highly variable across sites and dependent upon multiple factors.

C. Detailed Methods

1. Field Methods for Monthly Site Inspections:

- Equipment/Supplies:
 - Boat/Canoe/Kayak
 - Blank Data/Observation Sheets
 - Blank Site Maps
 - Reference Aerial Photos
 - Clipboard with Storage
 - Pencils & Permanent Markers
 - Ruler/Meter Stick/Tape Measure
 - Camera
 - GPS Unit
- Instructions for filling out observation sheet:
 - Time: Recording the time will help make conclusions considering tidal stage
 - Tide: Spring or neap? Falling or rising?
 - Sheet __ of __: If multiple pages are used for observations in a given area in a given day, then number them.
 - Observation ID: The observation ID is a number that corresponds with locations marked on the map.
 - Observations: Write down all observations using the procedure below.
- Procedure:
 - Note the time and tidal stage upon arriving at the site.
 - Walk systematically around each area of the project site, making observations of the above metrics as you go.
 - Take a photo at each permanently established photo point in each area and record the number of the photo and the photo point ID on the data sheet.
 - When making a new observation, mark the location on the blank site map. If necessary, use landmarks and/or satellite imagery from a cellphone to pinpoint location precisely. Label observation points with numbers, starting at one (1). Each project area – A, C, D, E, and F will have their own set of observation points. Observation point numbers will start back at one (1) when moving into a new area.
 - Note the exact time of the observation, and number each observation point on both the map and the data sheet.

- Record field notes at each observation point, making sure to define on the map and data sheets where you are in the project site. Observation points can be made any time there is information to record. There is no limit to the number of observation points.
- Whenever photos are taken, record the photo number on the data sheet under the correct observation point with a brief description of what the photo captures.

D. Data management and quality analysis/quality control

1. Data collection: All field observations will be recorded on blank observation sheets and blank site maps. Each monthly site inspection will be completed by the same individual to ensure each metric is observed in the same way month after month. In addition, various team members will join the monthly site inspections to eliminate any observation bias.
2. Data storage: Data sheets and maps will be scanned and uploaded to a cloud based server (BOX), along with any photographs and their original photo numbers. At the end of each monthly site inspection, a Microsoft PowerPoint will be created to share the observations with team members. The PowerPoint will include scans of the maps and all observations recorded on the data sheets, as well as supporting photos and any quantitative measurements. GPS data is written to a shapefile within the Trimble device and downloaded using Windows Media Center. The shapefiles will be uploaded into ArcGIS 10 and permanent, shareable layer packages will be created. These layer packages will then be uploaded to BOX and made available to the team. Any maps produced will be exported from ArcGIS and uploaded to BOX as PDF files. Quantitative data will be recorded in an excel spreadsheet. Original data sheets and maps will be retained by the Division of Fish and Wildlife until the end of the grant period, when they will be transferred to storage within the NJDEP.
3. Data analysis: Data collected on monthly site inspections is mostly qualitative and cannot be formally analyzed for significance. Data will be used in a qualitative/anecdotal fashion. It is possible to compare photographs and identify changes in percent cover of vegetation, but this is limited to the view shed of permanent photo points. Monthly site inspections are necessary to identify any issues that may not be noticed by the other project teams. The observations help inform the adaptive management plan.

E. Data Sheet (next page)

Date: _____
 Site: _____
 Area ID: _____
 Observer name(s): _____
 Tide: | _____
 Weather (temp, wind, sky): _____

Obs. ID	Obs. Type	Time	Map ID	Photo #s	Depth of sed. (cm)	Observations	Mgmt. action?