Chesapeake Bay National Estuarine Research Reserve in Virginia

Special Awards Condition Report

Chesapeake Bay National Estuarine Research Reserve in Virginia Sentinel Site Plan

Reserve: Chesapeake Bay National Estuarine Research Reserve in Virginia

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I. Introduction:

Primary Goals:

The CBNERR-VA SSP follows the protocols outlined in Coastal Habitat Response to Changing Water Levels NERR Sentinel Site Application Module 1 (NERRS 2015), which serves as an update to the previously published National Estuarine Research Reserve System Sentinel Sites Program Guidance for Understanding Climate Change Impacts (NERRS 2012). The SSP also follows guidance outlined in the 2011 NERRS Climate Change Initiative, the NERRS System-wide Monitoring Program (SWMP) Plan (2011), and the NERRS Sentinel Site Work Plan (Dionne et al. 2009). Additionally, the SSP complements plans outlined in the Chesapeake Bay Sentinel Site Cooperative Implementation Plan FY 2013 – 2018

This document outlines a detailed plan for the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR-VA) to establish a Sentinel Site Program (SSP) for understanding climate change impacts on estuaries. The National Estuarine Research Reserve System (NERRS) has established the Sentinel Sites Network with the benefit of linking reserves across the nation to integrate data streams for the broader understanding of ecosystem conditions at a scale relevant to regional and national management priorities.

The specific goals of the CBNERR-VA SSP are to 1) assess current conditions of target vegetation communities and relevant physical parameters; 2) document changes in marsh and submerged aquatic vegetation (SAV) as well as sediment levels within the four components of CBNERR-VA in response to climate-driven changes in sea level and inundation; 3) assess vulnerability of these vegetative communities based on changes in climatic conditions; 4) use a study design that is both locally relevant and comparable to other sentinel sites across the nation; and 5) synthesize, translate, and communicate findings to target audiences for use in future decisions.

Environmental Stressors:

Over one half of all Virginians live on the coastal plain that makes up a little under a third of the state's landmass (Colgan, 1990, Mason, 1993). This population pressure has resulted in increased impacts to salt marshes. Wetlands Watch, a Virginia NGO, has estimated that Virginia could lose between 50% and 80% of its remaining vegetated tidal wetlands by the year 2107 due to sea level rise (www.wetlandswatch. org, 2007). As sea level rises, homeowners will want to harden their shores to protect against property loss. This hardening may stop any shoreward progression of tidal marshes and more than likely increase tidal marsh losses. The tidal wetlands of the Chesapeake Bay perform a number of important ecological functions that are attributed high value by humans. The most important of these functions and values are primary production and detritus availability, wildlife and waterfowl support, shoreline erosion buffering, and water quality control.

The Chesapeake Bay, Virginia National Estuarine Research Reserve (CBNERRVA), a partnership between NOAA's Estuarine Reserves Division and the Virginia Institute of Marine Science, is a four-component reserve located on the York River sub-estuary of the Chesapeake Bay. Inundation of low-lying lands from sea level rise and land subsidence, coastal erosion and flooding from storms, and saltwater intrusion into coastal water bodies and groundwater aquifers represent significant threats to the natural resources, public and private property, and to the people of the Chesapeake Bay Region. It has been reported that more than half of the Chesapeake Bay's tidal marsh area already shows signs of degradation due to a combination of factors including sea level rise. Current relative sea level rise at the mouth of the York River estuary is 4.3 mm/yr and is expected to increase to 5.6 mm/yr in upriver reaches due to local subsidence resulting from groundwater extraction. These local sea level rise rates represent some of the highest reported within the Nation. CBNERRVA is engaged in understanding the vulnerability of critical Bay habitats within the York River estuary to climate related stressors, especially local sea level rise.

Several critical York River estuary ecosystems (i.e., emergent tidal wetlands and associated upland ecotones, underwater grass beds) are sensitive to and vulnerable to climate change factors; most often cited stressors include relative sea level rise (of which local land subsidence is significant), salt water intrusion, increasing temperatures, enhanced storm damage and spread of invasive species. These stressors and associated impacts on ecosystems (and key species) need to be better described/quantified and integrated into ecosystem vulnerability assessments and forecasting models so as to support effective communication and the development of appropriate long-term planning and management actions.

Tidal marsh resilience to sea level rise can vary due to differences in local rates of SLR, geomorphology, sediment availability and other factors. Resilience indicates the ability of a system to resist and recover from perturbation (Gunderson, 2000). Wetlands have been shown to be sensitive to factors such as tidal range and sediment supply (Fagherazzi et al. 2012) as well as differences in exposure to accelerated SLR (local hydrodynamics) – Sallenger et al. 2012). As marshes maintain a narrow elevation range within tidal range and must build vertically at rate equal to or greater than this accelerated SLR rate, there is concern that SLR might lead to loss of tidal marshes (but Kirwan et al. 2016).

There has been a projected acceleration in SLR in Chesapeake Bay (show CB-VA Grahic) (Kirwan and Megonigal, 2013). Relative Sea Level Rise rates in the Chesapeake Bay and more specifically the York River (estimated to range from 4.6 to 5.8 mm/year) are affected by a few factors which include: 1) eustatic or global change in sea level due to thermal expansion and melting of continental ice has been estimated to be 1.8 mm/year for the bay; 2) regional subsidence (due to glacial retreat from the last ice age and slowing of the Gulf Stream as the polar regions warm); and 3) local subsidence factors from industrial and domestic groundwater withdrawal.

Sea level rise is occurring along the entire eastern coast of the United States with the greatest changes occurring and predicted to continue to occur in the Mid-Atlantic region, including the Chesapeake Bay and its associated shorelines in Virginia, Maryland, and Delaware (CITATION). Some of the highest relative sea level rise rates (5.8 mm/yr or 0.23 in/yr) in the United States have been reported in the Chesapeake Bay region (Boon et al. 2010 update – rates are greater). This change in relative sea level is primarily due to subsidence (CCSP 2009) – not so, we can provide clarification.

<u>Core Research Question:</u>

The core research question for CBNERRVA's Sentinel Site wetlands program is: How does marsh sustainability/vulnerability vary as salinity, tide range, relative sea level rise, erosion, sediment supply, wetland elevation, and shoreline condition vary throughout the York River system? Is the within-site variability smaller than or greater than the between site variability. With this type of variability (and uncertainty) in the system, what are the management implications?

<u>Additional Research Questions:</u>

Overall Wetland Vulnerability to Sea Level Rise

- What are the controls on the ability of tidal marshes to vertically accrete and keep pace with local sea level rise.
    - Gain an understanding of the connectivity of SET Stations to local water level data and other wetland datasets (vegetation plots, sediment cores).
    - Increase capacity to measure sea level rise at a localized scale, installing local and site specific water level tide gauges as well as training to better understand and process water level data.

- What is the relative importance of controlling factors responsible for habitat loss/gain (retreat of shoreline perimeter edge (erosion), ponding, creek enlargement, and upland transgression) on historic marsh evolution.
    - Of these process listed above, which are influenced by sea level rise?
    - Increased understanding of physical conditions driving changes in habitat type and quality to support wetland inventories and develop strategies to increase adaptive capacity of vulnerable wetlands.
- Are there spatial patterns in wetland elevation change along the York River Estuary.
    - Are some York River wetland types more or less susceptible to flooding/inundation?
    - Are these patterns indicating what processes might be heling to maintain elevation capital (such as TSS).
    - What are some important processes that can explain the spatial variation in the controlling factors on marsh/forest evolution?
        - Gain a better understanding of marsh migration, barriers to marsh migration, and role of invasive species in promoting or complicating marsh migration, under changing sea levels.
        - Gain a better understanding of saltwater intrusion at marsh/forest ecotone and upland sites
            - Expand groundwater monitoring at CBNERRVA Sites
    - Determine strategic establishment of SET sites to address current gaps in wetland elevation change monitoring (and tie into subsidence studies).
- Do the spatial patterns of elevation change correlate with spatial patterns of wetland loss across the region?
    - Update local/regional estimates of vertical land motion from an analysis of repeat leveling, CORS, and GPS surveys in the Dlemarva.
- How do historical changes in terms of erosion, shoreline change, expansion of marsh using aerial imagery correlate with more current changes in SET data?
    - What does the future hold for this polyhaline marsh complex?
    - Conduct high resolution mapping of coastal habitats (e.g. wetland change).
    - Collect consistent imagery (or shorter time scale than 4 years provide by VGIIN) to analyze large scale habitat change (using imagery sources, drones, etc).
- What are the most appropriate models/indices to use to predict marsh response to SLR?
    - Future work will focus using critical sentinel information and forecasts models such as MEM to confirm these projections.
    - Standardize data for use by modelers and visualization tool developers.
    - Adapt and cater marsh models (such as the MEM) for local and regional scale.
    - Use basic data synthesis techniques (across site) to compare a variety of sentinel site metrics across a range of critical habitats.
    - Develop marsh condition indices to provide a current score of marsh vulnerability/resilience
- Potential additional discussion points include uncertainty in input datasets, value of transect information, factors affecting erosion/ponding rates, implications under higher sea level rise rates, value of NERRS Sentinel Site Data (especially SET Data).

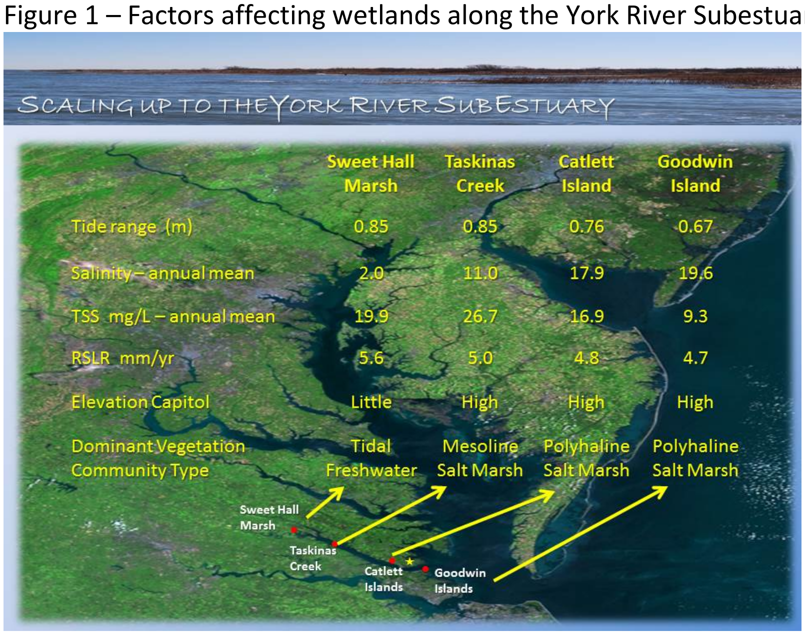
<u>Primary Goals of CBNERRVA Sentinel Site Monitoring Efforts:</u>

The CBNERR-VA monitoring program has focused on intensive and sustained observations to detect and understand physical and biological response to rising sea levels and salinity intrusion in the ecosystems and habitats (primarily the wetlands and low-lying maritime upland habitats) we manage on the York River. Priority strategies include establishing an integrated network of habitat sentinel sites, developing information products, supporting modeling efforts, enhancing data availability, and providing an advisory service and outreach role. As a result of these efforts, the CBNERR-VA serves as an approved NERRS Sentinel Site and establishing partner in NOAA's Chesapeake Bay Sentinel Site Cooperative (SSC). The goals of CBNERRVA's Sentinel Site Program include the following:

- Contribute to scientific understanding at Reserve;
- Assess current local habitat condition and vulnerability;
- Assess local capability for adaptation and mitigation;
- Transfer local findings to support regional and national assessments; and
- Translate and communicate findings to "other" target audiences.

Primary Goal of CBNERR-VA Sentinel Site Activities include increasing our understanding of climate change stressors on estuarine ecosystems to inform coastal management and to provide long term data, information, tools and educational resources, derived from local observations collected at sentinel sites to improve planning and management decisions regarding rising sea levels and inundation. We plan to focus on wetlands and coastal forest and how changes in sea level (including the impacts of inundation and salt intrusion) influence wetland vulnerability including loss from shoreline erosion, creek enlargement, and ponding as well as gains through marsh vertical growth and transgression. We intend to not only study long-term changes in wetland composition and health but also understand the role of episodic events in shaping these long-term trends. In addition, through managing a multi-component Reserve System, CBNERRVA plans to examine spatial trends in changes in habitat types and how these change might be correlated with other driving factors (such as different levels of turbidity, relative seal level rise rates, tidal range, etc.) as you move up the York River into the Pamunkey (and move from polyhaline to tidal freshwater conditions).

Figure 1 – Factors affecting wetlands along the York River Subestuary.

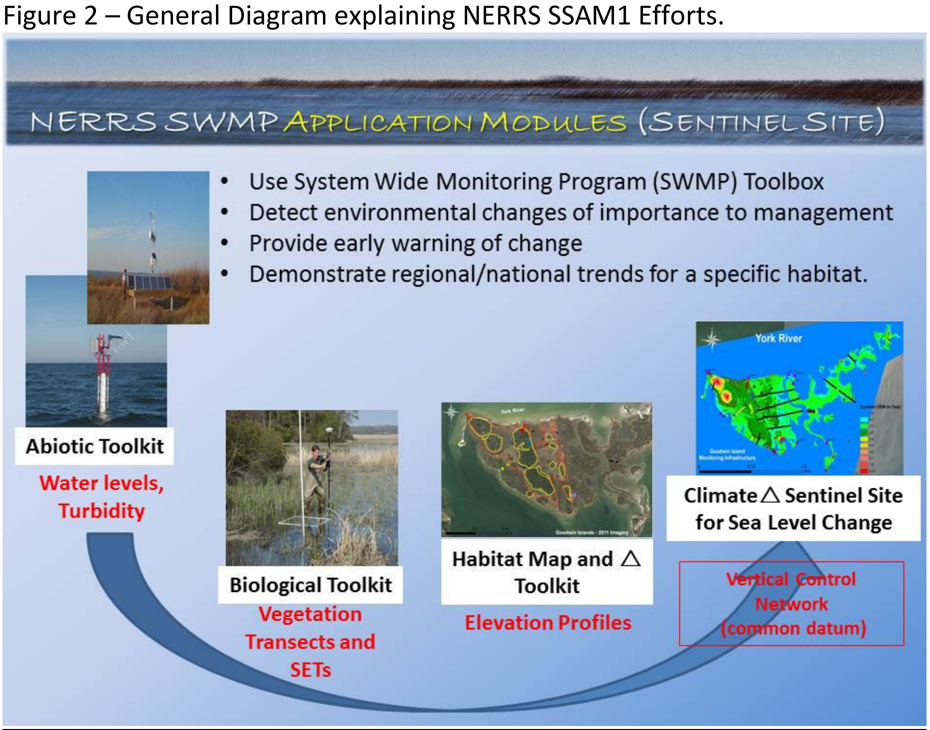


This is a list of the some of the local science/coastal management needs that will be addressed through CBNERRVA's Sentinel Site Program:

- Increase capacity to measure high resolution water level data
- Determine changes in marsh inundation with changes in local sea levels.

- Strategic establishment of Surface Elevation Tables (SETs) in critical habitats (and in critical geomorphic setting such as tidal freshwater habitats) to address gaps in wetland elevation change monitoring.
- Spatial analysis of wetland transition and loss along the salinity gradient of York River.
- Better understanding of salt water intrusion at marsh/forest ecotone and upriver sites.
- Expand groundwater monitoring at Reserves Sites to better understand interactions between groundwater and sea level rise.
- Better understanding of marsh migration under changing sea levels
- Assist in updating local estimates of vertical land motion (i.e. subsidence) from repeat surveys of GPS/leveling equipment at Reserve Sentinel Sites.
- Develop standardized data formats and analysis techniques to compare and assess vulnerability across CBNERRVA Reserve sites and critical habitats.
- Use marsh condition indices and marsh modeling techniques (such as the Marsh Equilibrium Model) to provide current and future measures of wetland vulnerability
- Use Reserve sentinel site data as calibration and validation data to assist with developing and testing dynamic model of marsh evolution that can provide accurate assessment of marsh sustainability at the scale of management decisions across large areas with highly variable estuarine conditions (such as CCRM Schism Model or NASA Roses Model).
- Use Reserves sentinel site sites to test adaptive restoration techniques such as thin layer placement of dredged materials.
- Develop a common set of messages on sea level rise and marsh vulnerability for use in Reserve Education and Coastal Training Programs.

Figure 2 – General Diagram explaining NERRS SSAM1 Efforts.



Prior Monitoring Activities

Since its initiation in 1995, CBNERR has fully participated in Phase I of the NERRS SWMP by successfully maintaining a network of long-term, year-round continuous water quality, meteorological and nutrient stations within the York River watershed. With respect to ecosystem based monitoring, as addressed in Phase II of NERRS SWMP, systematic and quantitative monitoring has generally been lacking until recently. Bay-wide SAV distribution surveys were initiated in 1971, and in 2004, CBNERRVA began SAV tier II biological monitoring at selected sites within the York River estuary (see Section 7.3.4; www.vims.edu/bio/sav; Moore and Campbell 2006 for greater detail) and the Reserve continues to quality SAV inter-annual variability within grass beds at Goodwin Islands.

A routine and comprehensive monitoring program for emergent wetlands was lacking at CBNERRVA and the Reserve relied on individual studies for information on wetland communities (Doumlele 1981; Perry and Hershner 1999; Davies 2004). That changed in 2007 with a partnership with NOAAs Restoration Center, as CBNERRVA was selected as one of five NERRS to establish their Reserves as restoration reference sites by collecting information on salt marsh vegetation, ground water, soil properties, and microscale change in sediment elevation (using SETs)(Figure 10.2). The data collected from Reserve reference sites was used to evaluate restoration success on nearby Restoration Projects funded with Estuarine Restoration Act Funds. As part of a larger effort associated with this project, CBNERRVA in partnership with NOAA NGS and CO-OPS began establishing a vertical control network within the York River watershed, including Reserve components, to facilitate the Reserves' ability to study and monitor vertical changes in coastal elevation with respect to local sea level, subsidence, erosion and other issues. This essentially was the foundation and starting point for CBNERRVA's sentinel site monitoring of wetland sand critical land margin ecosystems.

Primary End Users

The Chesapeake Bay National Estuarine Research Reserve strives to fully engage a variety of audiences and users, from K-12 educators to elected officials, and be a resource expert to support and guide natural resource managers, coastal communities, and policy-makers through the dissemination of unbiased, science-based information. Stakeholders as elected officials, policy makers, resource and land managers, federal, state, and local governments, NGOs, academic scientists, emergency responders, coastal farmers and property owners, and commercial industry groups (e.g., fishing, shipping, power companies, manufactures, etc.). The "public" includes all other general citizens such as coastal residents that live around and utilize Bay resources for recreational purposes, students, and their educators. Some researchers, state and county staff use CBNERR data in their technical work, and informal educators use it for outreach purposes

This service is focused at the local level and can occur in a variety of formats including the development of localized information products, providing topic and/or regional oriented speakers, attending public planning meetings for comment or advice, workshops, and supporting professional training programs. The primary mission of this group will be engaging coastal communities and natural resource managers faced with conservation and land management choices based on data from sentinel sites and stations. Existing climate oriented education and outreach programs will be leveraged including the NERRS education and coastal training programs in VA. Through the Coastal Training Program (CTP), the CBNERR in Virginia addresses critical coastal resource management issues by providing up-to-date scientific information, access to technologies, and skill-building opportunities to key professionals responsible for making decisions about coastal resources. Primary agendas for this group include more effectively informing planning decisions by conducting training on sea level rise and inundation models, promoting CBNERRVA scientists to be more involved at planning meetings, and shifting message delivery to ones that the community can relate to and trust.

II. Local Management Issues Addressed by the SSP Plan.

The CBNERRVA has developed four focus areas that address national, regional and local issues. Cutting across specific program boundaries, issue focus areas allow the Reserve to address key management concerns in a more integrated and comprehensive manner. Primary focus areas directing Reserve programs that provide direct support for coastal resource management include: 1) Functions and linkages of land-margin ecosystems; 2) Ecosystem vulnerability to climate and human-induced stressors; 3) Water quality and aquatic stressors; and 4)Integrated ocean observing systems. The CBNERRV Wetland Sentinel Site Program hits on focus areas 1 and 2.

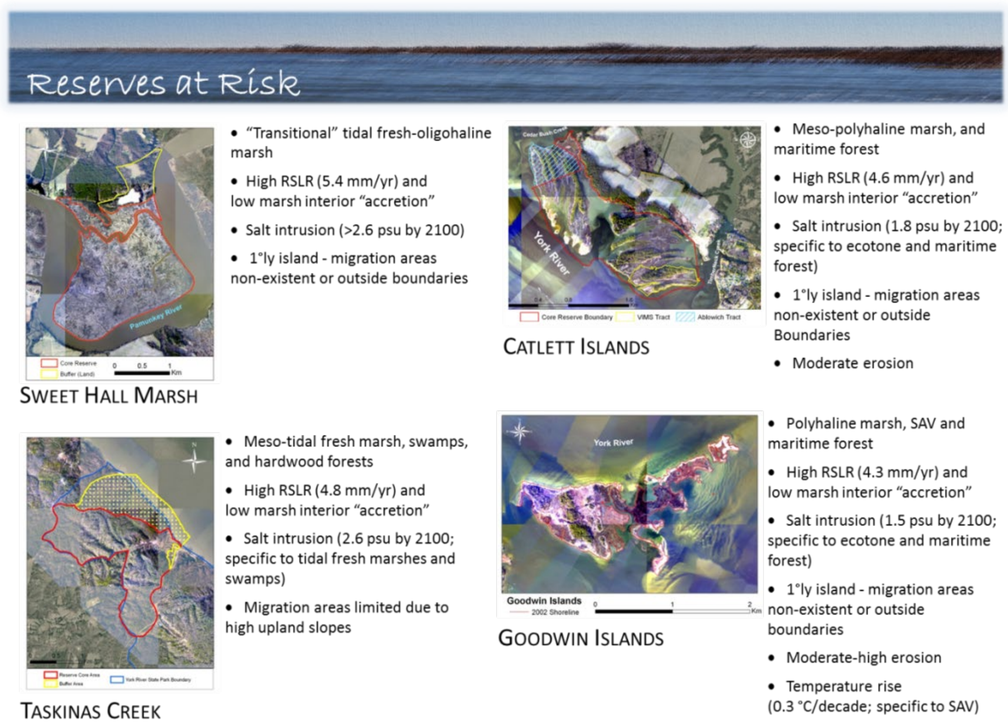
CBNERR-VA consists of four geographic sites, each of which contains representative habitats and physical features along a salinity gradient in the York River estuary. The sites, which are also referred to as reserve components, include Goodwin Islands, Catlett Islands, Taskinas Creek, and Sweet Hall Marsh. Assessment of relative sea level rise and associated impacts is identified as a management issue for all four sites. Several critical York River estuary ecosystems (i.e., emergent tidal wetlands and associated upland ecotones, underwater grass beds) are sensitive to and vulnerable to climate change factors; most often cited stressors include relative sea level rise (of which local land subsidence is significant), salt water intrusion, increasing temperatures, enhanced storm damage and spread of invasive species. The role of sea level rise and the ability of accretion in the salt marshes to keep up with the rise is poorly understood on all the York River marshes. These stressors and associated impacts on ecosystems (and key species) need to be better described/quantified and integrated into ecosystem vulnerability assessments and forecasting models so as to support effective communication and the development of appropriate long-term planning and management actions.

At Sweet Hall, as sea level rates increase, salinity and inundation period are also expected to increase. Data are needed to better understand the impact that these changes may bring to the tidal marshes in the York River. Several studies have documented changes in the vegetation communities of Sweet Hall Marsh (Perry and Hershner, 1999, Davies, 2004). These changes have been attributed to relative sea level rise since salt-tolerant perennial species, e.g. Spartina alternifolia and S. cynosuroides, have become more prominent (Perry and Hershner, 1999, Davies, 2004). Perry and Hershner (1999) predicted that salt – tolerant perennials will play a more important role in the future. Davis (2004) found that yearly changes in vegetation composition was more complex than believed and that both fresh and salt water perennial species had the ability to lay dormant through adverse environmental conditions. Research is needed to better understand the role of both annual and perennial plant species in vegetation succession brought on by sea level rise, and what any change in vegetation composition may mean to loss of, or changes in, habitat values of the marsh.

Data on the potential changes in tidal marsh nutrient processes due to increased salinity in the water column and soil pore spaces (as a function of increased rates of sea level rise) is poorly understood. Both above and below ground carbon storage may be affected (Blum and Christian, 2004), altering nitrogen and carbon storage. However, these data are lacking. Little is known about how an increase in nutrient input from agriculture, industry, and non-point sources may alter the turbidity of the water column and change the sediment content available to the York River marshes. The former effect may decrease the amount of photoactive light available to aquatic and marsh plants, as well as deliver toxic pollutants into the marsh. The latter may alter the available sediments needed by the marsh to keep up with increases in sea level rise rates.

Based on the specific conditions at each reserve site, additional and related management issues are identified at one or more of the sites. Issues at specific sites include assessment of shoreline erosion and impacts on critical habitats and geomorphic features (Goodwin Islands, Catlett Islands, Taskinas Creek), restoration of SAV beds to past aerial coverage (Goodwin and Catlett Islands), and impacts of relative sea level rise including subsidence due to groundwater withdrawal and other factors on emergent wetland plant communities (all reserve components Sweet Hall Marsh). For example, at Goodwin Island, researched issues include loss due to eroding marsh faces (Cicchetti, 1998, Cicchetti and Diaz, 2000, Laird, 2001)and the progression of an aggressive wetland invasive plant; Phragmites australis). Understanding the rate of erosion, and rate of spread of the P. australis, will help understand how these changes may alter the functions served by these marshes.

Figure 3 – Primary Environmental Stressors at each Reserve Component.



There were also several regional management Issues Identified at Mid-Atlantic NERRS Workshop back in 2015 which included those to be addressed in the short term and those to be addressed in the long-term. In the short term, there was some consensus to examine similarities and differences in trends in wetland vulnerability in tidal salt and freshwater marshes with the additional understanding that some of the fresh water marshes are in transition and that this should be captured by a sentinel site implementation strategy. In the longer term, potential actions include creating strategies for areas of high vulnerability, informing TMDL's, and examining impacts to carbon sequestration and marsh use by higher tropic levels (macroinvertebrates and fish).

Current Tidal Marsh Monitoring at CBNERRVA (Current Condition at Four Reserve Components)

The York River system, including the Mattaponi and Pamunkey Rivers, is the Chesapeake Bay's fifth largest tributary in terms of fall-line streamflow (4.07 to 106 m3/day) and watershed area (6,900 km2). It is classified as a microtidal (range: 0.7->1.0 m; Sisson et al. 1997), partially mixed estuary with an estimated tidal prism of 110 M m3 (Sturm and Neilson 1977). Principal bathymetric features consist of an axial channel flanked by broad, shallow shoals of <2 m in depth. Salinity distribution ranges from tidal freshwater to polyhaline regimes. The York River can exhibit both a primary and secondary estuarine turbidity maximum where suspended sediments occur at greater concentrations than observed upriver or seaward (Lin and Kuo 2001). Moderate tidal currents (spring range: 0.2-0.9 m/sec) Residence time ~ 60 days to West Point, 85 days to middle York and 100 days to York mouth Tidal water salinity varies from fresh to polyhaline conditions Bottom substrate in channels is mud (% >80%) with shoals being sandier (% > 50%) Relative sea level rise within the York River system is relatively high, currently 4.7 mm/yr at the mouth to an estimated 5.9 mm/yr at the head of the York River near West Point, due to multiple factors including eustatic rise due to increasing global temperature and glacier melt, regional glacial isostatic adjustment due to the retreat of the Laurentide ice sheet (Sella et al. 2007), oceanic processes due to weakening of the Gulf Steam (Ezer and Atkinson 2015) and local subsidence from excessive groundwater withdrawal (Eggleston and Pope 2013).

The York River watershed contains 7% of VA land base (6900 km2, 2660 mi2, 1.7 M acres and includes Virginia Coastal Plain and Piedmont physiographic provinces. Annual rainfall amounts average 104 cm (41") in upper reaches and 119 cm (47") in southern region of the watershed.   While there is no distinct fall line on the York River Estuary, freshwater flow averages 47 m3/sec (1660 ft3/sec as measured through USGS gauging stations on the Pamunkey and Mattaponi Rivers.   The York River watershed is defined by a primarily rural landscape with land uses in the following categories: forest (61%), croplands (21%) and wetlands (7%); developed lands comprise 2%. However, even being primarily rural in nature, there are still expected to be significant increases in the human population in the watershed moving forward with estimates of population size increasing from 372,500 in 2000 to an estimated ~584,000 in 2030, primarily driven through increases in population centers such as Poquoson, Ashland, West Point and Gloucester Point.

The CBNERRS-VA is a multi-component system established along the salinity gradient of the York River estuary. The Reserve consists of four components, Sweet Hall Marsh, Taskinas Creek, Catlett Islands and the Goodwin Islands, which represent a diversity of coastal ecosystems found within the southern Chesapeake Bay sub region (Figure 8).

- The Goodwin Islands (37° 13' N; 76° 23' W) are located on the southern side of the mouth of the York River.   The archipelago of salt-marsh islands are comprised of several habitat types, including meso-polyhaline marshes, maritime dune grasslands, salt scrub, and maritime upland forest. The surrounding aquatic zone includes extensive SAV beds, large expanses of unvegetated bottoms, and shallow open estuarine waters. The Goodwin Islands, located near the mouth of the York River, are an archipelago of polyhaline salt-marsh islands surrounded by inter-tidal flats, extensive submerged aquatic vegetation beds, and shallow open estuarine waters. CBNERRS maintains a system wide monitoring program, which includes water, weather and biological (i.e., underwater grasses, emergent wetlands and wetland-forest ecotone) components, within the York River system.   Tides at Goodwin Islands are semi-diurnal and display an average range of 0.7 m (2.3 ft). Mean salinity values range from 13.9-23.0 psu for spring, 17.2-23.0 psu for summer, 16.5-24.0 for fall, and 15.9-23.3 psu for winter. Water circulation patterns around the islands are influenced by York River discharge and wind patterns of the Chesapeake Bay. Stressors at Goodwin Islands include shoreline erosion, invasive plant species (Phragmites australis), native animal problem species, loss of critical nesting habitat for several coastal species, and increasing fishing and public access pressures.
- The Catlett Islands (37° 18' N; 76° 33' W) are located approximately 18 km (11 mi) from the mouth of the York River on the north side of the York River. Timberneck Creek flows into the York River on the eastern side of the Catlett Islands and Cedarbush Creek flows into the River on the western side. Catlett Islands consist of multiple parallel ridges of forested hammocks and emergent wetlands. Specific habitats include forested uplands, forested wetlands, estuarine scrub/shrub wetlands, and salt marsh meadows. The Catlett Islands consist of multiple parallel ridges of forested wetland hammocks, forested upland hammocks, emergent mesohaline salt marshes and tidal creeks surrounded by shallow subtidal areas that once supported beds of submerged aquatic vegetation (SAV). Tides at Catlett Islands are semi-diurnal and have an average range of 0.8 m (2.6 ft). Mean seasonal salinity values range from 10.7-22.6 psu for spring, 15.1-23.1 psu for summer, 13.2-25.2 psu for fall, and 10.3-23.1 psu for winter.

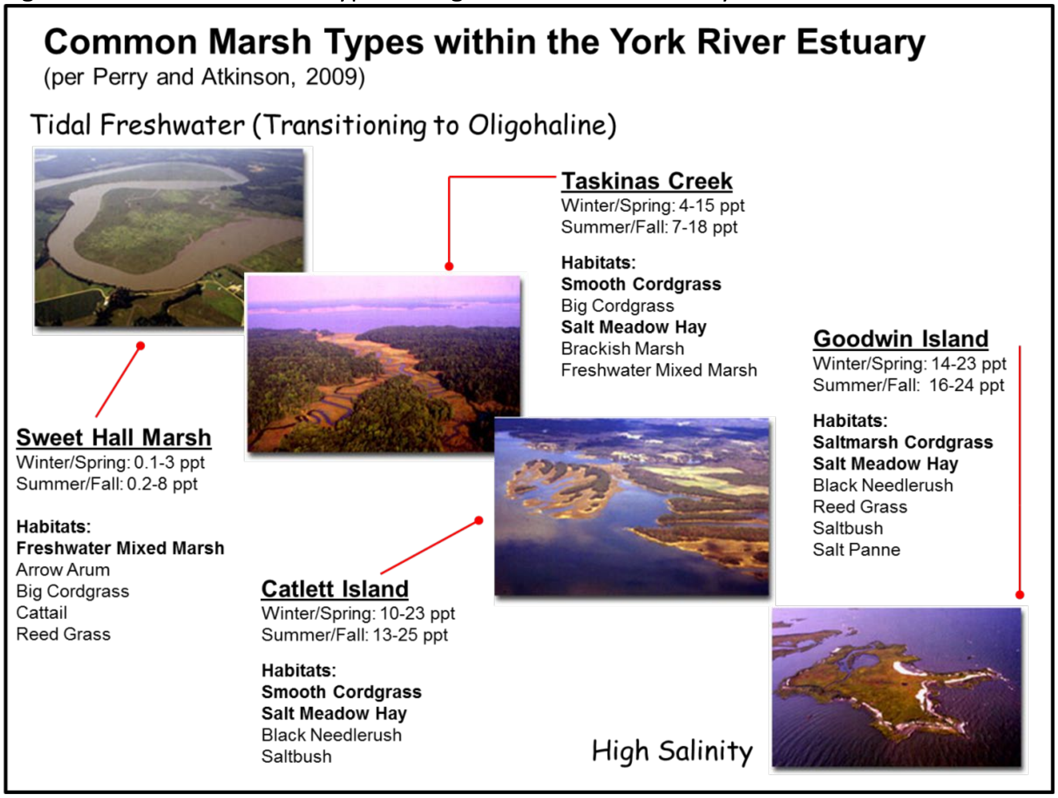
- The Taskinas Creek reserve component (37° 24' N; 76° 42' W) is located within the boundaries of York River State Park approximately 38 km (24 mi) from the mouth of the York River. The non-tidal portions of the Taskinas Creek reserve contain feeder streams that drain oak-hickory forests, maple-gum-ash swamps, and freshwater marshes which transition to tidal salt marsh habitat near the outlet to the York River. Water flow and quality into Taskinas creek is influenced by watershed drainage at low tide and mainstream York River at high tide. Tides at Taskinas Creek are semi-diurnal and display an average range of 1.0 m (3.3 ft). Mean seasonal salinity values range from 4.0-14.0 psu for spring, 7.0-18.2 psu for summer, 6.9-17.0 psu for fall, and 5.8-15.3 psu for winter
- Sweet Hall Marsh (37° 34' N; 76° 50' W) is located in the freshwater to low-salinity transitional zone of the Pamunkey River, one of two major tributaries of the York River. Historically, Sweet Hall Marsh has represented the lower-most extensive tidal freshwater marsh located in the York River system. The Marsh is located 75 km (47 mi) from the mouth of the York River. Sweet Hall Marsh consists of emergent, fresh, and low-salinity marsh, seasonally flooded forested wetlands, and scrub-shrub wetlands. Sweet Hall Marsh represents an extensive tidal fresh water-oligohaline marsh ecosystem located in the Pamunkey River, one of two major tributaries of the York River. Tides are semi-diurnal with an average range of (1.0 m) 3.3 ft. Mean seasonal salinity values range from 0.1-3.4 psu for spring, 0.1-8.4 psu for summer, 0.3-8.4 psu for fall, and 0.1-3.2 psu for winter.

Nine common vegetated marsh types have been described in the tidal freshwater, oligohaline, mesohaline, and polyhaline sections of the York River (VMRC 1980, Perry et al., 2001). These are arranged in the York River landscape along a salinity gradient with the polyhaline marshes at the mouth and tidal freshwater marshes further upstream from the saltwater influence (Wass and Wright, 1969, Odum et al.,1984, Perry and Atkinson, 1997). The tidal marsh communities of the York and Pamunkey Rivers can be separated into three divisions: halophytic (consisting of obligate and facultative halophytes), brackish (consisting of facultative halophytes, and freshwater (consisting of glycophytes) (Wass and Wright 1969, Hershner et al. 1991, Mitchell 1991). These tidal marshes provide a number of important functions and values to the estuarine systems including: high primary productivity, important habitat value, erosion buffering and filtering capacity useful for trapping sediments, pollutants and nutrients. High diversity of wetland community types in the York River sub-estuary supports strong commercial and recreational fisheries .

The tidal marsh communities within the four Chesapeake Bay Virginia National Estuarine Research Reserve sites are situated along the York system in polyhaline, mesohaline, oligohaline and freshwater salinity regimes. These range from the Saltmarsh Cordgrass community typical of Goodwin Islands dominated by Spartina alterniflora to the tidal freshwater mixed community at Sweet Hall Marsh that can have over 50 species in one marsh complex. The most saline of the sites sampled in this study, Goodwin Islands, has the second highest plant species diversity index. The Goodwin Islands and Catlett Islands components of the CBNERR-VA are estuarine embayment marsh island systems. These sites contain both short and tall forms of smooth cordgrass (Spartina alterniflora), saltmeadow cordgrass (Spartina patens), blackrush (Juncus roemerianus), and maritime forest species. This may be due in part to the presence of both obligate halophytes such as Borrichia -frutescens, Limonium carolinianum, Salicornia virginica, and Sueada linearis, and facultative species such as Spartina alterniflora, Distichlis spicata, and Spartina patens. Obligate halophytes were absent or occurred in only very small numbers on the other sites. The salinity of Catlett Islands and Taskinas Creek could exclude freshwater species that were found in Sweet Hall Marsh. Since Catlett Islands and Taskinas Creek were dominated by facultative halophytes, with few obligate halophytes, species diversities here were slightly lower than the more saline Goodwin Island site. The Taskinas Creek component of the CBNERR-VA is considered an estuarine brackish marsh. The most abundant species are smooth cordgrass (Spartina alterniflora), saltmeadow cordgrass (Spartina patens), and inland saltgrass (Distichlis spicata). The Sweet Hall Marsh component of the CBNERR-VA is considered a tidal freshwater marsh community with a reported 52 species. The most abundant species are green arrow arum (Peltandra virginica) and annual wild rice (Zizania aquatica).

Changes in the vegetation communities of each site have been documented over time; however more research is needed on the potential effects of projected sea level rise on these habitats and the roles of watershed sedimentation and nutrient enrichment, vegetation succession, and invasive species on the persistence and value of these tidal marsh areas.

Figure 4 – Common Marsh Types along the York River Estuary.



II. Communication and Outreach

Several primary audiences have been identified for this program. First, CBNERR-VA staff and its land management partners can utilize the knowledge gained from the SSP to make management decisions about options to protect and/or restore specific areas of the reserve based on observed changes and subsequent biological and sediment responses. Second, other scientists, including the broader NERRS network of professionals, may utilize the information gathered to inform further studies and better address scientific questions. Third, natural resource managers as well as municipal planners and managers may utilize the information from these representative sites to make more informed management decisions to similar sites, related features, or potential future changes. Utilizing information derived from the Sentinel Site Initiative and other research efforts, the Education and Coastal Training Program can assess user/stakeholder needs and develop curriculum, outdoor experiences, labs and workshops, demonstration sites and other information/tools products to support resource management and restoration efforts. Increased issue awareness and access to relevant information products/tools will support the development and implementation of planning and management plans designed to protect and restore York River water quality and coastal ecosystems. Lastly, students, teachers, and members of the general public will benefit from learning about the purpose, design, and findings of this study to improve overall understanding and climate literacy.

Sentinel Site Data in Chesapeake Bay Reserve Science Efforts

CBNERRVA Stewardship are also working with VIMS researchers on a project which focuses on a historical analysis and predictions of erosion patterns on York River estuary islands, specifically Goodwin Islands. The purpose of this project is to assess shoreline/forest rates of change and estimate area of land loss and relate these rates of change to physical/habitat factors. Coastal ecosystems and their tributaries are among the most vulnerable environments from climate change induced sea-level rise (SLR). This is of particular concern in the Chesapeake Bay region where current SLR rates (~5 mm/yr) are elevated as compared to national and global averages. By digitizing shoreline and forest boundary conditions on shoreline survey maps (t-sheets) and aerial imagery from 1853-2015, multi-decadal changes in saltmarsh and maritime forest boundaries were analyzed for a Late Pleistocene island complex in the lower York River, Virginia. Marsh-shoreline perimeter and marsh-forest boundary rate changes were generated through the Digital Shoreline Analysis System (DSAS). Rate changes determined by marsh loss processes, including shoreline perimeter erosion, extension and enlargement of tidal creeks, and interior ponding were quantified and compared. Mean long-term shoreline perimeter erosion rates were 0.26 m/yr at Goodwin Islands with no significant trend over the 162 year analysis period. On an area basis, the overall contribution to marsh loss was much greater through perimeter erosion than observed for enlargement of tidal creeks or interior ponding. Shoreline perimeter erosion rates were most sensitive to wave power. Marsh-forest boundary transgression rates were relatively constant from the mid-1800s to the 1960-1970s, averaging 0.35 m/yr at Goodwin Island. Increasing forest-marsh boundary transgression rates, with the most recent mean multi-decadal values increasing to 1.40 m/yr, were observed post 1970s. Increased fragmentation of the primary maritime forest unit also began to occur post 1970s resulting in numerous small forested hummocks that exhibited elevated boundary transgression rates. Results indicate that marsh transgression rates into higher elevations previously occupied by maritime forest were greater and more sensitive to recent accelerations in local SLR, than marsh perimeter erosion. From a resource protection perspective, allowing for marsh transgression should be a high priority when appropriate in the development of shoreline management policy and project designs.

CBNERR-VA staff have been participating in a project Science Collaborative Transfer Project led by the San Francisco Bay NERR and with the assistance of Professor Jim Morris. This project entitled "Utilizing NERRS Sentinel Site Data For Improved Management of Tidal Marshes" uses the Marsh Equilibrium Model (MEM) to integrate new data on suspended sediment concentrations with existing data generated in part through the NERRS Sentinel Site Program to yield predictions of tidal marsh responses to accelerating sea level rise and changes in sediment supply. This translation of data on marsh accretion, surface elevation, and water level in a way that decision makers can understand and use is a central premise of the Sentinel Site Program, but one that has currently been unrealized. During 2014, CBNERR-VA staff were trained on running the MEM, provided workplans for collecting the data for parameterizing the MEM model, and assisted San Francisco Bay Staff in developing webinar to demonstrate the calibration and spatial abilities of the MEM using data from CBNERR-VA's Goodwin Islands Reserve Component. This project and training have been crucial CBNERR-VA's current understanding, level of preparation, and future plans for running the MEM Model at all four of CBNERR-VA Reserve components. Future efforts include producing vulnerability maps of tidal fresh, brackish and salt marshes along the York River system using the MEM which would include seeking additional funding to support data collection and additional training to implement the MEM.

In support of land managers/stewards and local officials who are challenged with making conservation decisions in a changing environment, CBNERR-VA partnered with Rhode Island (Narragansett bay) and North Inlet-Winyah Bay (SC) NERRs to pilot and refine a decision support tool to assess habitat vulnerability to anticipated climate change impacts. Developed as part of a recent grant award from the NERRS Science Collaborative, CCVATCH is spreadsheet based and calculates numerical vulnerability scores based on collaborative input of local knowledge experts and habitat managers to a series of guidance document questions. Assign vulnerability scores for selected critical habitats. Then develop strategies to implement based on habitat vulnerability (both at the Reserve and Mid-Atlantic Scale). Researchers and decision makers understand the vulnerability of marshes to multiple stressors including climate and non-climate stressors. This NOAA/NERRS Science Collaborative funded transfer project is intended to address habitat change and restoration planning for climate change impacts by piloting and refining a climate change vulnerability assessment tool that has been specifically designed for coastal habitats. During the reporting period, the tool was pilot tested through a series of pilot workshops held at CBNERR Headquarters focused on different case study habitats. Case studies included Goodwin Island salt marshes (6/25/14), dunes and beaches of City of Virginia Beach and Matthews County (7/15/14), City of Norfolk saltmarshes (7/24/14) and scrub-shrub habitats (8/5/14). The representation of attendees was diverse (total numbers including project staff were between 7 to 9 people per workshop) and overall included 3 project team members, 3 land managers, 3 university researchers, 2 city/county staff, 1 federal employee, 4 state agency employees, and 2 from non-profit groups. The project team is reviewing the outcomes of these workshops, developing a plan for communicating the results with the workshop participants (and intended users) in the wrap up meetings, refining the guidance document, and developing a facilitation plan for applying the CCVATCH. The wrap up workshops are currently scheduled for January 2015 and the project end date (for reporting purposes) is March 31, 2015. Members of the project team (including CBNERR staff) will also be providing a training on this tool at the upcoming NERRS Annual Meeting in November, 2014. CBNERR staff also assisted in the development of two presentations given by project lead Jennifer Plunkett at two meetings including the Carolinas Climate Resilience Conference in April 2014 and the Society for Conservation Biology in July, 2014.

Use of Reserve Sentinel Site Data in Other Research/Management Efforts (Promoting Reserves as Research Platforms to Outside Researchers)

CBNERRVA Stewardship Staff have been instrumental in assisting researchers (including students/facility at VIMS and outside of VIMS) interested in sampling within Reserve components or at Reserve long-term monitoring platforms. Recently, Dr. Matt Kirwan has collaborate with the CBNERRVA program (and especially Reserve director, Dr. William Reay) in using Reserve components (and Sentinel Site data) in several projects leading to published manuscripts. This has included a recent paper on sea level driven marsh expansion in a coupled model of marsh erosion and migration (Kirwan et al. 2016). These authors have developed a simple model of marsh migration into adjacent uplands and coupled it with existing models of seaward edge erosion and vertical soil accretion to explore how ecosystem connectivity influences marsh size and response to sea level rise. The study finds that marsh loss is nearly inevitable where topographic and anthropogenic barriers limit migration. Where unconstrained by barriers, however, rates of marsh migration are much more sensitive to accelerated sea level rise than rates of edge erosion. This behavior suggests a counterintuitive, natural tendency for marsh expansion with sea level rise and emphasizes the disparity between coastal response to climate change with and without human intervention. In addition, Dr. Kirwan and Master Student Nathalie Schneider recently published a paper examining upland to wetland conversion compensating for historic marsh loss in Chesapeake Bay, Virginia (Schieder et al. 2017). Sea level rise leads to coastal transgression, and the survival of ecosystems depends on their ability to migrate inland faster than they erode and submerge. We compared marsh extent between nineteenth-century maps and modern aerial photographs across the Chesapeake Bay, the largest estuary in North America, and found that Chesapeake marshes have maintained their spatial extent despite relative sea level rise rates that are among the fastest in the world. In the mapped region (i.e., 25% of modern Chesapeake Bay marshland), 94 km2 of marsh was lost primarily to shoreline erosion, whereas 101 km2 of marsh was created by upland drowning. Simple projections over the entire Chesapeake region suggest that approximately 100,000 acres (400 km2) of uplands have converted to wetlands and that about a third of all present-day marsh was created by drowning of upland ecosystems since the late nineteenth century. Marsh migration rates were weakly correlated with topographic slope and the amount of development of adjacent uplands, suggesting that additional processes may also be important. Nevertheless, our results emphasize that the location of coastal ecosystems changes rapidly on century timescales and that sea level rise does not necessarily lead to overall habitat loss. Finally, Dr. Kirwan and REU summer Intern Josh Himmelstein worked on a project at Goodwin Islands in the summer of 2017 which examined the variance and history of marsh ponding at this Reserve component. This study focused on examining a variety of parameters (morphology, vegetation biomass, sediment composition and accretion rates) between ponds which have a connected and isolated ponds and calculated infilling times for each pond type. Josh relied on the CBNERRVA vertical control network for some surveying information as well as our GIS derived analysis (using historical imagery) of pond development over time to help place Josh's work in a larger context.

Additionally, researchers Rutgers's University are levering sentinel site information from three Reserve components to study the vertical distribution of salt-marsh foraminifera as sea-level indicators. Their overall objective is to take surface sediment samples across a series of transects from the upland/freshwater limit to the marsh/sea water interface to document the vertical distribution of salt-marsh foraminifera and their relationship with tidal level. The data collected shall go towards our publication investigating late Holocene sea level changes in the Chesapeake Bay

Stewardship staff have been contacted to participate in a long-term USGS study to measure the response of tidal freshwater forested wetlands to sea level rise and watershed sediment availability. A portion of this research would occur at our Sweet Hall Marsh component. The U.S. Geological Survey is starting a study to measure the response of tidal freshwater forested wetlands to sea level rise and watershed sediment availability. The USGS is examining five sites along both the Mattaponi and Pamunkey Rivers, from non-tidal floodplain to tidal freshwater forested wetlands to oligohaline marshes. They have been measure the ability of wetlands to survive rising sea level and identify the causes of wetland elevation responses with a strong focus on the ecogeomorphology of hummock-hollow microtopography in the freshwater wetlands. The initial study will last 5 years. Each site will have two deep-rod sediment elevation tables installed and they have leveraged groundwater well and SET data (using NERRS data) from Sweet Hall marsh. They are also measure sedimentation, erosion, root production, and soil respiration.

Recently graduated Master's student was studying consumer control of salt marsh geomorphic processes. Salt marsh resilience in the face of accelerated sea level rise relies on landward migration and vertical accretion. Vertical accretion relies on sediment trapping by Spartina alterniflora and the contribution of belowground organic matter. However, current ecogeomorphic models do not consider the indirect effect of animals on vertical accretion, through their interactions with plants. The fiddler crab, Uca pugnax, and the purple marsh crab, Sesarma reticulatum, co-occur in the same tidal range along the Atlantic coast of the U.S., but have contrasting effects on primary production. The fiddler crab can facilitate Spartina production through change in redox potential, while the purple marsh crab feeds directly on Spartina, decreasing production. The goal of the study was to understand the indirect effects of these species on sediment deposition, via their effects on Spartina production. This research will begin to demonstrate the importance of incorporating animals into ecogeomorphic models. Due to the long-history of monitoring data at Reserves, Bethany use Goodwin Islands as one of the study sites in her Master's work. The information from Bethany's work will also be useful to better understand the role of these macroinvertebrates in wetland vulnerability to sea level rise and provide useful context for analyzing our site-specific results from NERRS national level crab monitoring project conducted in the summer of 2017.

Potential Use of Reserve Sentinel Site Data in Grant Proposal Opportunities (yet unfunded).

The CBNERRVA sentinel site effort has also resulted in some promising, but yet unfunded, proposals designed to develop larger scale products based on the foundations of CBNERRVA sentinel site wetland monitoring along the York River subestuary. The first proposal was entitled: "Forecasting Coastal Habitat Distributions through Fusion of Earth Observations, Process Models and Citizen Science: A Climate Change Adaptation Tool for the NOAA National Estuarine Research Reserve System". This proposal was a timely opportunity to scale up the Reserve's current efforts to understand climate impacts on critical habitats from the level of individual Reserve marsh components to the broader York River estuary thereby providing greater regional wide applications. This decision support tool proposed in this collaborative work meets the high priority needs of multiple programs and initiatives. There is a need for an increased understanding of wetland condition and emerging issues such as sediment budgets and climate change impacts. As placed based sites, Reserves are well positioned to not only assist with the calibration of local/regional scale predictive models, but are also validate those models at certain time intervals through though the long-term collection of sentinel site data. Specific to CBNERR-VA, the model based decision support tool will assist with our current effort to develop a York River vulnerability assessment and provide projections of change for critical Reserve marsh habitats under different management scenarios or measures of adaptive capacity, support sensitive species critical habitat modeling and management, and aid in targeting our long-term land acquisition/protection efforts. This opportunity also is very important and timely due to the fact there are a currently a number of potentially related efforts by numerous entities underway that are being planned for the York River and/or adjacent Hampton Roads VA area. Land subsidence and its impact on relative sea level rise appears to be a common connecting point for those interested in groundwater resources, tidal wetlands and adjacent forests, and human-built sentinel sites. Plans for use of the tool include assisting with current Reserve efforts to understanding wetland and ecotone response to changing in water levels at specific Reserve components. CBNERR-VA would also use scenarios reflective of predicted climate change impacts on relevant parameters with local background information provided through an NCCOS project for which CBNERR-VA currently is a partner. For example, we could propose to run the tool under different scenarios including drought versus dry years, changes in stream flow, and with impacts of episodic events and compare model results and potential adaptive capacity opportunities. CBNERR-VA would introduce and promote this decision support tool to decision makers and land managers through a variety of Coastal Training Program venues including (but not limited to) workshops or trainings (e.g. focused on NOAA Digital Coast and Coastal Tools) as well as at local and regional conferences (such as a "State of the York" symposium).

The second proposal was a collaborative opportunity through the NERRS Science Collaborative to inform decision making under climate change using Virginia Reserve data to advance marsh modeling. The proposal acknowledged the previous work by CBNERRVA to develop the Climate Change Vulnerability Assessment Tool for Coastal Habitats (or CCVATCH) for use by land managers, decision makers, and researchers identifying habitats likely to be affected by climate change and the ways in which they will be affected. However, there were some significant uncertainties identified in the process that need to be addressed to improve the knowledge base. Specific to the York River, there was debate around the erosion/sediment supply stressor. Future climate impacts (including changes in precipitation, SLR, and extreme events) may actually result in a great supply of sediment for marsh building, however, the impact of erosion from increased SLR (uncertainty if this may increase erodibility of sediments) and increased winter storm events were scored as equally or more detrimental to this habitat. The variety of different settings along the York River means that a single entity can manage multiple marsh forms, all of which may respond differently to sea level rise. For example, the National Park Service shorelines include tidal creek marshes, embayed marshes and fringing marshes adjacent to eroding bluffs. Understanding the difference in marsh response between settings allows for the development of highly resolved management plans. Both CBNERRS and CCRM have worked extensively with land managers and have collected information about the knowledge needed to manage these marshes under changing climate. This project will rely on data collected at CBNERR sentinel sites to calibrate and verify the marsh model which will be used to extrapolate those observations along the estuarine gradient and could demonstrate the effective use of the Sentinel Site monitoring data in local and regional coastal resource management efforts. The resulting management guidance will rely on continuing integration of monitoring data in future risk scenario refinement. The objectives of the proposal were to test and refine the Tidal Marsh Model (TMM) hindcast of changes observed in the CBNERR sites on the York River. These sites provide a gradient of salinity, tide range, relative sea level rise, exposure, and sediment supply for calibration of the TMM. There will be limited field work necessary to ensure the model grid is appropriately representative of the bathymetry and sediment types in each reserve site.

Sentinel Site Data in Regional and National Level Assessments:

By being an early, and strong, contributor to the NERRS Sentinel Site efforts, CBNERRVA has been in a position to take part in several national and regional level studies/projects focused on understanding factor contributing to wetland resilience, ways to measure wetland/understand wetland resilience, ways to communicate wetland resilience to coastal managers, and projects to better understand adaptation strategies to increase wetland resilience.

The first project was an assessment of marsh resilience to sea level rise which was a project involving Research Reserves from around the country to develop a scientific feasible and nationally useful product for coastal managers. CBNERRVA served as a project lead in developing and applying tidal marsh resilience to sea-level rise (MARS) indices incorporating ten metrics that contribute to overall marsh resilience to SLR (Raposa et al, 2016). These MARS indices to tidal marshes at 16 National Estuarine Research Reserves in six biogeographic regions across the conterminous US. This assessment revealed moderate resilience overall, although nearly all marshes had some indication of risk. Pacific marshes were generally more resilient to SLR than Atlantic ones, with the least resilient marshes found in southern New England. The MARS indices can be applied at any spatial scale; we also used them to examine variation within three estuarine systems, which was modest compared to the national-scale variation. We provide a data template and calculation tool to facilitate application of the MARS indices to additional marshes. MARS index scores can inform the choice of the most appropriate coastal management strategy for a marsh: moderate scores call for actions to enhance resilience while low scores suggest investment may be better directed to adaptation strategies such as creating opportunities for marsh migration or creation of new, higher marshes rather than attempting to save existing ones. The MARS indices thus provide a powerful new approach to evaluate tidal marsh resilience and to inform development of adaptation strategies in the face of SLR. CBNERRVA has been working with members of the Chesapeake Bay Sentinel Site Committee in applying the MARS indices at a number of Chesapeake Bay Sentinel Sites, first determining which sites meet the standards to run the MARS analysis, secondly rating sites in terms of resilience using the MARS analysis, and finally performing sensitivity analysis to tease out the metrics most important in determining wetland resilience in Chesapeake Bay.

Kenneth B. Raposa, Kerstin Wasson, Erik Smith, Jeffrey A. Crooks, Patricia Delgado, Sarah H. Fernald, Matthew C. Ferner, Alicia Helms, Lyndie A. Hice, Jordan W. Mora, Brandon Puckett, Denise Sanger, Suzanne Shull, Lindsay Spurrier, Rachel Stevens, Scott Lerberg. 2016. Assessing tidal marsh resilience to

sea-level rise at broad geographic scales with multi-metric indices. Biological Conservation. Vol. 204 (B). 263-275.

CBNERRVA is also involved in a recent NERRS Science Collaborative Project entitled: "Thin-Layer Sediment Placement: evaluating an adaptation strategy to enhance coastal marsh resilience across the NERRS". In this project Reserves are moving beyond studying resilience (MARS indices) to actively testing strategies to enhance it by conducting replicated restoration experiments examining the effectiveness of thin-layer sediment placement as a climate adaptation strategy at eight NERR sites across the nation. Novel aspects of our project include the broad distribution of sites, the examination of effectiveness at different marsh elevations, a standardized monitoring protocol, and the incorporation of biochar to improve soils and plant health. Beneficial use of dredged sediment to enhance coastal resilience is a concept that resonates in many coastal states, and we have already interviewed 32 and surveyed 86 end users in funding, permitting, implementation or monitoring of thin-layer sediment projects. Our project will address the needs they identified, including a vetted monitoring protocol to assess restoration success, a synopsis of permitting issues, and an evaluation of effectiveness of different treatments detailed in a technical report and summarized in a brochure and webinar.

CBNERRVA is also involved (in an advisory role) in the first NERRS National Product Project entitled "A Landscape Scale Assessment of NERRS Marsh Resilience: Creating a Framework for Effective Monitoring Program and Tool Implementation". The purpose of this project is to develop a framework of Marsh Study Unit (MSU) boundaries for the national system to facilitate assessment of marsh resilience throughout Reserves and regions. MSUs are areas of broadly similar landuse/cover and hydrology. They can be used to develop a remote sensing-based methodology, using a consensus based suite of landscape scale metrics, to compare marsh resilience as assessed by current condition, vulnerability and adaptation potential over broad geographies. The results will provide: 1) an efficient and consistent methodology for deriving regional maps of marsh resilience; 2) an understanding of how representative high resolution but spatially limited monitoring efforts such as MARS and NERRS Sentinel Sites are of the broader system; and 3) a spatially explicit framework useful for design of monitoring programs, implementation of tools such as the Climate Change Vulnerability Assessment Tool for Coastal Habitats (CCVATCH) that can display their results spatially, and for scoring additional stressors exacerbated by SLR.

The value of CBNERRVA sentinel site data (especially long-term SET data) has been demonstrated by providing value information to a study led by Don Cahoon (and colleagues) to examine impacts from Hurricane Sandy to coastal wetland resilience. The goal of this project was to evaluate the immediate impacts of Hurricane Sandy on surface elevation trends in marshes located across the northeast region of the United States from Virginia to Maine using data from an unplanned network of surface elevation table – marker horizon (SET – MH) stations. Pre-Sandy elevation trends that were compared to post-Sandy elevation measurements to determine the storm impact on each station trend for 965 individual SET stations in the Northeast region which varied by geomorphic setting and wetland type. The study findings supported previous research showing that the physical characteristics of the storm (e.g., wind speed, storm surge height, impact angle of landfall) combined with the local wetland conditions (e.g., marsh health, groundwater level, tide height) are important factors determining a storm's impact on soil elevation. Analyses revealed that the general geographic coverage of SET – MH stations is limited given the low percentage of marsh patches with stations, low density of stations, the clumped distribution of stations, and the often limited and uneven distribution of stations in wetlands with a high probability of hurricane strikes and storm surge impacts.

One other regional efforts relying on CBNERRVA's Sentinel Site efforts was the NERRS Funded "Mid-Atlantic Pilot" which had 3 goals including: 1) seeking end-user input on how SSAM1 data can support tidal marsh management priorities related to sea level rise in the Mid-Atlantic region; 2) inform research proposals such as the NERRS Science Collaborative and 3) develop a transferable roadmap that reserves in other regions can use to identify regional management priorities that can be informed by SSAM-1 data. Through a collaborative process involving a needs assessment and data/tools inventory, the FOC (and Roca Communications and Sea Connections) determined the focus area on "thin layer sediment application and better understanding the information that managers need to make decisions about whether to how to use this adaptive management technique. For this project, CBNERRVA provided detailed information about it's SSAM-1 (Sentinel Site) monitoring infrastructure including information on surface elevation tables (SETS), vegetation transects, vertical control network, water level monitoring equipment, marsh equilibrium modeling efforts, and historical imagery. This data (along with other Reserves in the Mid-Atlantic, will be used in a tool to be presented at a workshop entitled "Exploring Thin Layer Sediment Placement for Wetland Restoration in the Mid-Atlantic" to be focused on how the NERRS can support research and capacity building relating to the use of thin layer application as a restoration/adaptation strategy in the mid-Atlantic.

Management Team and SET Sub-Team Partner in Chesapeake Bay Sentinel Site Cooperative

CBNERRVA has been heavily involved in providing advisory service and metadata/data findings from Sentinel Site activities as part of the Chesapeake Bay Sentinel Site Cooperative. The Chesapeake Bay including CBNERR-VA was identified as one of five initial sites for the National Oceanic and Atmospheric Administration (NOAA) Sentinel Site Cooperatives (SSC). Due to its participation in the SSC, much of the infrastructure, staff training, data collection, and communication about the program are already in place and occurring at CBNERR-VA. Efforts included contributing to the development of the Chesapeake Bay Sentinel Site Cooperative 2013-2018 Implementation Plan. CBNERRVA has contributed to Involvement on Management Team which has included conference calls, individual discussions, assistance in setting priority areas of the CBSSC, serving as a note-taker for particular meetings, developing presentations for sharing of CBNERR-VA related sentinel site work, participating in several surveys to help develop a water level training program for CBSSC members, assistance with developing a data inventory/needs survey as well as populating that survey for CBNERR-VA, assistance in developing priorities and goals for a in person meeting of the CBSSC based on the data inventory assets and gaps, identifying funding sources and developing proposal ideas for the CBSSC, providing input on a letter of support for Sarah Wilkin's position as the CBSSC Coordinator, and assistance in developing a communication document to highlight the relevancy and goals of the CBSSC. During this period, this has included providing input in future directions for the Cooperative, providing updates for the data inventory for CBNERVA, and edits to the CBSSC Data and Infrastructure Report. CBNERRVA assisted with development of invitations, contacting individuals and developing agenda for October SET Workshop and attended CBSSC SET Workshop at Virginia LTER on October 24th, 2016. Also assisted with development of SET template for CBNERRVA Site for workshop and planning for a second follow up workshop in March of 2017 to focus on exploratory data analysis and synthesis of SET data. There is some hope (and discussions) focusing on how a synthesis of sentinel site data across the Chesapeake Bay Sentinel Site Cooperative may be used to help address questions of wetland vulnerability/resilience for the Chesapeake Bay Program, especially towards understanding trends in the status and conditions of wetlands to be used towards modeling efforts and long-term assessments.

Member of the NERRS Sentinel Site (SSAM-1) Oversight Committee

Staff from CBNERRVA have also served on the NERRS SSAM1 Oversight Committee and have assisted in the development of Development of Tri-Office Protocols Document CBNERR-VA staff comprised one member of a four member writing team responsible for producing a document entitled "Accurate Elevations for Sea Level Change Sentinel Sites." This document, which has taken over three years to write, has been based on over seven years' of experience in applying surveying instrumentation and methodologies to coastal (wetland) settings in support of partners' needs for high accuracy elevations and water levels in these settings. This document was formally approved by CO-OPS and NGS in early 2014 and is going currently being finalized for publication and public distribution. This document will be considered a "living," and will need updating on a regular basis (e.g. OPUS Projects, tidal datum computations, etc.). Other responsibilities including leading a workgroup tasked with developing SET data template/metadata for CDMO and coordinating efforts with other federal agencies. Assisting with a workgroup tasked with developing CDMO policy with respect to water level data on CDMO with DMC as well as working on a sensor classification scheme based on sensor stability, design, calibration and maintenance similar to benchmark stability classifications. Finally, CBNERRVA staff has assisted in revising the SSAM1 plan development guidance for Reserves to develop their site based Sentinel Site plans which was released around September of 2016.

Technical Assistance to the Coastal Management Community through CBNERRVA SSAM-1 Efforts.

Through the Coastal Training Program (CTP), the CBNERR in Virginia addresses critical coastal resource management issues by providing up-to-date scientific information, access to technologies, and skill-building opportunities to key professionals responsible for making decisions about coastal resources. Focus areas generally include coastal habitat restoration, natural resources management, water quality, stormwater management, land use and coastal development issues. Although CBNERRVA has had some challenges in matching training needs with current Reserve Sentinel Site activities at the Reserve's four components, there have been a number of examples of how CBNERRVA sentinel site efforts can be leveraged for the greater coastal management community.

For example, there have been some recent efforts to better understand subsidence in Chesapeake Bay including the informal formation of a "York River Subsidence/SLR/Riparian-Emergent Wetland Interest Group". CBNERR-VA is actively engaged in this group and at a minimum helping to coordinate efforts in order to identify areas of collaboration and synergy. Ongoing and proposed efforts to aid in our collective understanding of habitat change and SLR/subsidence monitoring in this region include tidal freshwater forested wetlands response to sea level rise (Key entities: USGS), headwater stream forest impacts to sea level rise stressors (EPA,VIMS), climate variability influences on the Chesapeake Bay NERR (NOAA/NCCOS), groundwater withdrawal and associated land subsidence studies (USGS, VADEQ, NASA, DOD), urban/human built sentinel site development (Chesapeake Bay SSC) and inundation modeling (VIMS). CBNERRVA, using equipment and training with GPS equipment, has also been able to assist Dr. Philippe Hensel (National Geodetic Survey) to better understand regional subsidence in Chesapeake Bay. CBNERR-VA has assisted by collecting Static GPS data from benchmarks with leveled heights in the NGS Database that were leveled prior to 1970 which also have GPS derived coordinates from the early 2000's (for comparison). This information will be very useful in understanding the role of regional subsidence in our assessments of wetland vulnerability. On a more local scale, CBNERRVA has been contacted to potentially use information from our SETS at Sweet Hall marsh to better understand subsidence in the Upper York River and the role of groundwater withdrawal (a partnership involving USGS and VA-DEQ).

CBNERRVA has also used participation in needs assessments (such as Mid-Atlantic Pilot), workshops, and symposiums as a means to provide technical advice and provide up to date information from Reserve Sentinel Site (or SSAM-1 efforts) to address connection to local and regional audiences which will include the research community, coastal management community and education community. For example, CBNERRVA Staff have given presentations at a number of scientific conferences on SSAM-1 efforts including the Coastal and Estuarine Research Federation conference, the Atlantic Estuarine Research Society meetings, and the Delaware Wetlands Conference to name a few. In addition, CBNERRVA staff have been invited to present at various workshops/webinars including the GOM SET Working Group Webinar and the North Carolina SET Operators Webinar. In addition, CBNERRVA has hosted several York River Symposiums (the latest one in 2016) at the Virginia Institute of Marine Science (VIMS in which invited individuals included local county, city and locality staff, state and federal agency employees, researchers, academicians and graduate students, regulatory and land management staff, environmental and engineering consultants, non-profit environmental organization staff, and informal educators.   The symposium ultimately hosted 20 oral presentations and 6 posters of which represented submissions from researchers and students from colleges and universities, state and federal agencies, private organizations, consulting firms, and others invited to submit abstracts describing research conducted within the watershed of the York River. This symposium highlighted research, information synthesis and management adaptation strategies as related to estuarine system response to climate change and variability and featured 6 presentations based on the concept of sentinel sites and sentinel networks for understand critical habitat vulnerability and resilience. These included:

- Sentinel for Ecosystem Change: The York River Initiative.
- The Chesapeake Bay Sentinel Site Cooperative: A regional collaborative network to monitor sea level change impacts and build coastal resilience.
- Assessing changes in seagrass species dominance and habitat services after a die-off event in the York River, VA. Erin Shields*, Kenneth Moore, Emily French, and Bongkeun Song
- Understanding Coastal Habitat Vulnerability to Sea Level Rise Impacts to Inform Resource Management Efforts.
- A Dendrological Assessment of Loblolly Pine (Pinus taeda) Along a Salinity Gradient Within Four Tidal Wetland Sites Along the York River Estuary, VA.
- Competition between marsh erosion and forest retreat drives 150 years of wetland change inferred from historical maps of the Chesapeake Bay.

Incorporation of Sentinel Site Data/Results into CBNERRVA Education Programs'

A fundamental challenge of our Reserve Sentinel Site effort has been to use data and information generated from our long-term sentinel site research and monitoring efforts to promote climate literacy and public understanding (which could be the general public, coastal decision makers, and students) of climate impacts on natural communities (i.e. that data translation piece). To become a fully operational NERRS sentinel site program, a reserve must move beyond infrastructure installation, data collection, and data integration to incorporating strategies for synthesizing information and reaching intended audiences. Through prior B-WET funding, focused on promoting climate education, the Education Group at CBNERR-VA has been critical in translating our science-based efforts to their targeted audiences (i.e. K-12 students and their teachers) as well as developing mechanisms to use accessible Reserve sentinel site infrastructure (such as our Surface Elevation Tables (SETs) or vegetation transects) as educational platforms to provide on-site climate related education programs and more meaningful field experiences.

CBNERR-VA demonstrated the power of program integration as data and protocols from long-term wetland monitoring efforts, under the CBNERR-VA "Sentinel Sites for Sea Level Change" project, were used to support the CBNERRVA education program in their "Climate for a Changing Bay" program for students and teachers.   The National Oceanic and Atmospheric Administration (NOAA) Bay Watershed Education and Training (BWET) grant program funded this two year project with high school students and teachers in rural Virginia. All High School teachers in Gloucester and Matthews Counties received training on the SSP and approximately 100's of students completed both classroom and field-based instruction and experiences in conducting mock sentinel site monitoring efforts. The CBNERR-VA Education Program developed a lesson plan and field trip based on the SSP as part of Climate Education for a Changing Bay. The lesson is now integrated into two local school systems, has been published in a professional journal (Nuss and Beck 2015), and is being shared with other educators via oral presentations at professional meetings throughout 2015 and 2016. In addition, a 2016 NOAA Hollings

Scholar will join the reserve in summer 2016 to develop new lessons based on the SSP. Reserve Stewardship Staff and RTK equipment were used to installing temporary benchmarks at two local high schools to support program lesson plans. Stewardship staff also assisted with a very successful CECB Teachers Workshop in June of 2014, as invited speakers/experts, both in the classroom and during a site visit to Goodwin Islands. General information on wetlands and a comprehensive summary of CBNERR-VA Wetland Sentinel Site efforts were also presented to the general public through the CBNERRVA Education Program monthly discovery lab through a presentation entitled "The Wonder of Wetlands" on March 18th, 2014. Finally, based on the success of the CECB program in 2014, Sarah McGuire submitted a proposal in early 2015 for funding through BWET to continue the "Climate Education for a Changing Bay" program for which Stewardship Staff provided a letter of support and edits/comments to the final proposal.

CBNERRVA has also able to collaborate with the National Aquarium in Baltimore over multiple summers (2008, 20011, and 2012) with interns (and the Conservation Coordinator) from the Aquarium's conservation program came down for a learning experience and to provide field support in some of our Sentinel Site monitoring activities. Some activities have included the installation of SETs on Goodwin and Catlett Islands, mapping of critical habitat using high accuracy GPS units, and developing a protocol for mapping "ghost" trees (i.e. dying or dead trees) on multiple Reserve components to better understand long –term changes in the high marsh/forest ecotone.

CBNERRVA has also been working for the past couple of summers to bring in motivated undergraduates looking for some work experience to assist with our sentinel site monitoring efforts through the NOAA College Supported Internship Program. The project application has been titled "Climate and Anthropogenic Impacts on Critical Reserve Habitats: The Chesapeake Bay National Estuarine Research Reserve Sentinel Site Program (VA)" and Claudia Deeg (Smith College for summer of 2016) and Nickolas Farr (Evergreen State College for summer of 2017) were selected and participated in this internship opportunity. These undergraduates participated in a number of Reserve activities including habitat mapping using GEOXH GPS units, sediment core collection (and sediment processing), vegetation characterization, groundwater well monitoring, surveying, assistance to the water quality program (CBIBS and Shoal Monitoring), assistance to the SAV program (biomonitoring), assistance to graduate student work at Taskinas Creek, and building boardwalks for marsh research activities. Claudia Deeg also produced a report on potential options for diamondback terrapin management and submitted to the Reserve to review and consider to use this for a citizen project. This opportunity has been a great educational and professional experience for the interns and has provided our Reserve with very valuable and needed field assistance during our busy summer monitoring periods.

Another example of how CBNERRVA Sentinel Site information is being used not only for research but also for education can be demonstrated by the value added of this information in courses taught at the Virginia Institute of Marine Science. Dr. Matt Kirwan has taught (in 2016 and 2018) a Wetland Ecogeomorphology course which features a field component which has been focused on the Goodwin Islands Reserve component. The focus of the project was to compare how ecosystem function varies with marsh age and in addition to the on the ground information collected by Dr. Kirwan's students (such as sediment cores for nutrients and vegetation biomass from marsh sites of different ages) has been able leverage some of the information being collected as part of CBNERRVA's sentinel site monitoring including elevation information, wetland surface change measurements from our SETs, and the spatial information for certain habitat types based on previous field mapping activities. The ultimate goal of these efforts is ultimately to produce a manuscript to be published in a scientific journal.

Current Programmatic Capacity/Training to Continue to Carry out Sentinel Site Activities at CBNERRVA

CBNERR-VA stewardship and research staff has received training and currently has the capacity to carry out the CBNERRVA Sentinel Site Program (SSP). Scott Lerberg, the CBNERR-VA Stewardship Coordinator, manages the SSP. Scott Lerberg has 10+ years as Stewardship Coordinator at Chesapeake Bay, VA NERR; helped initiate the marsh resilience index project, participated in leadership team of marsh resilience index project for the past two years; coordinator for CBNERR-VA's emergent wetland Sentinel Site monitoring effort and member of management team for the Chesapeake Bay Sentinel Site Cooperative; co-project lead on NOAA Restoration Program funded Reference Site Project to assess effectiveness of nearby restoration projects: site lead on multi-Reserve collaborative transfer project to improve management outcomes of sea-level rise modeling (using a Marsh Equilibrium Model): co-developer of the Climate Change Vulnerability Assessment Tool for Coastal Habitats (CCVATCH) and CBNERR-VA Pilot Site Coordinator for a previously funded NERRS Science Collaborative project designed to test the reliability of CCVATCH. Scott has completed RTK Training through NERRS Training Programs (CBNERRVA in 2008, Wells, Maine in 2009, CBNERRVA in 2016), Digital Leveling training (VIMS in 2010 and Corbin in 2012), training on running Opus Projects (Corbin, 2011 and 2014) and training on Processing Tidal Datums (SERC in 2017). Additionally, Scott has taken courses on conducting vulnerability assessments (Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment, NERRS Shepherdstown, West Virginia. 2012) and remote sensing (Remote Sensing using ArcGIS 10.X Workshop, Richmond, VA. 2014).

Alex Demeo, CBNERR-VA Stewardship Assistant, is responsible for conducting much of the field work associated with the program with the support and guidance of the Stewardship Coordinator. With a background in biology and previous work for a general contractor Alex Demeo is an integral part of the Sentinel Site monitoring team. He is able to assist in the daily operations for data collection, processing, and management. He is well versed in different aspects of installation and maintenance of equipment used for the build out of the monitoring sites. Alex has also undergone several training courses to better understand survey techniques and equipment. The first training course was to better understand the setup and use of RTK Systems (RTK training at APNERR in Florida in April of 2015). This enabled Alex to go out and preform regular elevation checks on instruments installed on the reserve. The second training was an NGS training course on the use of Digital leveling (NOAA Digital Leveling Course at NGS Facility in Corbin, VA). This course taught him how to collect data using a digital level and how to process that data. Alex has also received training in collecting spatial data using Trimble Geo7x units (from Duncan Parnell , fall of 2016) as well as training in processing spatial data in Trimble Business Center (Trimble Technical Training – Field to Finish) in November of 2017 in Ashland, Virginia.

Dr. William Reay, CBNERR-VA Manager and Virginia Institute of Marine Science (VIMS) faculty member, provides support and expert guidance of the program. Reay has William Reay is the Director of the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA) with extensive research experience in coastal systems, particularly wetlands. He has an active focus on acquisition and use of monitoring data. He has developed a multi-site NERRS along the estuarine gradient with sophisticated monitoring of wetlands and water quality. Willy's research interests encompasses two focal areas including: (1) watershed hydrology and nutrient dynamics with an emphasis on the study of groundwater-surface water interactions, and (2) wetland and ecotone response/adaptability to climate change and episodic impacts. I am also actively engaged in the development and implementation of shallow-water monitoring programs, their integration into ocean and coastal observation systems, and more recently the development of climate-change sentinel sites. Willy is relied on heavily for his experience and expertise with field collection methods for groundwater, sediment, water quality, and sediment data.

Additional staff (primarily for field and lab support) include Hank Brooks (Field Manager) and Eduardo Miles (Marine Scientist). In addition Dave Parrish (Marine Scientist II) assists with technical support, database support, and manages the VECOS (water quality) database and website. CBNERRVA also uses summer interns and hourly support to assist with the intensive summer monitoring program.

Funding has been primarily through a combination of NOAA/NERRS Operations Funding, NOAA/NERRS Procurement, Acquisition, and Construction Funding (PAC Funding) primarily for our Sentinel Site Buildout at selected Reserve Components, State Funding (funding for salary support for Stewardship Coordinator), various grant opportunities (primarily through the NERRS Science Collaborative), and he VIMS Equipment Trust Fund (which has been used to purchase equipment over time including our RTK System and our newly acquired eBee AUS system.

CBNERRVA has secured a number of resources critical for our Sentinel Site Monitoring efforts over the last decade which include: 1) Trimble R8 GNSS System (RTK System), 2) DNA03 Precision Digital Level with 2 meter Invar Rods, 3) Leica Sprinter 150M Electronic Level with Telescopic Leveling Staffs; 4) TopCon Auto Level with Graded Rod; 5) 2 Geo7x Dual-frequency GNSS Receivers with Floodlight technology and integrated laser rangefinder with Flightwave technology; 6) senseFly ebee Plus AUS System with Pix 4D Mapper Pro; 7) Ricoh GPS Camera, 8) Multiple In-Situ Aquatroll 200 Data Loggers, 9) Solinst Water Level Meter, and 10) YSI Pro 2030 DO, Conductivity, and Salinity Instrument, and 11) 3 tide gauges (Vega, H360, and H360i) provided by NOAA COOPS OSTEP group in Chesapeake, Virginia.

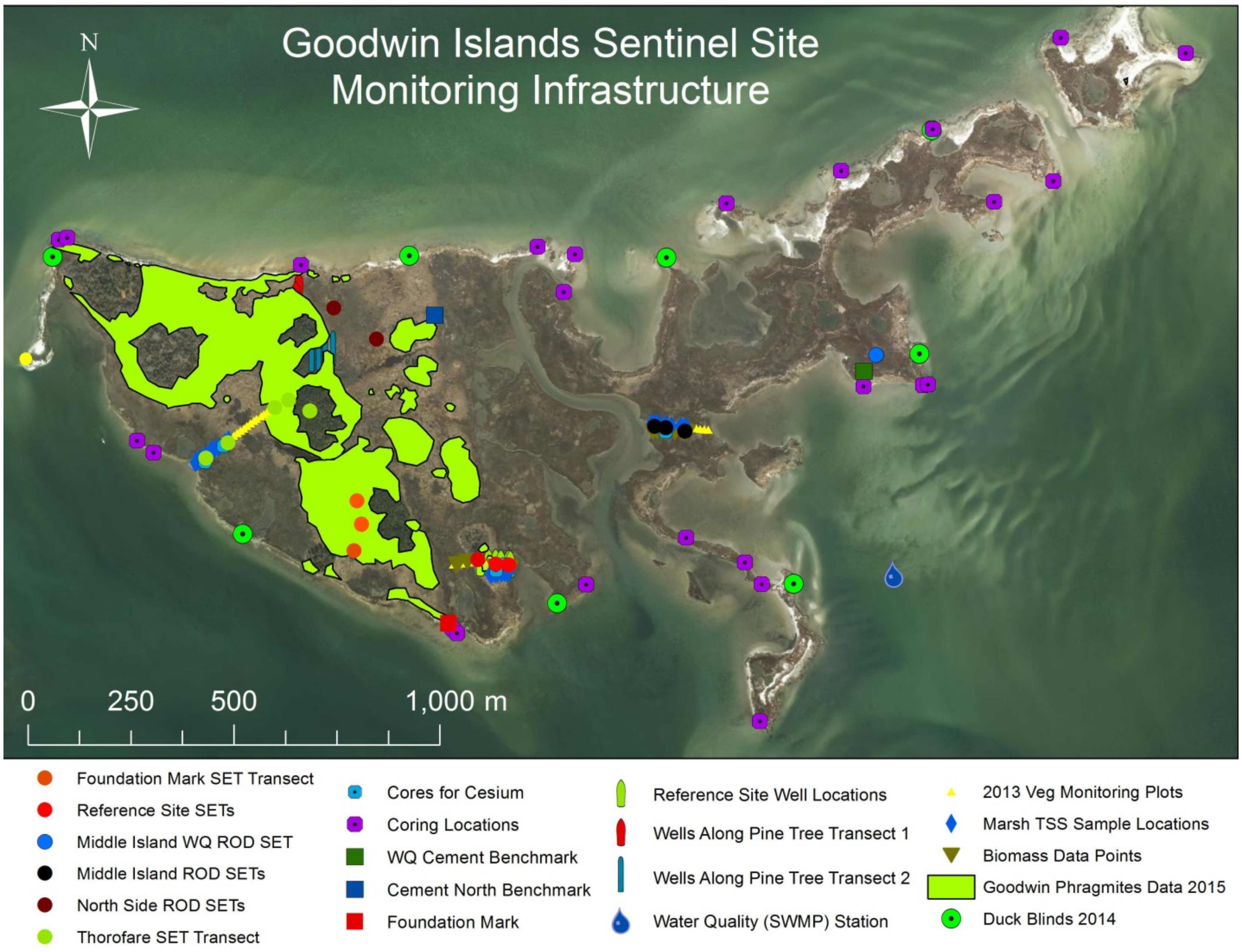
Due to a very ambitious monitoring schedule, staffing time is always a problem for the CBNERR-VA Sentinel Site Program. Staffing needs for basic program implementation is primarily met by two people (the Stewardship Coordinator and Field Technician) supplemented by assistance by the water quality program Field Manger (Hank Brooks), Reserve Director (Dr. William Reay), and Marine Scientist (Eduardo Miles) when needed (and they are available). CBNERRVA does try to take advantage of opportunities of assistance from hourly support, volunteers, and summer interns but this also comes at a cost of additional time for training and basically getting new staff comfortable with the different monitoring protocols. CBNERRVA is also challenged by the need for additional training (and the timing of that training is important) in aspects of vertical control and processing of certain types of data which are critical for obtaining high quality data and products from this program. For example, CBNERRVA staff may not use a certain survey instrument (i.e. digital level) or certain type of software (i.e. Opus Projects) for months to years in some cases which presents a challenge (and steep learning curve) to get back “up to speed” on that equipment or analysis method. Being a multi-component site with over 45 SETS, 30 groundwater wells, 100’s of vegetation plots, and many other additional monitoring elements also presents a logistical challenge in obtaining enough data in a great enough spatial coverage with limited resources (with sacrificing data quality). One other hurdle (and this also relates to funding) is keeping up with all the different hardware upgrades and software firmware upgrades (some of which come at a cost) for the field (primarily surveying) equipment. We often find we do not have the resources to keep up with these upgrades (as suggested by the equipment vendors) and have to hope we can keep using our current version and that we are using a firmware version which continues to be supported by the vendor. We anticipate future training needs focused on using R for statistical analysis, additional training on Opus Projects for processing our GPS solutions, PIX4D Mapper (for processing our aerial photography data), and refreshers on digital leveling and RTK.

III. Site Based Monitoring Plan.

In order to incorporate the diversity of habitats in the southern Chesapeake Bay subregion, CBNERR established a multi-component system along the salinity gradient of the York River estuary. Reserve components include Sweet Hall Marsh, Taskinas Creek, Catlett Islands and the Goodwin Islands. Goodwin Islands are located at the mouth of the York River estuary with a marsh area of approximately 111.7 hectares and a total size of 154.5 hectares. Catlett Islands are located approximately 35.2 kilometers upstream from the mouth of the York River with a marsh size of 84.2

hectares and a total size of 168.4 hectares. Taskinas Creek is located approximately 44 kilometers upriver from the mouth of the York River with a marsh size of 33.6 hectares and a total size of 210.7 hectares. Sweet Hall Marsh is located in the Pamunkey River approximately 83.3 kilometers upriver from the York River mouth with a marsh size of 385.0 hectares and a total size of 444 hectares. The following maps, text, and tables will describe our current sentinel site monitoring infrastructure at each Reserve component.

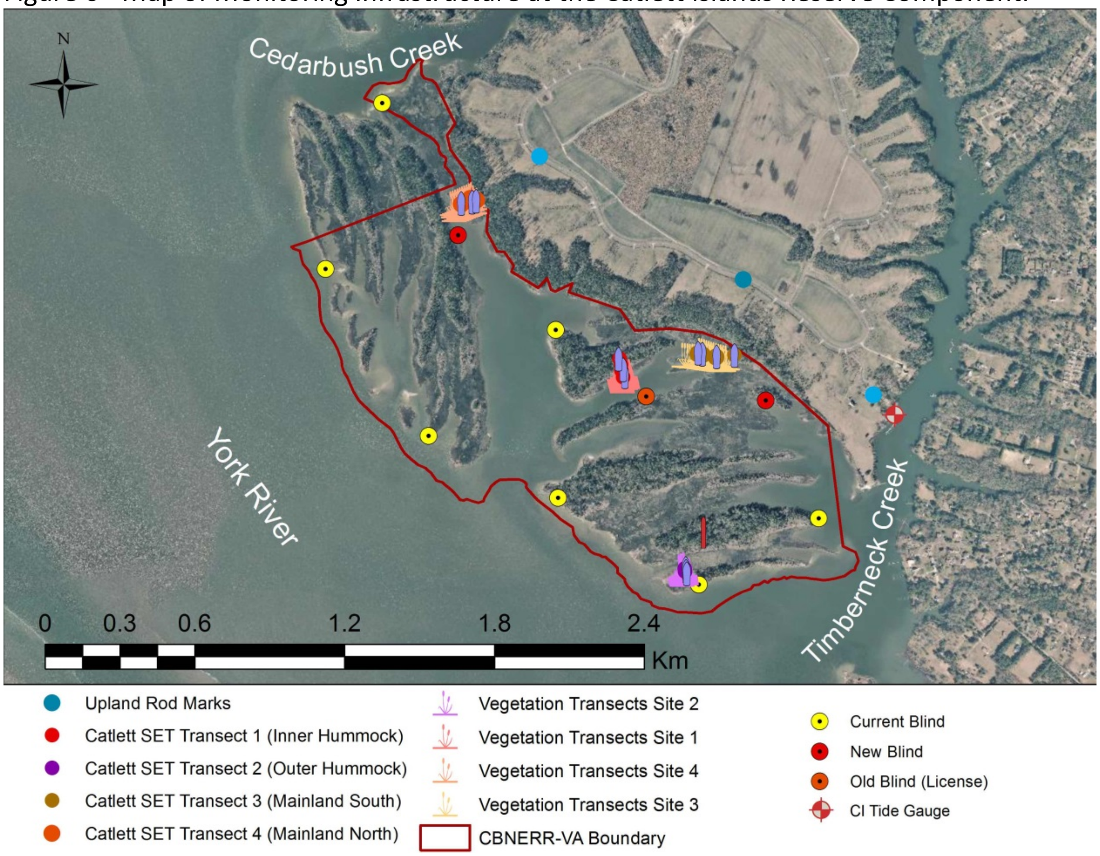
Figure 5 - Map of Monitoring Infrastructure at the Goodwin Islands Reserve Component.



Sentinel site infrastructure at Goodwin Islands was initiated from Reference Site Project Work (Transect 1), building of historical transects (Transects 2 and 3), co-locating SETs with vegetation plots (Transects 1 to 3), co-locating groundwater wells with SETS (Transect 1), pine tree study (GW Pine Tree Transects), establishing vertical control points around island (cement marks, foundation mark, ROD SETs), establishing control near WQ Station (cement WQ mark), and replication of SETS in critical habitats including Phragmites/Forest zone and maritime Forest (SET Transects 4, 5, and 6). A historical analysis of shoreline loss, forest retreat, and pond abundance has also been completed for the Goodwin Islands Reserve. CBNERRVA staff are currently using some of the methods and procedures (including using DSAS) from the Shoreline Studies report (which only examined data from three years from Catlett Island – 1953, 1978, and 2007) to take a more comprehensive examination of historical shoreline and forest change at both the Goodwin Island and Catlett Island components. The Digital Shoreline Analysis

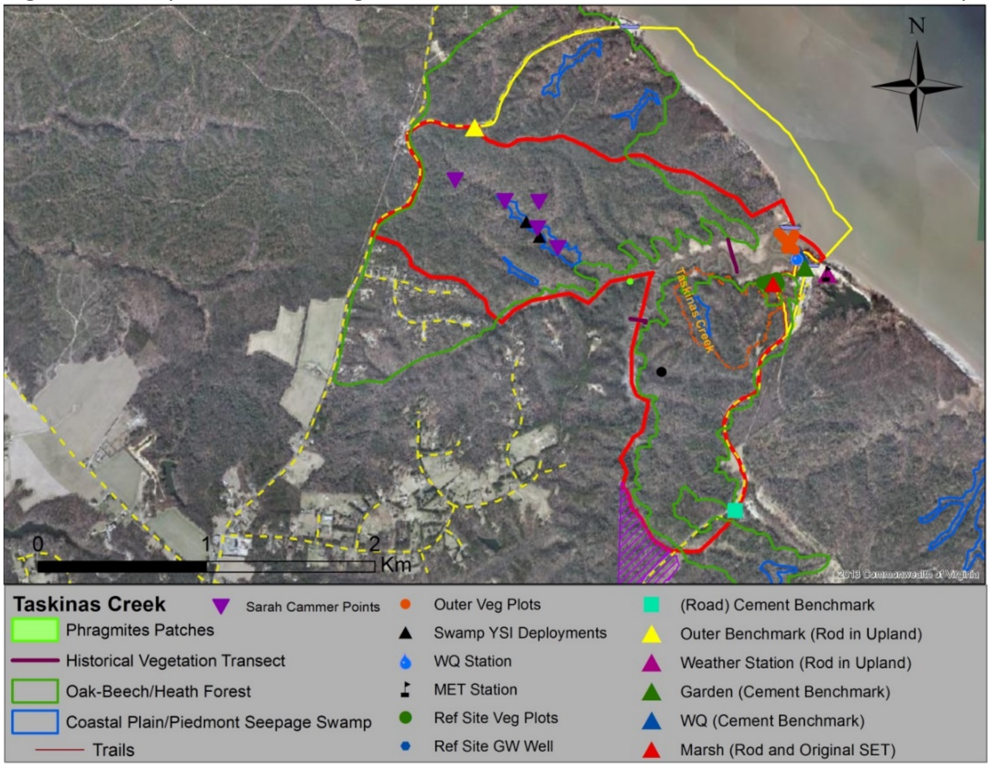
System (DSAS) was developed by the USGS and is a computer software program that reside in ArcGIS and computes rate-of-change statistics from multiple historic shoreline positions. Focusing back on the Goodwin Islands Reserve, we used DSAS (Transect Based Approach in GIS) to calculate change to examine historical trends in the shoreline and forest boundary. Examined change over time intervals based on available imagery (9 years available) which took the form of T-Sheets, Aerials, and field collected GPS.

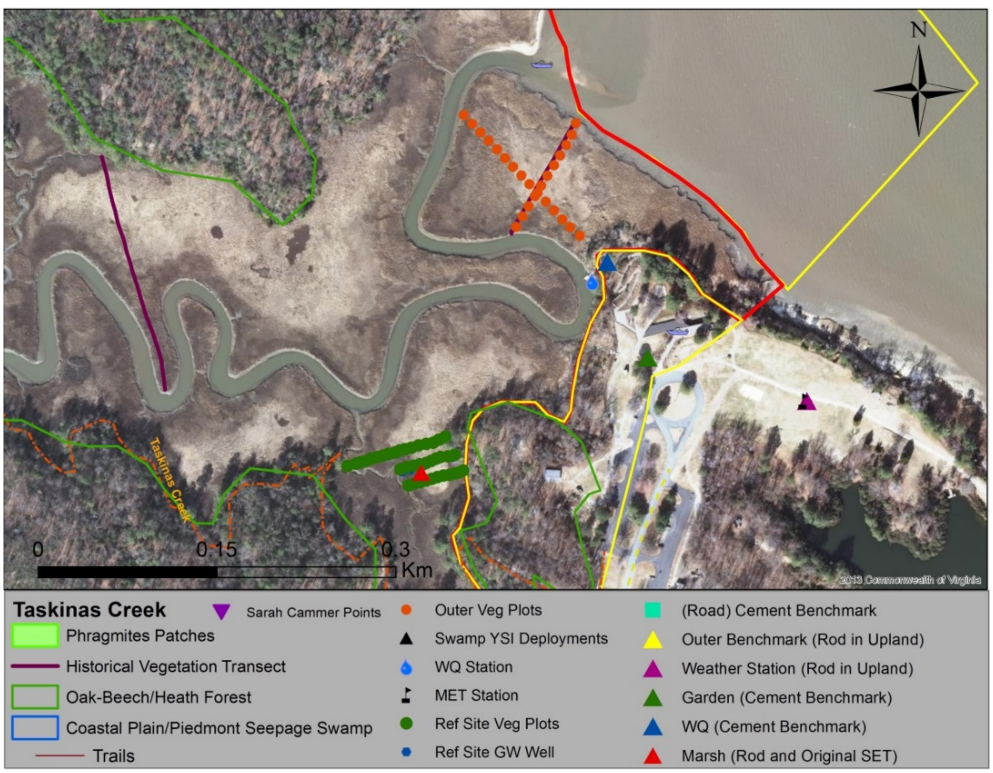
Figure 6 - Map of Monitoring Infrastructure at the Catlett Islands Reserve Component.



Catlett Islands was the most recent Reserve component instrumented with sentinel site infrastructure to examine wetland vulnerability to accelerated sea level rise. At Catlett Islands, the positioning of the vertical control marks allows for CBNERRVA staff to be able to digital level to all SET, vegetation, and groundwater transects from a single upland benchmark. Placement of an additional upland benchmark near the newly installed tide gauge station allows for CBNERRVA staff to level to the newly installed tide gauge station on a routine basis. As with other sites, CBNERRVA staff have co-located vegetation plots, SETs, and groundwater wells along each transect (Transects 1-4). CBNERRVA staff determined transect locations based on the presence of historical vegetation data as well as the opportunity to study impacts on marsh systems on hummock islands as well as those connected to the mainland. We are examining habitat changes along hummock forested systems (Transects 1 and 2) and upland forested system (groundwater dynamics) along Transects 3 and 4. Overall, CBNERVA has replication of SETS and groundwater wells in critical habitats including low marsh, high marsh/ghost forest, Juncus, and maritime forest.

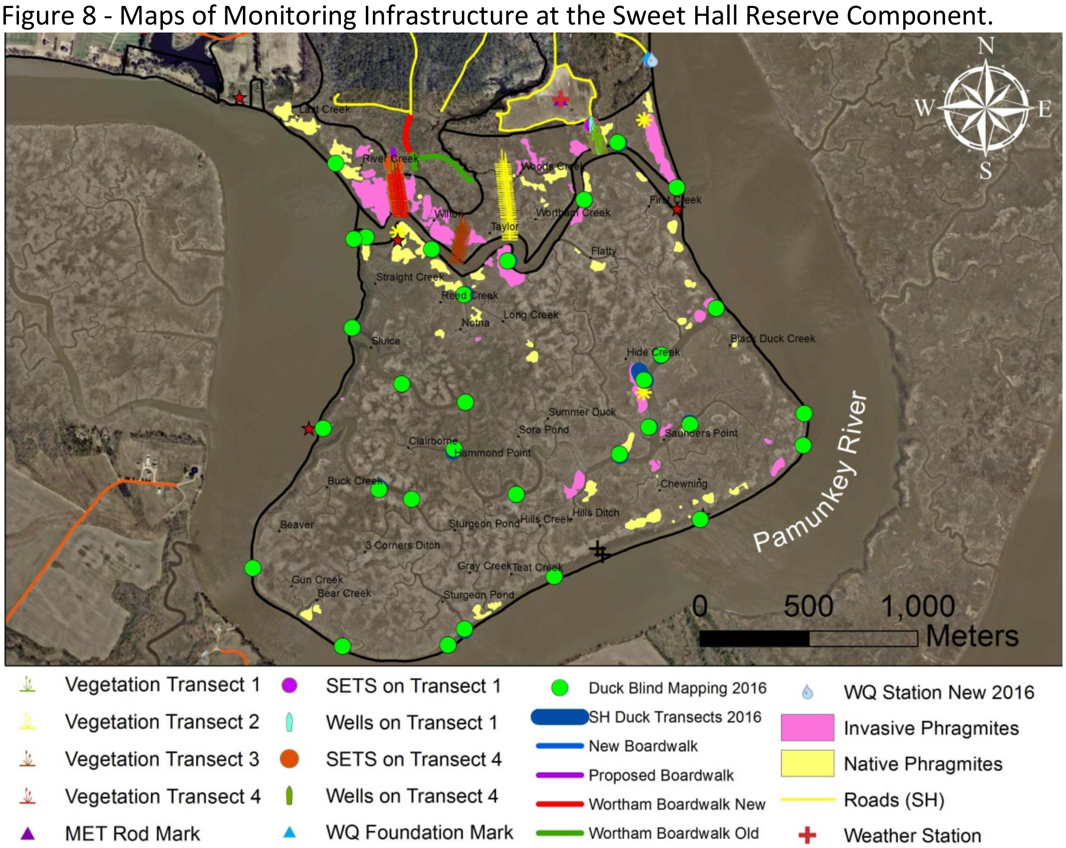
Figure 7 - Maps of Monitoring Infrastructure at the Taskinas Creek Reserve Component.

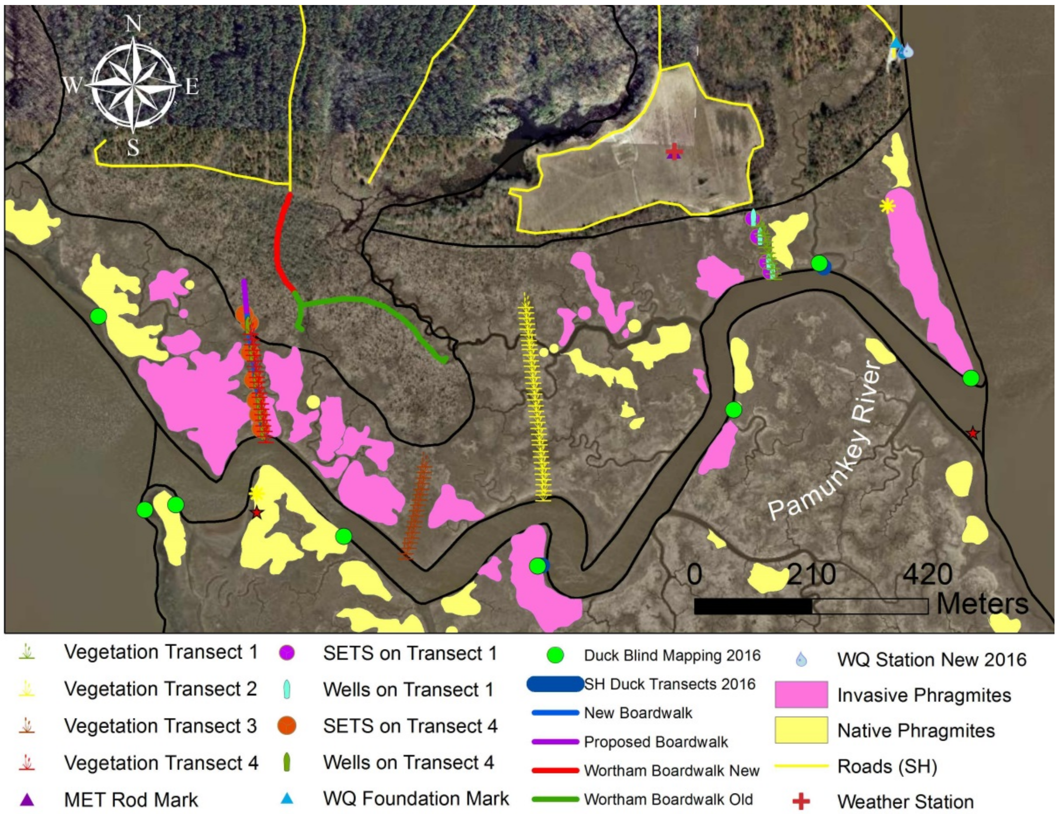




The investment in Sentinel Site monitoring infrastructure at the Taskinas Creek Reserve component is less than at other sites (only 2 SETs and 4 Groundwater Wells), but understanding wetland vulnerability at this Reserve component is critical for understanding impacts in embayed wetland habitats with a much more substantial contribution and influence from the surrounding watershed. As with Goodwin Islands, the initial sentinel site monitoring infrastructure was installed during the work on the Reference Site Project (Transect 1). As with other components, at this initial transects SETs were co-located with groundwater wells and vegetation transects. Additional transects were placed on the outer most section of marsh to increase plot sample size in the low marsh, high marsh, and tall cordgrass habitats and were based on some historical transect work from Dr. Jim Perry. Extensive vertical control has been placed on the uplands including a deep rod mark at the MET station which serves as our primary benchmark for GPS work and additional cement marks on the upland to allow for leveling points to sentinel site infrastructure (including a cement mark near the WQ Station and newly installed tide gauge stations which allow for one-shot leveling to that infrastructure for checks/repeat measurements. We are planning to install one additional transect at this site in 2018 which will be include 2 to 3 additional SETs in the high and low marsh zones, 3 to 4 additional groundwater wells (marsh levee, low marsh, high marsh, and upland) as well as number of vegetation plots following NERRS biomonitoring protocols.

Figure 8 - Maps of Monitoring Infrastructure at the Sweet Hall Reserve Component.





Sentinel Site monitoring efforts at Sweet Hall marsh included 4 vegetation transects located based on historical transect work at Sweet Hall Marsh by Jim Perry and Sarah Davies above the main thorofare (Sluice Creek). At Transects 1 and 4, we co-located vegetation monitoring, SETS, and groundwater wells and attempted to sample in multiple habitats including marsh levee, flats, marsh/upland interface, ghost forests, maritime forests. Transects 2 and 3 included vegetation plots only. There is a long-term water quality station (SWMP Station) and tide gauge located on pier at boat house. Vertical control includes primary benchmark inside fence of weather station which allows for leveling to secondary benchmark (foundation mark) on boat landing (which allows for a one-shot check of water quality station/tide gauge) and leveling to Transect 1. Control along Transect 4 achieved through GPS Occupations on SET ROD Benchmark (SET 4-3) and then leveling from that mark to other infrastructure along transect. Sweet Hall had recent aerial photography acquisition (through AUV) providing good base for habitat mapping work.

Table 1 – Current Sentinel Site Monitoring Infrastructure at CBNERRVA Reserve Components located along the salinity gradient of the York River subestuary.

Reserve		SETs	Vegetation Plots	Groundwater Wells	Water Quality Stations	Tide Gauge	Weather Stations	Vertical Control Marks
Goodwin Islands		**17 Total**	**58 Total (2013)**	**14 Total**	**1 (1997) Moved (2010)**	**.**	**1 (2006-2011)**	**2 Cement, 1 Foundation**
Transect No.	Transect Name							
1	Reference Site	3 (2008, 2016)	22 (2008), 19 (2013)	6 (2008, 2010)				
2	WQ Station	1 (2009)	.	.				
3	Middle Island	3 (2011)	15 (2013)	.				
4	York River	2 (2011)	.	.				
5	Thorofare	5 (2011, 2016)	24 (2013)	.				
6	Foundation	3 (2016)	.	.				
7	Pine Tree 1	.	2017 (1 Time)	4 (2010)				
8	Pine Tree 2	.	2017 (1 Time)	4 (2010)				
Catlett Islands		**14 Total**	**79 (2017)**	**13 Total**	**None**	**1 (2017)**	**None**	**3 Upland**
1	Interior Hummock	4 (2011, 2017)	28 (2013), 12 (2017)	3 (2017)				
2	Exterior Hummock	2 (2011)	22 (2013), 8 (2017)	3 (2017)				
3	Upland South	4 (2017)	29 (2017)	4 (2017)				
4	Upland North	4 (2017)	30 (2017)	3 (2017)				
Taskinas Creek		**2 Total**	**45 (2017)**	**4 Total**	**1 (1995), Moved (2009)**	**1 (2017)**	**1 (1997)**	**2 Upland, 2 Cement**
1	Reference Site	2 (2008)	40 (2008), 19 (2013)	4 (2008)				
2	Outer Transect 1	.	11 (2013)					
3	Outer Transect 2	.	15 (2013)					
Sweet Hall Marsh		**12 Total**	**99 (2017)**	**10 Total**	**1 (1999), Moved 2016**	**1 (2011)**	**1 (1998)**	**1 Upland, 1 Foundation**
1	SET Transect 1	5 (2008, 2009)	11 (2007)	4 (2008)				
2	Veg Transect 1		35 (2007)					
3	Veg Transect 2		25 (2007)					
4	SET Transect 2	7 (2009, 2011)	25 (2007)	6 (2008, 2009)				

Table 2 – Past and future monitoring efforts along each Reserve component Sentinel Site Transect.

Reserve		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Transect No.	Transect Name														
Goodwin 1	Reference Site	.	V , S, G	V , S, G	V , S, G	S, G	S, G	V , S, G	S, G	V , S, G	S, G	V S	S, G	V , S, G	S, G
Goodwin 2	WQ Station	.	.	S	S	S	S	S	S	S	S	.	S	S	S
Goodwin 3	Middle Island	.	.	.	.	S	S	V, S	S	V, S	S	V	S	V, S	S
Goodwin 4	York River	.	.	.	.	S	S	S	S	S	S	S	S	S	S
Goodwin 5	Thorofare	.	.	.	.	S	S	V, S	S	V, S	S	V	S	V, S	S
Goodwin 6	Foundation	.	.	.	.	.	.	.	.	.	S	S	S	S	S
Goodwin 7	Pine Tree 1	.	.	.	G	G	G	G	G	G	G	V	.	.	.
Goodwin 8	Pine Tree 2	.	.	.	G	G	G	G	G	G	G	V	.	.	.
Catlett 1	Interior Hummock	.	.	.	.	S	S	V, S	S	V, S	S	V, S	S, G	V, S, G	S, G
Catlett 2	Exterior Hummock	.	.	.	.	S	S	V, S	S	V, S	S	V, S	S, G	V, S, G	S, G
Catlett 3	Upland South	.	.	.	.	.	.	.	.	.	.	V, S	S, G	V, S, G	S, G
Catlett 4	Upland North	.	.	.	.	.	.	.	.	.	.	V, S	S, G	V, S, G	S, G
Taskinas 1	Reference Site	.	V, G	V, S, G	V, S, G	S, G	S, G	V, S, G	S, G	V, S, G	S, G	V, S	S, G	V, S, G	S, G
Taskinas 2	Outer Transect 1	.	.	.	.	.	.	V	.	V	.	V	.	V	.
Taskinas 3	Outer Transect 2	.	.	.	.	.	.	V	.	V	.	V	.	V	.
Sweet Hall 1	SET Transect 1	V, S	V, S	V, S, G	V, S	S, G	S, G	V, S, G	S, G	V, S, G	S, G	V, S	S, G	V, S, G	S, G
Sweet Hall 2	Veg Transect 1	V	V	V	V			V		V		V		V	
Sweet Hall 3	Veg Transect 2	V	V	V	V			V		V		V		V	
Sweet Hall 4	SET Transect 2	V	V	V, S, G	V, S	S, G	S, G	V, S, G	S, G	V, S, G	S, G	V, S	S, G	V, S, G	S, G

Section B – Vegetation Monitoring

In locating our vegetation transects, we have tried to build off historical transect work by Dr. Jim Perry and other wetland scientists who have conducted wetland monitoring at Reserve components. The data collected from permanent transects provides a description of marsh vegetation communities and baseline data for future quantifying and monitoring of temporal-spatial changes within CBNERRVA Sites. For example, it has been suggested (by Dr. Jim Perry in previous work at Sweet Hall Marsh) that research and monitoring to determine salinity and tidal inundation tolerances of individual species, as well as the effects of inter-specific competition on diversity in these salinity regimes are badly needed. Other identified needs for long-term vegetation monitoring have included: identifying shifts in species composition due to SLR; assessing vulnerability of critical habitats; to develop marsh indices; to assist in developing marsh equilibrium models; to evaluate change in horizontal marsh migration; and to ground truth our habitat maps.

In addition, our objective has been to replicate sampling in as many critical wetland zones (stratifying major vegetation communities by elevation (Roegner et al. 2008) as possible including, but not limited to, marsh levee, low marsh, high marsh, scrub-shrub zone, and transition to maritime forest. Along our long-term vegetation transects at all Reserve components, the delineation of tidal wetland zones was guided by local knowledge of tidal wetland vegetation communities and then confirmed by the acquisition of elevation data..

Vegetation data were collected from multiple monitoring plots located at regular intervals along three transects established at each project site. All transects were established following the NERRS Biomonitoring protocol (Moore 2012; largely based on Roman et al. 2001). Transects extended from the lowest intertidal emergent wetland elevations up through the wetland/ upland transition. A minimum of one transect per community was established perpendicular to the shoreline with quadrats located at 10 meter intervals along the transects. Transects terminated at the upland boundary of the site or where open water was encountered. Individual transects were no less than 10 m apart to maintain independence and in all cases ran perpendicular from the primary controlling surface water feature to the upland margin.

Each plot consisted of a 1.0-m2 quadrat in which percent cover of all emergent vegetation species (including invasive species such as Phragmites australis) and other structural attributes (e.g., woody debris, bare ground) was quantified using the basal percent cover for each species through visual inspection and values were recorded based Braun-Blanquet cover-class ranges (i.e., trace, 1-5%; 6-25%, etc.)(Doumlele, 1981). Vegetation species richness (number of species per quadrat) was also quantified by visually identifying all emergent vegetation species present in each quadrat. Stem density for each species was also determined within a subsample (25 cm by 25 cm in most cases, sometimes smaller for species with high abundances) of each meter squared permanent plot. Plant height was determined for each species by taking measurements of the 3 (or up to 3) tallest individuals of each species within the plot. Photos are also taken of each plot. Protocols for species abundance, height and stem density follow those outlined in Neckles et al. (2002) and Moore (2009). Vertical Control information at each plots (collected using either digital leveling or RTK) was collected at two points at every plot (top and bottom of plot along the transect line). All vegetation data were collected during the middle or end of the growing season each year (typically July through September) to capture peak biomass and to facilitate taxa identification.

Table 3 (attachment) provides a summary of each long-term vegetation transect which is part of NERRS sentinel site monitoring efforts. We plan to sample along each transect every two years as well as collect new information on elevation on that frequency as well (conducted in alternate years). As of the sampling event in 2017, there are approximately 60 current plots at Goodwin Islands which can be found in salt marsh (low marsh, high marsh, juncus), transitional (high marsh/shrub/phragmites), and forested habitat. At Catlett Islands there are approximate 115 current plots which can be found in salt marsh (low marsh, high marsh, juncus), transitional (high marsh/shrub zone), and forested habitat. At Taskinas Creek there are 65 current plots can be found in two distinct salt marsh zones (low marsh, high marsh). At Taskinas, there transition from marsh to upland is very distinct (and abrupt) which has not allowed for meaningful vegetation sampling in that particular transition area. At Sweet Hall Marsh there are approximately 100 current plots can be found in tidal freshwater marsh at Sweet Hall Marsh. At Sweet Hall Marsh, you tend to get a slightly elevated Creekside levee (10 to 20 cm) before extending into a lower (and very flat) marsh interior with a slight rise in elevation when transitioning into the shrub zone/forested transition.

CBNERRVA is considering (based on research questions, resources, and time) building out additional monitoring transects at Taskinas and Sweet Hall Marsh. At Taskinas Creek, the priority will be one more transect on the north side of the main creek thorofare which will run from the creek to the marsh/forest transition zone and provide additional vegetation plot as well as SETs and groundwater wells in the marsh levee, low marsh, and high marsh zones. At Sweet Hall Marsh, our priority is to extend Transect 4 northward for additional vegetation plots, SETs, and groundwater wells in more healthy (i.e. less impacted currently by sea level rise) forested habitat along this transect. We also hope to connect this transect to the main upland area to allow access to this transect by land (and not by vessel) on poor weather days.

Vegetation monitoring data are collected on waterproof field sheets (designed in-house) and entered into Microsoft Excel table and reviewed by a separate member of the staff (from the person who entered the data). Eventually, we intended to push all this information into an Access database with the assistance of the VECOS (water quality) database manager, Dave Parrish.

Section C – Surface Elevation Monitoring

An primary objective of CBNERRVA's long-term sentinel site monitoring efforts is to measure wetland surface elevation, vertical accretion, and shallow subsidence in different wetland habitat types which are responding to a variety of environmental stressors (as well as Sea Level Rise). Marsh elevation is influenced by a number of surface (sediment deposition) and subsurface (root growth, decomposition, porewater flux, and compaction) processes. As with many other NERRS sites around the country, our primary method for measuring changes in marsh elevation is using the Surface Elevation Table (or SET) which was originally designed by Don Cahoon and others (see recent NPS SET Document, Lynch et al. 2015). The SET provides a reference plane from which distance to sediment surface is measured on a consistent basis and has been shown (when done correctly) 95% CI of plus/minus 0.5 to 1.5 mm (depending on the type of substrate). The SET has been effectively used in long-term monitoring or to determine the influence of a single episodic event (such as the impact of Hurricane Sandy on critical coastal habitats along the East Coast).

There are many potential uses of SET data which have been demonstrated not only at CBNERRVA but within the Chesapeake Bay Sentinel Site Cooperative as well. This include: to determine if certain marsh habitats are keeping pace with SLR; to understand if certain marsh zones (i.e. low marsh to high marsh)are gaining elevation at different rates; to understand marsh transgression and/or migration and contribute to local/regional subsidence studies; to better understand sediment transport process: to be used to help calculate effects of global change on soil carbon sequestration rates : to be used in the development of marsh indices and Marsh Equilibrium Models; and to be used by land managers as a powerful tool to better understand wetland vulnerability and resilience.

According to the most recent National Park Service proposal (and an approach used at CBNERRVA< there are three primary objectives of elevation monitoring in tidal wetlands which include: 1) measuring rates of elevation change in wetlands, 2) measuring surface sediment deposition in wetlands using the marker horizon technique; and 3) measure marsh elevation to a consistent vertical datum (i.e., NAVD88) to allow comparisons among sites and with local water levels and tidal datums. CBNERRVA staff have followed the protocols provided by Don Cahoon, Jim Lynch, Philippe Hensel and others to install (to date) a total of 44 SETS (with marker horizon plots) within the four CBNERRVA Reserve Components. This has included 17 SETS at Goodwin Islands, 13 SETS at Catlett Islands, 2 SETS at Taskinas Creek, and 12 SETS at Sweet Hall Marsh. SET deployment design includes replicate stations in key emergent vegetation communities in low marsh habitats (i.e., Big Cordgrass, Mixed interior, Cattail) and high marsh habitats (i.e, Saltmarsh Cordgrass, Black Needlerush and Saltmeadow) across tidal marshes along the salinity gradient of the York River. SET and accretion measurements now span a range of 0.6 to 10.2 years across site with an average of 5 years. Please see Table 4 (attachmen) for more information on SET and Marker Horizon metadata across the four CBNERRVA Reserve Component (includes a readme file).

When in the field, measurements are collected from nine distinct points on the wetland surface at up to eight (but normally four) individual positions around the SET mark. At each fixed position, the SET is extended horizontally over the wetland and leveled. Nine pins are lowered from the SET arm until they make contact with the wetland surface. The remaining length of pin above the SET arm (or "platform" in the original design SET) is measured to the nearest millimeter. At the next measurement event (semi-annually to annually), the pins reoccupy the same surface of the wetland and are measured again. Over time, the change in the height of each pin is a reflection of the changing elevation of the sediment surface with respect to the base of the SET mark. Changes are typically normalized per year and reported as mm y-1. Four positions yield a total of 36 observations and additional positions allow for flexibility when encountering obstructions which may limit readings in a particular direction (i.e., muskrat holes, crab burrows, plant mounts, etc.).

We have attempted to survey in the SETS to our vertical control benchmarks on a consistent basis, but given time and resources, we have had to be opportunistic in many cases. However, we are attempting to make sure we re-level each SET at least every 5 years (and hope to bring that down to every 2 to 3 years in the future). Please see Column T in Table 4 (attachment) for notes on most recent efforts to survey in (using either digital leveling or auto leveling) each SET benchmark.

As discussed in the vegetation monitoring section, CBNERRVA is considering (based on research questions, resources, and time) building out additional SETs at Taskinas and Sweet Hall Marsh. At Taskinas Creek, the priority will be establishing two to four additional SETS to provide for some replication in the low marsh and high marsh zones at the Reserve component. At Sweet Hall Marsh, our priority is to install a few (1 to 2) SETS in more healthy transition forest habitat along current Transect 4.

SET data and metadata collected on waterproof field sheets (designed in-house) and entered into Microsoft Excel spreadsheet designed by the NPS (Jim Lynch) and Philippe Hensel). CBNERRVA staff (Scott Lerberg) are leading a workgroup within the NERRS to develop a standardized data template and metadata template across the NERRS which will allow for more consistent submission to CDMO, a more consistent template for data analysis (including recent attempts by Kim Cressman to develop standardized R-scripts for analysis), and allow for opportunities to collaborate and share SET across agencies (including recent discussions between the NERRS and DOI (i.e. NPS and FWS). Eventually, within CBNERRVA, we intend to push all this information into an Access database with the assistance of the VECOS (water quality) database manager, Dave Parrish.

SET data and marker horizon data has proved to be one of the more valuable datasets collected as part of our sentinel site monitoring program. As discussed extensively in the "Communication and Outreach Sections, our SET data has already been used in the development of manuscripts on the local level (Kirwan et al, 2016), in regional level analysis/products such as through the Chesapeake Bay Sentinel Site Cooperative and Mid-Atlantic Pilot, as a key parameter in the MARS indices (a national level product) as well as for the Hurricane Sandy Study (led by Don Cahoon). In addition, our SET data has been valuable to visiting researchers as well as potentially being used to help document local subsidence related to groundwater withdrawal.

Section D – Vertical Control Networks at CBNERRVA Components.

As defined in the NGS/COOPS/NERRS Protocols document, a sentinel site for coastal habitat monitoring will have a system comprised of at least (1) a local, high accuracy vertical control network; (2) high accuracy local water level sensor(s); and (3) long-term coastal habitat monitoring infrastructure, including but not limited to Surface Elevation Tables (SETs). The goal to be to relate water levels to observable changes in the ecosystem.

Ideally, we wanted to use digital leveling to bring in elevations to the site from a previously surveyed NGS first or second order level line. However, early on in the process we realized this was not feasible for a number of reasons (there previously leveled lines were too far away from the site to be feasible and/or benchmarks along those lines were destroyed or could not be found). So, for all of the sites, we used the concept of Local Control Marks (LCM's) (from the NOAA/COOPS/NERRS Guidelines) as a means to develop a vertical control network at each site. In the guidelines, it suggests that at least three permanent Local Control Marks (LCMs) need to be identified for each site and these will be highly stable marks for which you will obtain high accuracy coordinate information (horizontal and vertical) and provide a connection to the NSRS. Ideally (and this is the case for three of our four Reserve components, these LCMs will be in proximity to each other and to the monitoring infrastructure so that their relative height differences can be routinely checked via surveying techniques.

At CBNERRVA, our vertical control activities are summarized in Table 5 (attachment) and here is a brief description of how we are using the vertical control network at each site. Our Goodwin Islands site is our most challenging site although our most active site for sentinel site monitoring efforts. Due to the challenges of leveling across the marshes/pannes/pools at this site, we have tried (to our best ability) to have a vertical control network but in practice, we are basically using one foundation mark (very stable mark) and deep rod SETs as our LCM's (for static occupations and for which to survey in other infrastructure) – see Table 5 (attachment). At Catlett Islands, we have installed three deep upland marks which serve as an upland local control network at that site. We have decided to use CI Mark 21 as our primary benchmark (for repeated GPS Occupations) and have surveyed in the other marks (using optical leveling) to this mark in 2017. The CI Upland WQ Mark serves as the primary benchmark for the newly installed CI Tide Gauge and CI Mark 29 allows for more efficient and easier (less distance covered) to CI Transect 4. All other transects have or will be leveled from CI Mark 21 (this has been done for CI Transect 1 and CI Transect 3 and still needs to be completed for CI Transect 2). At Taskinas Creek, the deep rod upland Mark installed in the MET Station) serves as the primary local control mark for all GPS occupations at that site. We have then used a variety of leveling approaches to survey to the TC WQ Mark (which provides a one-shot solution to the SWMP Station and Tide Gauge) and to survey to TC SET 1-2 (which is a deep rod SET in the high marsh which is then used to survey to all other infrastructure along TC Transect 1. Although the vegetation plots along TC Transects 2 and 3 have only been surveyed in through RTK , future plans will be to survey these plots using the TC WQ mark as the closest LCM. Finally, the deep ROD upland Mark installed on the other side (northern side) of the Taskinas Creek watershed will be useful for surveying to a future planned sentinel site transect (located on the northern side of the primary creek system). Finally, at Sweet Hall Marsh, we used a similar strategy to Taskinas Creek and installed a deep ROD upland mark within the fence line of the Sweet Hall MET Station (SH MET Station Mark) to serve as the primary local control mark for GPS occupations at the site. We then have used leveling approaches (primarily digital leveling at this point) to survey from this mark to a foundation mark down at the SH boat landing (SH Boat Landing Mark) which provides a one- shot solution to the SH SWMP Station and Tide Gauge) and to survey to ROD SET 1-3 (the only deep ROD SET along SET Transect 1) which is then used to survey to other infrastructure along SH Transect 1 (vegetation plot and groundwater wells). As Sweet Hall Transect 4 is on the other side of the marsh (and the Sweet Hall Marsh is very difficult to survey across given the very soft nature of the sediments), we have used one of the two deep ROD SET Benchmarks (SH ROD SET 4-3) as a local control mark for which to conduct multiple GPS occupations over time and then used this mark to survey to the other infrastructure along Transect4.

For all our OPUS Solutions, we primarily use the following CORS Stations which are the nearest in proximity to our Reserve components along the York River Subestuary.

- Virginia Gloucester Point (VAGP) – (37 14 55.03676, -76 29 57.7437, 10.5 km from GI)
- Loyola X, (LOYX) - (37 16 35.05890, -76 41 43.83247, 27.44 Km from GI)
- Driver 5, (DRV5) – (36 57 31.16407, -76 33 23.91528, 32.14 Km from GI)
- Loyola LOYW (LOYW) – (37 31 41.0239, -75 50 52.67, ~ 80.5 km from GI)
- Loyola LS02 (LS02) – (37 15 47.9281, -77 24 39.9261, ~ 90 km from GI)

Ideally, we would like to conduct maintenance surveying efforts (leveling from our primary local control marks to these secondary local control marks (and Sentinel Site infrastructure) every other year (the plan being to conduct this leveling in the years in which we are not conducting vegetation sampling. In terms of getting static GPS data on our primary local control marks, we anticipate being able to do this several times a year during different sampling events (although these are usually for shorter duration periods – approximately 4 to 6 hour sessions. In the future, we hope to be able to work with the NGS Corbin office to do some long-term (12 or more hour) simultaneous occupations on one or two primary local control marks at all sites in order to collect some valuable information for future processing in OPUS projects to bring down the error (increase the accuracy) in the solutions for these primary local control marks (ideally, we could conduct this exercise every other year).

Section E – Water Level and Water Quality at CBNERRVA Reserve Components.

Water Quality

Water quality is a major driver of ecosystem change. Researchers and managers monitor parameters such as temperature, total suspended solids, dissolved oxygen, pH, conductivity, chlorophyll, and nitrogen. Consistent water quality sampling is achieved through the deployment of water quality sondes and/or discrete sampling at fixed location across the sentinel sites. CBNERRVA has a long-term SWMP Station installed at three of four Reserve components With respect to water quality monitoring, near continuous (15 minute data collection intervals) will be collected at three primary long-term York River estuary water quality stations (Goodwin Islands, Taskinas Creek, and Sweet Hall Marsh) and three additional stations (Clay Bank, Gloucester Point and White House) within the York River/Pamunkey River/Mattaponi River system. The addition of three near continuous monitoring stations is deemed necessary to adequately measure water quality along the salinity gradient of the York River estuary. Continuous monitoring stations will be equipped with YSI datasondes (6600 EDS and 6600 V2 models), remain operational year-round unless environmental conditions necessitate temporary retrieval, and be serviced weekly or bi-weekly at each site depending on the level of biofouling. All YSI datasondes will be calibrated and maintained to collect data which will be formatted in accordance with the YSI instrument operation manuals. Monthly nutrient and chlorophyll a grab samples will be collected at the four primary and two supplemental York River stations. Diel nutrient and chlorophyll a samples will be collected with an ISCO sampler at 2.5 hr intervals once a month at the Taskinas Creek component of the Reserve. Dissolved nutrient analysis will include ammonium, nitrate, nitrite, orthophosphate, and total dissolved nitrogen and phosphorus. Plant pigment analysis will include chlorophyll a and pheopigments. Inorganic nutrient and plant pigment analysis will be conducted by the CBNERR Water Quality Lab and total dissolved nutrients will be analyzed by VIMS Analytical Service Center; both labs follow strict quality assurance guidelines. CBNERR will meet all NOAA Central Data Management Office (CDMO) water quality data submission requirements and deadlines. Please see Table 6 (WQ Sondes CBNERRVA for Information on the Water Quality Station and please see Table 5 (attachment) and the Vertical Control Section D (above) for more information on how these stations are surveyed into NAVD88.

Water Level

The local NWLON Station in the York River is in Yorktown (Yorktown USCG Training Center, VA - Station ID: 8637689) and is approximately 6 kilometers from Goodwin Island and 10 kilometers from Catlett Islands and over 20 km from the Taskinas Creek Reserve Component. NOAA COOPS defines Goodwin Islands and Catlett Islands as being "NEAR NWLON Coverage" which means that there is an NWLON nearby, and that the reserve falls within the area of coverage by that NWLON (for the purposes of datum computation). Taskinas Creek is listed as "Near (NWLON-Edge)" which means that that there is an NWLON, but that the reserve is on the boundary of coverage (which would mean that local control would be especially important). Sweet Hall Marsh is listed as "Outside NWLON coverage" which means that any tidal datums would have to be derived using local instrumentation.

For example, for Goodwin Islands the suggestion give to use for obtaining tidal datums at that Sentinel Site were to: Transfer tidal datums from USCS Training Center (Yorktown) through GPS, b) establish bench marks for Goodwin Islands SWMP site and compute tidal datum; and c) Use simultaneous datum comparison (NWLON to SWMP) to derive/update local tidal datums referenced to current NTDE. This approach would probably work well for Catlett as well but would not be appropriate for Taskinas Creek and especially Sweet Hall Marsh.

CBNERRVA Staff have also increased their ability to more accurately track water levels at Reserve components with the installation of two additional tide gauges at Catlett Islands and Taskinas Creek. This work will complement the tide gauge data being collected at Sweet Hall Marsh (on SWMP Station – using a Microwave Radar Gauge H360 installed in 2011) and the water level information being collect at the mouth of the York River through the NOAA/COOPS NWLON Station. The Catlett Tide Gauge (using the Microwave Radar Gauge H3611I) was installed on June 8th on a wooden bridge which connects a boat slip on Timberneck Creek to the upland property. The second new tide gauge (at Taskinas Creek) is a Omhart Vega VegaPuls 62 system which has been mounting on an existing piling which also holds the SWMP Station. This setup required the installation of a new foundation mark on the upland to hold a radio tower. The cement foundation was poured on July 24th and the radio tower and gage were installed on August 22 after the foundation cured. This provides CBNERRVA the unique opportunity (at two sites – Taskinas and Sweet Hall Marsh) to have two instruments recording water levels (the YSI and Microwave Radar Gauge) allowing for tidal datum computations (and comparisons) using instruments with different sensors (pressure sensor versus radar sensor) with different sampling frequencies (15 minutes versus 1 minute) and the opportunity to demonstrate the reliability of the YSI SWMP Stations for Water Level Measurements. As we also have the unique ability to do interesting (and hopefully informative) tidal comparisons between different water level gathering products (i.e. YSI and H360 Microwave Radar Gauge), our understanding of how to process this information might lead to some error estimates for using different water level products which might be beneficial to the NERRS system

To assist with processing those tidal datums, CBNERRVA staff members were fortunate to have been trained in using a new Tidal Datum Calculator developed by NOAA COOPS Please see Table 6 (attachment - Water Level CBNERRVA tab) for more information. This course provided baseline information and tools about processing and analyzing water level data associated with real world case studies. Hands-on exercises helped us understand and apply the water level tools and methodologies . Participants were able to connect to web-based NWLON and non-NWLON water level data, calculate tidal datums (long-term averages) and conduct inundation analysis (frequency and duration) through tools provided in this training. The ability to calculate tidal datums will be useful for a number of products and outcomes including the following:

- Connect local vertical observations to ecologically meaningful water level datum (such as Mean High Water)
- Collect and store observed water level data referenced to a local known datum (tidal or geodetic)
- Inundation analysis (monitoring changing frequency and inundation patterns, perform inundation analysis relative to known datum)
    - Understanding wetland plant responses
    - Support wetland restoration via MHW – NAVD 88 relationship
- Monitor local water level trends (monthly means)
    - Seasonal analysis
    - Long-term trends
- Support higher accuracy regional sea level rise modeling
    - Locally validate modeling tools like SLAMM or VDATUM

Note: Data is current maintained internally (at CBNERRVA) for Water Levels and Water Quality Data sent to CDMO.

Section F - Meteorological Data

CBNERRVA currently maintains meteorological stations at Taskinas Creek and Sweet Hall Marsh (with Taskinas Creek being a reported station to CDMO and Sweet Hall marsh being reported internally to NERRS (and real time information to HADS). Parameters collected at each station include temperature, precipitation, wind speed, wind direction, relative humidity and barometric pressure. CBNERRRV follows NERRS protocols for maintenance and reporting. This effort includes biweekly maintenance site visits and assuring sensor quality through replacement or recalibrations. The Reserve is following the CDMO procedures including submitting the provisional biweekly data download to CDMO within one week of collection. CBNERR also continually updates its sensor inventory and implements both a maintenance and recalibration plan for Taskinas Creek weather station based SWMP approved protocols. Please see Table 6 (attachment - MET Sensors Tab) for more information.

Section G. Elective Parameters

Groundwater

In addition to the required elements of the Sentinel Site Program, groundwater is also monitored at the CBNERR-VA sentinel sites to monitor episodic and long-term patterns in groundwater parameters as well as to explore the relationship between groundwater, vegetation, and sediment level changes. CBNERRVA is also interested in better understanding how groundwater might migitate salinity intrusion from sea level rise and impact the spread of invasive species. Groundwater wells are located along six transects at three Reserve Components for a total of 28 wells (please see Table 1). Three transects are associated with Goodwin Islands, one transect is associated with Taskinas Creek, and two transects are associated with Sweet Hall Marsh. The number of wells varied at each site, but capture dominant elevation features (e.g., creek bank, levee, low marsh, high marsh) and dominant plant communities (low marsh and high marsh zones at each study site). Shallow (1 m depth) monitoring wells will be established constructed of 2.5 cm dia. PVC casing and 2 mm slotted screen and follow the basic design of USCOE (2000). Screens will be gravel packed and wells will be fully developed by surging water across the screen and pumping until clean. Continuous data is collected from each groundwater well on a quarterly basis to provide information on water level, temperature, and salinity using pressure transducers (either Solinst Leveloggers or InSitu Aquatrolls) to continuously measure water table dynamics, water temperature, and specific conductance at a 15 minute sampling rate. All wells and surface water datalogger platforms will be surveyed to a reference point and depth measurements from unvented sensors will be corrected for variations in barometric pressure.

Porewater Sippers

Meaurements of interstitial salinities within the upper root zone (5-20 cm) were determined using pore water samplers ("sippers") designed to allow for multiple sampling over time without disturbing marsh sediment (Montgomery et al. 1979). Sippers collect pore water through a 15 cm porous PVC window at a depth of 5 to 20 cm below the sediment surface. Water is collected using a syringe from the tubing and measured by a handheld YSI (YSI-85). Placement of sippers was co-located with placement of wells and were chosen to represent the dominant vegetation communities (and marsh zones) within the marsh .

Cesium Coring

In order to support upcoming Marsh Equilibrium Modeling (MEM) efforts at Goodwin Islands, marsh substrate cores (high and low marsh along GI Reference Site Transect 1) were collected and subjected to 137Cesium analysis to provide intermediate (post 1963) estimates of marsh accretion. Rates are in relative agreement with more current SET rate estimates. For the low marsh, 6.3 mm/yr for the SET and 4.3 mm/yr for 137Ce method. For the high marsh, 1.5 mm/yr for the SET and 2.5 mm/yr for 137Ce method. Both SET and 137Ce derived values are lower, as expected, from the feldspar markers values that are on the order of 6 mm/yr.

An additional 3 marsh substrate cores were collected from our Goodwin Islands component and subjected to 137Cesium analysis to provide intermediate (post 1963) estimates of marsh accretion. . Cores were collected from three sites at Goodwin Islands on March 27th, 2017 which included two along one existing vegetation transect (a Juncus roemerianus site and a high marsh mix (dominated by Spartina patens and Distichlis spicata) site) and one along a separate transect (taken in the low marsh, Spartina alterniflora zone). These cores were cut into sections (by band saw) on April 6th, 7th, and June 13th, dried and weighed, packaged into appropriate containers, and send to the cesium detector lab after a 30 day settling time. CBNERR-VA Staff are currently interpreting the results

Sediment Characteristics

In order to better characterize the sediment conditions at each SET, in the spring/summer of 2017, CBNERRVA began to collect a single meter-long sediment core (using in house methodology to minimize compaction) from each SET (currently 44 in total among four Reserve components). Physical and hydrophysical properties are being determined on surficial and deeper sediments to define sediment structure and water transmission characteristics. Measured sediment properties included (1) percent organic matter and (2) bulk density. Samples for bulk density and sediment organic matter (i.e loss of organics on ignition) and grain size. Sediment organic matter and bulk density were determined by combusting dried samples at 500 °C for 5 hrs, followed by reweighing (Dean 1974) and expressed as a percentage weight loss from combustion of the dried sample. Grain size was determined using an in=-house protocol developed by CBNERRVA staff (Eduardo Miles). CBNERRVA decided to begin this effort at our Goodwin Islands component and started with three cores collected at Goodwin Islands on June 1 (SETs 5-1, 5-2, and 5-3) and with four cores collected on June 22nd (SET 1-1, SET 1-2, SET 1-3, SET 4-2).

Pine-Tree Recruitment Data

CBNERR staff have examined the encroachment of emergent wetlands into forested systems through the establishment of two groundwater well transects with pine tree seedling plantings located in transitional habitats (running from the high marsh into the riparian forest) at the Goodwin Islands component of the Reserve. These transitional habitats provide one of the first visual impacts of Sea level rise on coastal habitats. Groundwater measurements and measurements of pine seedling survival have been collected multiple times along each transect over time (from 2010 to 2017).. Eight discrete sampling "runs", each approximately one month in duration, have occurred at transect 1 (established April 2010) and two "runs" have occurred at transect 2 (established April 2012). Monitoring wells and ground surfaces have been surveyed and elevations have been referenced to NAVD88 using digital leveling techniques from nearby benchmarks (first transect: February 2012; second transect: April 2012).

Marsh Equilibrium – Required Sampling Parameters.

Inputs listed below are essential parameters to running the MEM, while others are tuning parameters that are lower priority in calibrating the model (and may be derived from the literature). A model calibration step is listed in red at the end of this work plan. Additionally, Lisa Schile worked with CBNERRVA to use data from the Goodwin Islands site as a demonstration for calibrating and running the MEM during the second webinar under this transfer grant. Schile's initial efforts with the data will be useful in applying the most recent version of MEM. Will discuss additional data parameters for running MEM.

- Century Sea Level Rise
- Initial Rate of SLR
- Mean Sea Level (MSL) and Mean High Water (MHW) / Mean Higher High Water (MHHW)
- Suspended Sediment Concentration (SSC)
- Marsh Elevation at Time Zero
- Max and Min Elevation of Wetland Vegetation
- Peak Biomass and Elevation of Peak Biomass
- Sediment profiles of organic matter (OM) content and bulk density;
- Sediment accretion rates

Section H – Habitat Mapping Efforts

- Please See Appendices 2 and 3 for some information on Reserve Habitat Mapping Efforts.

Section I: Timeline of Major Sentinel Site Activities (Chronological).

1984 Water quality monitoring begins along a main channel transect of the York River (VIMS)
1986 Meteorological station is established at VIMS
1995 First SWMP station established at CBNERR-VA at Taskinas Creek Reserve
1997 Taskinas Creek meteorological station established
1997 SWMP water quality station established at Goodwin Islands
1998 Sweet Hall Marsh meteorological station established
1999 SWMP water quality station established at Sweet Hall Marsh
2002 SWMP water quality station established at Clay Bank
2003 SWMP water quality station established at White House
2003 SWMP water quality station established at Gloucester Point
2004 SAV fixed transects installed at Goodwin Islands
2006 Goodwin Islands meteorological station established
2007 Boardwalk Constructed for Sweet Hall Transect 1
2007 First SET Stations (SH SET 1-1, SH SET 1-2) established at Sweet Hall Marsh
2007 Emergent vegetation transects (Transect 1 to 4) established at Sweet Hall Marsh
2008 Boardwalk Constructed for Sweet Hall Transect 4
2008 First SET Stations (GI SET 1-1, GI SET 1-2) established at Goodwin Islands
2008 Emergent vegetation transects (Veg Transect 1 – Ref Site) established at Goodwin Islands

2008 Groundwater Well transect (GW Transect 1 – Ref Site) established at Goodwin Islands
2008 First cement benchmark established on Goodwin Islands (Cement North)
2008 Goodwin Islands Old SWMP Station Surveyed (using Auto Level)
2008 Goodwin and TC REF Site Wells and Vegetation Transects Surveyed (using Auto-Level).
2008 Boardwalk constructed at Taskinas Creek Reserve
2008 Groundwater Well Transect (GW Transect 1 – Ref Site) established at Taskinas Creek
2008 First benchmark (upland rod mark) established at Taskinas Creek (TC MET)
2008 First SET Stations (TC SET 1-1, TC SET 1-2) established at Taskinas Creek
2008 Emergent vegetation transects (Veg Transect 1 – Ref Site) established at Taskinas Creek
2008 Taskinas Creek SWMP Station (old Station) First Surveyed (using Auto Level)
2008 Additional SET Stations (SH SET 1-4 and 1-5) established at Sweet Hall Marsh
2008 Groundwater Well Transects (GW Transect 1 and 4) established at Sweet Hall Marsh
2009 Additional SET Station (GI 2-1) established on Goodwin Islands
2009 6 Additional SETs (SET 1-3, SET 4-1, 4-2, 4-3, 4-4, and 4-5) established at Sweet Hall Marsh
2009 Purchase Trimble GeoXH for Field Mapping Efforts.
2009 Purchase DNA03 Digital Leveling System
2009 Boardwalk constructed at Goodwin Islands (Reference Site Transect)
2009 Second cement benchmark established on Goodwin Islands (Cement WQ)
2009 Goodwin Islands and TC Ref Site GW Wells and Vegetation Surveys (using RTK)
2009 Second benchmark (upland rod benchmark) established at Taskinas Creek (TC Croaker)
2009 Third benchmark (cement benchmark) established at Taskinas Creek (TC Garden)
2009 Fourth benchmark (cement benchmark) established at Taskinas Creek (TC WQ).
2009 Taskinas Creek SWMP Station (Old and New Station) First Surveyed (using Digital Level)
2010 Goodwin Island SWMP Station (new) Surveyed (using Static GPS)
2010 Third benchmark (foundation mark) established at Goodwin Islands.
2010 Additional Groundwater Transects (Pine Tree 1 and 2) established at Goodwin Islands.
2010 Upland Pine Tree Regeneration Transects (Pine Tree 1 and 2) established at Goodwin Islands
2010 Additional GW Well (Forested) added to GW Transect 1 at Goodwin Islands.
2010 Vertical Control Network Work (Digital Leveling) at Goodwin Islands
2010 Goodwin Islands (Ref Site) Wells, VEG Survey Work (using digital leveling).
2010 Vertical Control Network Work (Digital Leveling) at Taskinas Creek
2010 Survey TC SETS (using Digital Level) along Taskinas Creek Transect 1
2010 Two benchmarks (upland ROD mark and foundation mark) established at Sweet Hall Marsh.
2010 Vertical Control Network Work (Digital Leveling) at Sweet Hall Marsh
2010 Sweet Hall Marsh Old SWMP Station Surveyed (using Digital Level)
2010 Sweet Hall vegetation survey (both Transects) (using digital leveling).
2010 Survey to Sweet Hall SETS (using Digital Level) along Transect 1 and Transect 4
2011 Purchase R8 GNSS RTK System for Survey (RTK) Work.
2011 Additional 7 SETs (GI SET Transect 3, 4, and 5-1, 5-2) established on Goodwin Islands
2011 First SET Stations (CI SET 1-1, CI 1-2, CI 2-1, CI 2-2) established at Catlett Islands
2011 Tide Gauge Installed at Sweet Hall Marsh (old Pier)
2011 Additional 2 SETS (SH SET 4-6 and SH SET 4-7) established at Sweet Hall Marsh
2011 Survey to Sweet Hall Transect 4 Groundwater Wells and Veg Plots (Digital Level)
2011 LIDAR Data Available for All Reserve Components
2012 Survey to Goodwin Islands Transect 1 SETS (Reference Site).
2012 Survey to GI Pine Tree Transect Wells and GI SETS
2012 Vertical Control Network Work (Digital Leveling) at Taskinas Creek
2012 TC Vertical Control Network Leveling Work

2012 Survey to Taskinas Creek SWMP Station (using Digital Level) from WQ Mark.
2012 Vertical Control Network Work (Digital Leveling) at Sweet Hall Marsh
2012 Sweet Hall Marsh New SWMP Station Surveyed (using Digital Level)
2012 Chesapeake Bay, including CBNERR-VA, established as Sentinel Site Cooperative
2012 Survey to Sweet Hall SETs (along Transect 1 and Transect 4)
2013 Manned Aerial Flight of Goodwin Islands in support of habitat mapping.
2013 Goodwin Islands Sediment Core Work (Erosional Edges) and Survey (using RTK).
2013 Goodwin Island SWMP Station (new) Surveyed from Cement WQ Mark (using Auto Level)
2013 Emergent vegetation transects (Veg Transects 1 and 2) established at Catlett Islands
2013 Sweet Hall Marsh Radar Gauge Surveyed (using Digital Level)
2013 Education lesson plan on sentinel site work developed for grades 9-12
2014 Replace all Groundwater Wells at Goodwin Islands (Ref. Site Transects, Pine Tree Transects)
2014 Survey to Goodwin Islands Groundwater Wells (All Transects) (using Auto Level)
2014 Survey GI Vegetation Transects and Additional Transects in Support of MEM, MARS (RTK)
2014 Collect GI Biomass Data (Support of MEM)
2014 Survey to TC SWMP Station (using Auto Level) from WQ Mark.
2014 Replace all Groundwater Wells at Taskinas Creek (Reference Site).
2014 Survey to Taskinas Creek Groundwater Wells (using Auto Level)
2015 Field Habitat Mapping (GeoXH) of Goodwin Islands in support of habitat mapping.
2016 Purchase Geo7X GPS Units with Rangefinders
2016 Additional 7 SETs (GI SET 1-3, 5-3, 5-4, 5-5, and SET Transect 6) established on Goodwin Islands
2016 Collect Goodwin Island Biomass Data (in support of MEM)
2016 Survey Goodwin Islands Groundwater Wells (All Transects)- Auto Level
2016 Survey (Auto-Level) to Goodwin Island new SETS (SETs 1-3, 5-3, 5-4, 5-5, 6-1, 6-2, and 6-3).
2016 Begin Collecting Cesium Cores at GI SET Stations (SET 1-2, 3-2)
2016 Habitat Mapping (GeoXH and Geo7x) of Catlett Islands in support of habitat mapping.
2016 AUV Flight (with NGS) of Catlett Islands in support of habitat mapping.
2016 Tide Gauge Re-installed on New Pier at Sweet Hall Marsh (and surveyed).
2016 Sweet Hall SWMP Station on New Pier at Sweet Hall Marsh (and surveyed).
2017 Additional Cesium Cores Collected at GI SET Stations (SET 1-1, 5-1, 5-2).
2017 Catlett Islands Vertical Control Work (Leveling in all SETS and Wells) from BM 21
2017 Vertical Control Network Work (AutoLeveling) at Goodwin Islands.
2017 Begin Collection of Sediment Cores (for Sediment Characteristics) at Goodwin Island SET Stations (includes SET 1-1, 1-2, 1-3, 2-1, 5-1, 5-2, and 5-3)
2017 Groundwater Wells (Transects 1, 2, 3, and 4) established at Catlett Islands
2017 Vertical Control Network Work (AutoLeveling) at Catlett Islands
2017 Three Upland Rod Benchmarks established at Catlett Islands (on Timberneck lands)
2017 Additional 10 SETs (CI SET 1-3, 1-4, Transect 3 and Transect 4) established on Catlett Islands
2017 Tide Gauge Installed and Leveled (using Auto Level) at Catlett Islands
2017 Vertical Control Network Work (Auto Leveling) at Taskinas Creek
2017 Survey to Taskinas Creek SWMP Station (using Auto Level) from WQ Mark.
2017 Tide Gauge Installed and Leveled (using Auto Level) at Taskinas Creek
2017 Rebuild Taskinas Boardwalk (Reference Site)
2017 AUV Flight (with NGS) of Sweet Hall Marsh in support of habitat mapping
2018 Purchase of eBee AUS System in support of habitat mapping efforts
2018 Re-Build Sweet Hall Boardwalks 1 and 4

Attachments to this Sentinel Site Plan

Table 3. Detailed information for each CBNERRVA Long-Term Monitoring Transect. Information included is Reserve component, Number of Plots, Whether or Not SETS and Groundwater Wells are Co-Located along Transect, Starting and Ending Coordinates, Parameters Measured, Survey Information, and Monitoring Frequency.

- Please see attached Microsoft Excel Spreadsheet entitled: **"Table 3 – CBNERR-VA Vegetation Transects.xlsx"**

Table 4: SET Metadata for CBNERRVA Sentinel Site Monitoring Efforts.

- Please see attached Microsoft Excel Spreadsheet entitled: **"Table 4 – CBNERR-VA SET Metadata.xlsx"**

Table 5 - Vertical Control Efforts Related to CBNERRVA Sentinel Site Monitoring.

- Please see attached Microsoft Excel Spreadsheet entitled: **"Table 5 - CBNERR-VA Vertical Control Metadata.xlsx"**

Table 6: CBNERR-VA WQ, WL, and MET MetaData.

- Please see attached Microsoft Excel Spreadsheet entitled: **"Table 6 - CBNERR-VA WQ, WL, and MET Metadata.xlsx."**

Appendix A – Maintenance Plan for CBNERRVA Sentinel Site Activities

- Please see attached Microsoft excel spreadsheet entitled "**Appendix A - Sentinel Site Plan Maintenace.xlsx**"

Appendix B: Abstract for Historical Shoreline and Forest Change Analysis at Goodwin Islands.

CBNERRVA wanted to take a historical examination of changes occurring at our Reserves. CBNERRVA staff are currently using some of the methods and procedures (including using DSAS) from the Shoreline Studies report (which only examined data from three years from Catlett Island – 1953, 1978, and 2007) to take a more comprehensive examination of historical shoreline and forest change at both the Goodwin Island and Catlett Island components. The Digital Shoreline Analysis System (DSAS) was developed by the USGS and is a computer software program that reside in ArcGIS and computes rate-of-change statistics from multiple historic shoreline positions. By extrapolating out using current rates of shoreline loss, we anticipate total loss of above ground habitat at Goodwin Islands in or around 2300 and around 2325 for Catlett Islands. Important due to services provided by these habitats – and can they be replaced? These shorelines were also used by NOAA Coastal Services Center for developing initial segments (through Ecognition) for the Reserve's Habitat Mapping and Land Use Change efforts.

Coastal ecosystems and their tributaries are among the most vulnerable environments from climate change induced sea-level rise (SLR). This is of particular concern in the Chesapeake Bay region where current SLR rates (~5 mm/yr) are elevated as compared to national and global averages. By digitizing shoreline and forest boundary conditions on shoreline survey maps (t-sheets) and aerial imagery from 1853-2015, multi-decadal changes in saltmarsh and maritime forest boundaries were analyzed for a Late Pleistocene island complex in the lower York River, Virginia. Marsh-shoreline perimeter and marsh-forest boundary rate changes were generated through the Digital Shoreline Analysis System (DSAS). Rate changes determined by marsh loss processes, including shoreline perimeter erosion, extension and enlargement of tidal creeks, and interior ponding were quantified and compared. Mean long-term shoreline perimeter erosion rates were 0.26 m/yr at Goodwin Islands with no significant trend over the 162 year analysis period. On an area basis, the overall contribution to marsh loss was much greater through perimeter erosion than observed for enlargement of tidal creeks or interior ponding. Shoreline perimeter erosion rates were most sensitive to wave power. Marsh-forest boundary transgression rates were relatively constant from the mid-1800s to the 1960-1970s, averaging 0.35 m/yr at Goodwin Island. Increasing forest-marsh boundary transgression rates, with the most recent mean multi-decadal values increasing to 1.40 m/yr, were observed post 1970s. Increased fragmentation of the primary maritime forest unit also began to occur post 1970s resulting in numerous small forested hummocks that exhibited elevated boundary transgression rates. Results indicate that marsh transgression rates into higher elevations previously occupied by maritime forest were greater and more sensitive to recent accelerations in local SLR, than marsh perimeter erosion. From a resource protection perspective, allowing for marsh transgression should be a high priority when appropriate in the development of shoreline management policy and project designs.

Appendix C: Chesapeake Bay NERR FY2017 Habitat Mapping Data Sharing Plan

(1) Types of environmental data and information to be created during the course of the project:

The Reserve will develop land cover/ land use maps.

(2) The type of collection method:

Land cover and land use maps:

CBNERR will use a combination of the best available imagery and remotely sensed data to create the land cover and land use maps. This may include VGIN (Virginia Geographic Information Network) VMBP (Virginia Base Mapping Program) imagery (true color and infrared) collected on a four year time scale (last effort was 2013, 2017 data being currently collected and processed for distribution). This imagery is delivered to counties at the 200 scale, 1 foot pixel resolution with optional upgrades at the 6 inch and 3 inch pixel resolution. CBNERRVA may also use the leaf-on, 1-meter true color imagery (ortho imagery) available through the National Agriculture Imagery Program which acquires aerial imagery during the agricultural growing seasons in the continental US. An additional and valuable will be LIDAR data which has been collected by VGIN, in cooperation with USGS, FEMA, NGA, NRCS and some localities. Most of these datasets meet USGS specifications for accuracy and quality, with vertical accuracies of 24.5 cm (0.82 ft) or better and each Reserve component has been covered (at least once) with the latest available datasets from 2011-2012. When available, CBNERRVA will also take advantage of special opportunities for imagery collection through partnerships with NOAA including a recent data collection using an eBee drone which provided 6 inch resolution data (collected in October of 2016) for our Catlett Islands component and 6 inch true color aerial imagery (georectified orthomosaic) collected through the a private vendor in 2016 (Flying H Aerial Pictures LLC).

(3) Tentative date by which data will be shared:

All land cover and land use maps and associated products will be submitted to NOAA for review by the Habitat Mapping and Change Technical Committee (HMCTC) according to the schedule proposed in the associated grant task (Operations award task 315-8; task end date: August 2018). Reserve staff will respond to the edits and submit a final map within 2 months of receiving the edits.

(4) Standards to be used for data/metadata format and content:

Land cover and land use map data format and content is described in the table below for two different land cover/land use mapping strategies. The Reserve intends to use high resolution strategies. Ground-truth surveys and accuracy assessments are conducted.

(5) Policies addressing data stewardship and preservation:

The NERRS System-wide Monitoring Program (SWMP) Data Management Committee (DMC) and the Habitat Mapping and Change Technical Committee (HMCTC) ensure Quality Assurance/Quality Control (QA/QC) compliance with the standards established by the Habitat Mapping and Change Plan. HMCTC provides approval that maps comply with established standards. Final data and products (maps) are housed at the Centralized Data Management Organization http://cdmo.baruch.sc.edu.

(6) Procedures for providing access to data and priori experience in publishing such data:

In collaboration with the University of South Carolina Research Foundation, CDMO is maintained in support of the NERRS Habitat Mapping and Change program. All data is made available via the CDMO online data information server (ODIS) http://cdmo.baruch.sc.edu. CDMO houses over 35 million NERRS data records dating back to 1995.

For more information, including a copy *of Mapping Land Use and Habitat Change in the NERRS: Standard Operating Procedures; Version 2 Amended September, 2012* contact nina.garfield@noaa.gov

	High Resolution/ Moderate Classification Accuracy	**High Resolution/ High Classification Accuracy**
Resolution	1-meter or 3-meter; (Reserves should refer to using highest resolution imagery available)	1-meter or 3-meter; (Reserves should refer to using highest resolution imagery available)
Scale	1:12,000 or 1:24,000	1:12,000 or 1:24,000, or higher (i.e. 1:5000)
Minimum mapping requirement	Inter-tidal, supra-tidal	Inter-tidal, supra-tidal
Data source	Varies depending on reserve; If using supervised semi-automated classification, RGB, and IR is required. LiDAR is helpful.	Varies depending on reserve; If using automated classification, RGB, and IR is required. LiDAR is helpful.
Data type	vector, polygon (shapefile)	vector, polygon (shapefile)
Data processing	Heads up digitizing or semi-automated process if possible (CSC will support)	Heads up digitizing or semi-automated process if possible (CSC will support)
Target minimum mapping unit	0.1 ha (0.25 ac)	0.1 ha (0.25 ac)
Classification	NERRS Hierarchical Classification System (class level)	NERRS Hierarchical Classification System (sub-class level)
Metadata	FGDC Compliant – produced by reserves	FGDC Compliant – produced by reserves
Projection	Transverse Mercator	Transverse Mercator
Collection Interval	Minimum of every 10 years	Minimum of every 10 years
Accuracy Assessment	Conducted at the Class Level of the NERR Classification scheme	Conducted at the Sub- Class Level of the NERR Classification scheme unless prohibitive based on resource availability.

Appendix D: Example of a York River Impact Assessment in Response to Hurricane Sandy.

York River submerged aquatic vegetation (SAV) beds and emergent wetlands (along with adjacent ecotones) located within CBNERR are representative of the southern Chesapeake Bay region and the broader mid-Atlantic coast of the U.S.. These estuarine habitats were highly exposed to the passage of Hurricane Sandy. York River SAV beds are vegetated with eelgrass (Zostera marina) and widgeon grass (Ruppia maritima) and the meso-polyhaline wetlands are dominated by Spartina alterniflora in the low marsh and S. patens and Distichlis spicata in the higher elevation salt meadow community.
CBNERR has monitored these habitats as part of the NERRS System-wide biological monitoring and Sentinel Site programs. While these habitat types are stressed by a number of factors, including elevated summer temperatures, nutrients and suspended sediments in the case of SAV, and elevated sea level rise rates and salt intrusion in the case of meso-polyhaline emergent wetlands and associated ecotones, the passage of Hurricane Sandy had the potential to further significantly impact these and other coastal natural resources. Reserves are responsible for the management of NOAA trust resources, as such, evaluating the impact of Hurricane Sandy on Reserve associated natural resources is a priority. Additionally, serving as coastal sentinel sites for quantifying anthropogenic and climate related impacts, evaluation of post-Sandy habitat response will allow us to evaluate how well systems under chronic stress are affected by episodic, large-scale storms which are expected to increase both in frequency and magnitude.

Example SAV Workplan

- *Winter 2012/2013*. Develop local physical characterization of Hurricane Sandy which would include angle of approach, storm tide and surge heights and duration, wave and current fields, impact on water quality (e.g., temperature, salinity, turbidity), photosynthetically active radiation (PAR), wind speed, and rainfall.
- *Spring 2013*. Quantify reproductive shoot density along existing long-term transects to assess possible impacts of Sandy on reproductive output.
- Spring 2013 – Fall 2013. Monthly monitoring of existing long-term NERRS vegetation monitoring transects to assess small-scale changes in SAV bed morphology, such as percent cover, shoot density, and canopy height compared to pre-Sandy conditions.
- Spring 2013 – Fall 2013. Monthly depth measurements along existing long-term transects to identify any changes in bed elevation due to sediment deposition and/or shifting sand bars related to Sandy effects.
- Spring 2013 – Fall 2013. Monthly seed bank cores along existing NERRS vegetation monitoring transects to evaluate any changes in density and viability of the eelgrass seed bank as a result of the storm.
- Summer 2013. Aerial mapping survey assessment using existing annual aerial photography to measure changes (changes from what? 2012?) in SAV abundance and distribution at both the bed and river-wide scale. This would be used to quantify open areas or patchiness in the beds and changes in sediment dynamics such as movement of submersed bars or sediment deposition

Example Emergent Wetlands (including marsh-forest ecotone) Workplan

- *Winter 2012/2013*. Develop local physical characterization of Hurricane Sandy which would include angle of approach, storm tide and surge heights and duration, wave and current fields, impact on water quality (e.g., temperature, salinity, turbidity), photosynthetically active radiation (PAR), wind speed, and rainfall.
- *Winter 2012/2013*. Develop storm inundation maps to assess flooding frequency, duration and areal extent within dominant and critical wetland and ecotone habitats.
- *Winter 2012/2013*. Measure changes in marsh surface elevation using SETs to assess sediment erosion and deposition by dominant and critical vegetative community types.
- *Winter 2012/2013*. Measure marsh substrate accretion or loss through cryogenic coring and measurement of pre-established marker horizons.
- *Winter 2012/2013*. Collect near surface cores adjacent to SETs to characterize storm deposited sediments.
- *Winter 2012/2013*. Collect aerial photography and compare shoreline boundaries to determine areal loss of wetlands and linear erosion rates and compare with historical imagery and rate of change analyses. Note: most recent aerial imagery is 2011 (for 2 Reserve Components)
- *Winter 2012/2013*. Measure distances from marsh erosion pins to shoreline edge at selected locations to verify aerial image analysis.
- *Winter 2012/2013*. Measure plant survivability and soil and water table salinity within ecotone *Pinus taeda* (Loblolly or southern yellow pine) transplant plots.
- *Winter 2012/2013*. Analyze continuous water table elevations and groundwater salinity measurements collected during Hurricane Sandy and compare to historical data for insight on potential impacts on subsurface processes.
- *Winter 2012/2013* – Fall 2013. Through aerial photography or GPS survey, map and determine distribution changes in invasive (*Phragmites australis*) species distribution.
- *Winter 2012/2013* – Fall 2013. Through aerial photography or GPS survey, determine areas of marsh wrack deposition and relate to changes in sediment elevation and vegetative community types and production over time.
- Fall 2013. Collect aerial photography and compare ecotone boundaries and rate of boundary changes with historical imagery and rate of change analyses. Note: most recent aerial imagery is 2011.