



NATIONAL  
ESTUARINE  
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RESERVE  
SYSTEM

# National Estuarine Research Reserve System

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# Sentinel Sites Program Guidance for Climate Change Impacts



A guidance document for determining effects of changing  
sea level/lake level and inundation on coastal habitats

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The National Estuarine Research Reserve System is a network of protected areas established for long-term research, education and stewardship. This partnership program between NOAA and the coastal states protects more than 1.3 million acres of estuarine land and water, which provides essential habitat for wildlife; offers educational opportunities for students, teachers and the public; and serves as living laboratories for scientists.

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**Mailing Address:**

Estuarine Reserves Division, N/ORM5  
Office of Ocean and Coastal Resource Management  
NOAA National Ocean Service  
1305 East West Highway  
Silver Spring, MD 20910

**Phone:** 301-713-3155

**Fax:** 301-713-4012

# National Estuarine Research Reserve System





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# NERRS Sentinel Sites for Understanding Climate Change Impacts on Estuaries



The impacts of a changing climate on coastal areas will be expressed across a diverse suite of ecosystem variables (e.g., changes in air, water and soil temperatures; water chemistry; the quantity, timing and intensity of precipitation; the intensity of storm events; and changes in sea level and water levels in the Great Lakes). This document describes a general approach for establishing a NERRS Sentinel Sites Program to understand climate change impacts, as well as the context of the NERRS Sentinel Sites Program in relationship to a larger NOAA Sentinel Site Program. The specific goal of this document is to provide guidance for the NERRS and NERRS partners

to establish Sentinel Sites for understanding the impacts of sea level/lake level change and inundation on coastal habitats. It also contributes to the NERRS System-wide Monitoring Program (SWMP) as a SWMP Application Module<sup>1</sup>. Although the initial focus of the NERRS Sentinel Sites Program will be on changes in marsh, mangrove, and submerged aquatic vegetation responses related to changes in sea level/lake level and inundation, we anticipate that in the future other documents would be developed to provide guidance for NERRS Sentinel Sites that are established to address the effects of other climate-related stressors on coastal habitat.

# Background and Relevance to Other NERRS Programs and Plans



In July 2008, the National Estuarine Research Reserve System (NERRS) released a strategy document entitled “*Climate Change: Science, Education and Stewardship for Tomorrow’s Estuaries*” (<http://nerrs.noaa.gov/DOC/PDF/Background/NERRSClimateChange.pdf>). This document described a framework for the reserve system to address the challenges of climate change, and outlined several potential impacts that were specifically relevant to the reserves (e.g., changes in sea level, shifts in salt marsh community structure and spatial extent, increased shoreline erosion, and deteriorating water quality). The document also stressed the need to accurately measure climate impacts in order to better inform decision-making by the coastal management community. Over the past few years, the concept for a NOAA/

NERRS Sentinel Sites Program (see below) has developed along several pathways, including as a foundational program for a NOAA Sentinel Sites Program1 (NOAA SSP), as part of the NERRS Strategic Planning Process, and through the individual efforts of several reserves who added infrastructure and built capacity for a NERRS Sentinel Sites Program (NERRS SSP). In January 2011, the NERRS launched a Climate Change Initiative, with the goal to better understand, mitigate, and adapt to climate change impacts on estuaries and coastal communities. The developing NERRS SSP became a fundamental component of this Initiative and will provide key contributions to our understanding of climate change impacts on reserve habitats and human communities.

## **NERRS SYSTEM-WIDE MONITORING PROGRAM:**

The NERRS SSP builds upon more than 15 years of monitoring that has been conducted through the NERRS System-wide Monitoring Program (SWMP; <http://nerrs.noaa.gov/RCDefault.aspx?ID=18>). The broad objective of the revised NERRS SWMP Plan<sup>2</sup> is to better understand the underlying processes and impacts of existing anthropogenic, natural, and climate change stressors on coastal habitats and human communities. The NERRS SSP will build upon SWMP by focusing data collection and measurements on specific climate related issues, and by leveraging resources and partnerships to provide the necessary support. The ultimate goal of the NERRS SSP is to help determine reserve vulnerabilities to climate change (initially, sea level/lake level change and inundation and habitat response), and to translate our understanding to coastal communities and coastal managers.

The NERRS SWMP Plan describes how SWMP “Application Modules” can be developed by assembling a suite of SWMP elements (i.e., NERRS monitoring activities with associated protocols, parameters, and budgets) to address specific management issues in a systematic way. This NERRS Sentinel Sites Guidance Document also functions as a SWMP Application Module for “NERRS Sentinel Sites Program for Sea Level Rise and Inundation Impacts” (Figure 1).

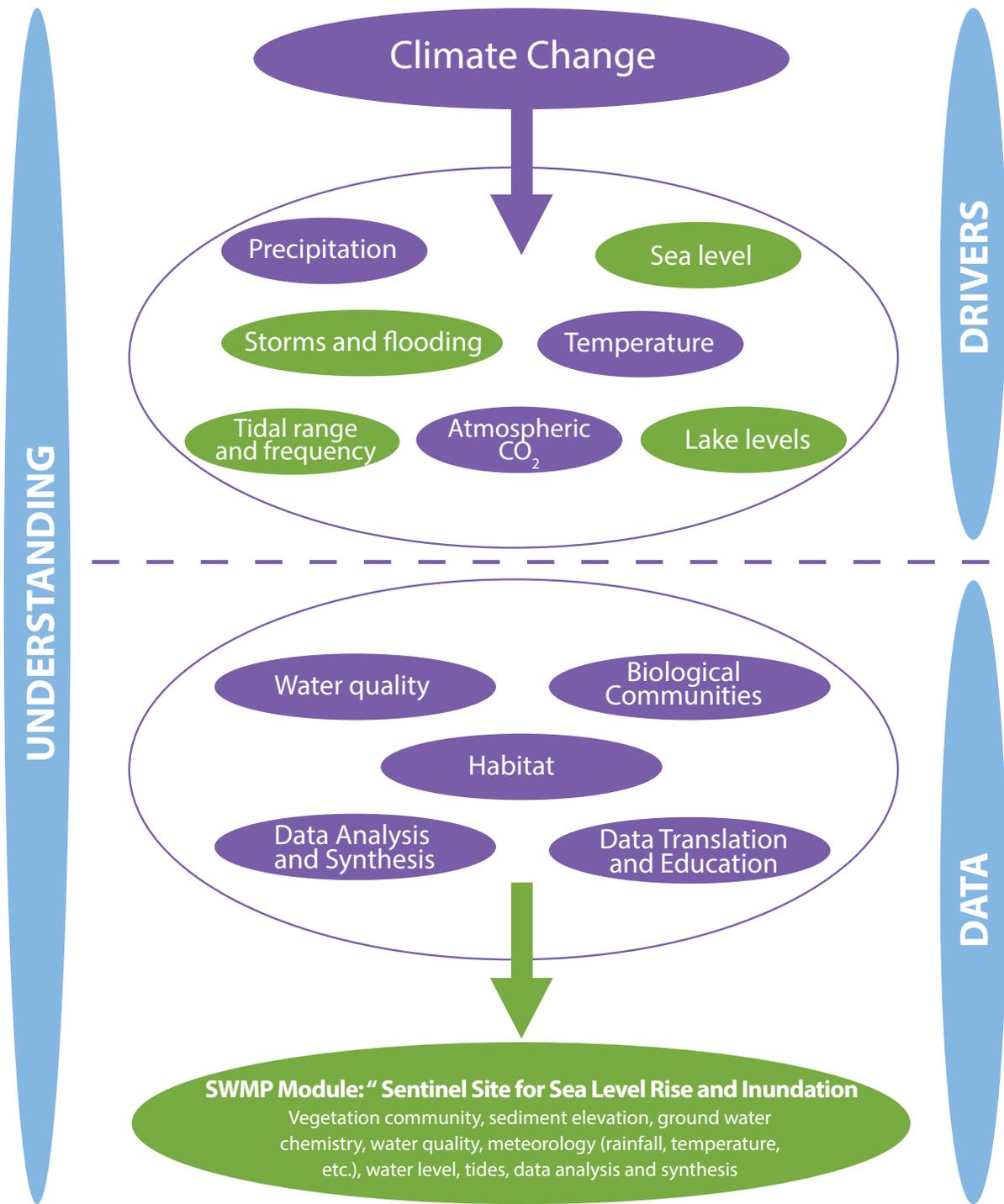
## **CONTEXT WITHIN THE NOAA SENTINEL SITES PROGRAM:**

The NOAA SSP established a collaborative framework for coordinating local and regional planning efforts with those of national programs at NOAA headquarters. The NOAA SSP encourages and facilitates integration of NOAA’s existing assets with those of its federal, state, and local partners. Like the NERRS SSP, the primary issue driving the NOAA SSP is changing climate, and initial implementation is focused

on understanding the effects of sea level change and coastal inundation in five “cooperatives” that have been identified based on their scientific relevance to addressing sea level change and coastal inundation, capacity for leveraging existing resources, partnerships, and assets, and potential to inform the larger issues and respond with management action. These pilot cooperatives are: Hawaii, the San Francisco Bay Area, the Chesapeake Bay, North Carolina, and the Northern Gulf of Mexico. Each cooperative includes at least one federally managed or funded coastal or marine protected area (e.g., a NERR or a National Marine Sanctuary) and a coastal commerce center. In each cooperative, the concept of Sentinel Sites will be implemented to maximize the benefit to coastal communities and economies.

The NOAA SSP provides a larger context and supporting framework for the information generated by the NERRS SSP. Because the NERRS are place-based, and have substantial current investment in infrastructure and data products that can inform national and regional coastal management issues, they are a foundational component of the larger NOAA SSP. However, the added value of the NERRS SSP is that it is focused on developing protocols and generating data products that can be compared across a network of reserves or reserve components. This ability to create a network of sentinel sites increases the capacity to address coastal management issues beyond the capacity provided by an unlinked group of separate sites. It establishes a framework that can stand alone to meet NERRS goals, while providing critical support to the larger NOAA effort. NERRS SSP definitions therefore differ from the NOAA SSP definitions, as illustrated in Table 1.

By these definitions, reserves (or individual components of a single reserve) that have installed the essential infrastructure and established programmatic support for monitoring and collecting the relevant information are operational as NERRS sentinel sites. A group of reserves (or



*Figure 1. Conceptual model of NERRS SWMP capacity to address a variety of climate change issues through the development of a SWMP Application Module. In the case illustrated here, a subset of climate drivers that are directly related to sea level change and inundation (in green) are investigated by a subset of SWMP elements and associated protocols (larger green box) to generate the necessary data to improve the understanding of these particular climate change impacts. Other climate change issues (e.g., drought or ocean acidification) could be addressed by different Application Modules that target another subset of drivers and relevant SWMP elements.*

a group of components of a single reserve) that are sentinel sites addressing the same management issue in a similar way make up a NERRS sentinel site network, or a component of a larger network. 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, reaching intended audiences, and making results relevant to coastal managers. It is important to recognize that various partners within and outside of NOAA, and other NERRS programs that support and utilize information transferred from NERRS sentinel sites or networks, are integral to the success of the NERRS SSP, and any or all NERRS SSP elements can provide fundamental support for the NOAA SSP.

Term	NOAA Sentinel Sites Program	NERRS Sentinel Sites Program
Sentinel station	Instruments and measurement stations (platforms and sensors) located within a geospatial framework, that provide information and data that can be synthesized to provide an understanding of the variables of interest.	NERRS instruments and measurement platforms (e.g., SWMP data loggers, telemetered weather stations, vegetation transects, SETs), located within a geospatial framework and providing information that can be synthesized to provide an understanding of the variables of interest.
Sentinel Site	Areas in coastal and marine environments that have the operational capacity for intensive study and sustained observations to detect and understand changes in the ecosystems they represent.	Reserves or components of a reserve that have the operational capacity for intensive study and sustained observations to detect and understand changes in the ecosystems they represent.
Sentinel Site Network		A group of linked NERRS Sentinel Sites whose integrated data and information streams provide a broader understanding of ecosystem conditions at temporal and spatial scales relevant to local, regional, or national science and management priorities.
Sentinel Site Program		Collective assets, efforts, and plans that support and guide individual NERRS Sentinel Sites or Sentinel Sites Networks in implementing place-based strategies, concentrating and leveraging resources, and engaging and supporting resilient coastal communities by informing management response and adaptation planning related to stressor impacts.
Sentinel Site Cooperative	Spatial extent for which the outputs, products, and services from all applicable Sentinel Sites are scientifically relevant and applicable to local management issues. Cooperatives bound not only the physical and biological data, but also the socioeconomic information necessary to deliver useful products to coastal communities.	

*Table 1. Comparison of Terminology used by NOAA Sentinel Sites Program and NERRS Sentinel Sites Program*

# NERRS Sentinel Sites Program for determining effects of changing sea level and inundation patterns on marine and freshwater coastal habitats

The initial focus of the NERRS SSP is on understanding changes in sea level/lake level and inundation and the associated responses of marsh, mangrove, and submerged aquatic vegetation. This focus could be expanded to include ecologically important transition zones that are characterized by scrub-shrub and coastal maritime forest. Carefully planned sampling designs and the use of standardized protocols are critically important for detecting changes and attributing them to related climate stressors, as well as characterizing the high natural variability in these coastal habitats. Standardized approaches are also critical for comparing data between sentinel sites in a larger sentinel site network. Audiences for the immediate products of the NERRS SSP (e.g., rates and extent of inundation, short-term changes in water levels due to storm events, changes in coastal vegetated communities) are reserve staff and their partners who need to understand the vulnerability of reserve resources to climate change impacts and who may assist reserves in developing sensitivity and vulnerability assessments and science-based strategies for adaptation. The data are also important for other resource managers and coastal

communities in the vicinity of the reserve to understand climate change vulnerability to support adaptation planning. The needs of both of these target audiences and a plan for translation and communication of the program outcomes should be incorporated into the planning process when a reserve initiates the establishment of a Sentinel Site.

The NERRS SSP vegetation sampling protocols<sup>3</sup> are uniquely designed to quantify horizontal rates of marsh migration and upland transgression, changes in species composition, and changes in the areal extent of SAV communities. Protocols associated with measuring marsh accretion and subsidence, and for establishing a geodetic frame of reference while simultaneously measuring water levels, provide the vertical component of the spatial reference system. Shifts in vegetation community are measured by sampling along transects that traverse the elevation gradient from the creek bank to the upland for marsh and mangrove communities, and from the shoreline bank to the deepest edge of the bed of SAV growth, as delineated when transects are initially established.

The NERRS SSP protocols are standardized and the different components are outlined below, so that information collected from each can be synthesized to address the issue of concern. While the current strength of the approach is found in the use of standardized protocols and sampling designs that provide a group of reserves with the ability to measure and compare the responses of vegetative communities to changes in water levels and patterns of inundation, the information collected at a NERRS Sentinel Site will also be valuable for answering other questions about environmental stressors that impact vegetative communities. The initial questions to be answered by the NERRS Sentinel Sites Program require fundamental data and information on the effects of changing local sea level and inundation patterns on the response of vegetative communities, although knowledge about other factors such as changes in precipitation, temperature, water chemistry, and invasive species is needed to segregate the impacts of changing land and water levels from other environmental influences. These questions are framed in the context of the responses of vegetated communities to factors that function on long and short time scales, and in the context of habitat responses to long-term changes in water levels and inundation.

To develop protocols for conducting these measurements, the appropriate temporal and spatial scales must be considered. The responses of coastal habitats to the separate and combined effects of episodic inundation (e.g., due to storm surge, inland flooding, shallow coastal flooding) and their interactions with longer term coastal inundation due to relative (local) sea level/lake level change are not well understood. For example, inundation from episodic storm or precipitation events can be measured on short time scales and at the local level, while data on longer-term coastal inundation driven by climatic stressors such as changes in the relative sea level is most useful when collected over long time periods and a regional scale, and requires numerical models and simulations to make predictions. While there are many other relevant questions that can be asked, progress on answering these questions can

be made with current resources that are available in the NERRS and its partners. An analysis of existing reserve infrastructure and capacity that can be applied to a NERRS SSP is currently underway and the current status of the NERRS reserves is attached to this document, and will be updated as appropriate.

### FRAMING QUESTIONS:

1. What are the current distributions of vegetation communities with respect to elevation and tidal range, and how sensitive are spatial distributions and community composition of marshes, mangroves and SAV beds to interannual variability, including that driven by discrete episodic inundation events, in local sea/lake level, tidal range, and inundation patterns?
2. What is the response, in terms of spatial distribution and community composition of marshes, mangroves and SAV beds, to long term changes in local water levels and inundation patterns (e.g., changes in mean water level, tidal amplitude, and storm frequency and intensity)?
3. What is the response of sediment elevation of marsh, mangrove and SAV habitats (with respect to changes in sediment deposition, accretion and/or subsidence) to discrete episodic inundation events as well as long term changes in local water levels and inundation patterns?

# NERRS Sentinel Site Methodology and Required Components



The initial focus of the NERRS Sentinel Sites Program is on monitoring and assessing the impacts of changing water levels and inundation on key coastal habitats. Specifically, the NERRS will link information from SWMP to a network of specialized infrastructure that will allow precise measurements of the impacts of changing coastal water levels on marshes, mangroves, and SAV.

To be an established and operational NERRS Sentinel Site Program, reserves must address the following (detailed protocols can be found in the supporting documents, and Figures 2 and 3 illustrate how different measures will be integrated):

- Development of a Sentinel Sites Program Plan: Working with NOAA staff and external partners, reserves must develop

a sentinel site implementation plan that describes how each of the following components of their Sentinel Sites Program will be implemented, and articulates a rationale for the location and sampling regime for sentinel site infrastructure. A Plan template (page 19) has been developed by the Sentinel Sites Workgroup with input from reserves, and all reserve Sentinel Sites Program Plans will be reviewed by the NERRS Sentinel Sites Workgroup. A timeline for implementation must also be included in the Plan, and the reserve's Biological Monitoring work plan should be used as a foundational document. Any deviations from the requirements described below must be justified in this plan. A plan with protocols that deviate from these

requirements must be approved first by the Sentinel Sites Workgroup and then by the Sentinel Sites Oversight Committee, which is composed of NERRS representatives who have expertise and experience with implementation of NERRS sentinel sites. The Oversight Committee is a sub-committee of the NERRS Data Management Committee (NERRS SWMP Plan 20112) and is responsible for ensuring compliance with reporting and data submission (see below).

- Identification of Appropriate Audiences and Management Issues. Reserve staff, in collaboration with local and national stakeholders, must develop an explicit written plan and rationale for the use of the information generated by sentinel site monitoring, and should clearly articulate the relevance to management issues both within the reserve and in adjacent coastal communities. The plan should also include how the reserve will communicate the data or related activities to resource managers and other stakeholders, how it will be used in education activities and other outreach programs, and how experiences and “lesson learned” will be communicated within the NERRS.
- Establishment of Programmatic Capacity. Reserve staff must be trained to collect and analyze sentinel site data and ancillary information. These requirements are in addition to existing training requirements for collecting SWMP data. The Sentinel Site plan for each reserve must identify resources for long-term continuous support (including staffing and funding) for sentinel site activities at the reserve. The Sentinel Site plan should be incorporated into the reserve management plan and the appropriate tasks should be included in reserve operations awards.
- Tidal Marsh, Mangrove, or SAV Monitoring: Monitoring the quantity and quality (through sampling vegetation transects) of vegetation must be conducted in accordance with SWMP biological monitoring protocols for emergent or submersed vegetation<sup>3</sup>, and the use of appropriate habitat maps and mapping protocols<sup>5, 6</sup>
- Wetland Surface Elevation Change Measurements: Measurement of initial elevation and elevation change (both deposition/accretion and subsidence/erosion) of wetland sediments will be accomplished by using Surface Elevation Tables (SETs) within the vicinity of permanent vegetation transects, so elevation changes can be correlated to changes in vegetation communities<sup>7</sup>.
- Vertical Reference System for Water Level Measurements: NOAA protocols and procedures for establishing high accuracy local geodetic control networks to connect SETs, SWMP stations, vegetation transects, ground water wells and digital elevation models on the same vertical datum must be followed. Working with NOAA’s National Geodetic Survey (NGS) and Center for Operational Products and Services (COOPS), reserves will establish a local network of benchmarks tied to both local tidal datums and the National Spatial Reference System (NSRS). All relevant SWMP monitoring locations, including vegetation monitoring transects, SETs and dataloggers must be surveyed in to this local network consistently through time to establish and accurately track the spatial relationships between the observed environmental parameters.<sup>8</sup>
- Ability to Detect Elevation Changes: Elevation surveys should be conducted every two to three years at permanent vegetation transects, or a Digital Elevation Model (DEM) with appropriate resolution in the area of interest should be produced and updated every three to five years.<sup>6</sup>

- Water Quality Data: Continuous monitoring of core SWMP parameters including pH, turbidity, dissolved oxygen, temperature, and salinity<sup>2</sup> at stations located adjacent to or within ecologically relevant proximity of sentinel site vegetation transects must be conducted.
- Meteorological Data: Continuous monitoring of core SWMP parameters including temperature, relative humidity, barometric pressure, wind speed and direction, rainfall, and photosynthetic active radiation<sup>2</sup> must be conducted at stations located adjacent to or within ecologically relevant proximity of sentinel site vegetation transects.
- Data synthesis and translation: Any data that are collected as part of the NERRS Sentinel Sites Program must be retained by each reserve and archived using agreed upon data procedures. All reserves that receive dedicated funding for NERRS Sentinel Sites must retain data and when directed, submit the data to Centralized Data Management Office (CDMO). An appropriate data template will be developed by the Sentinel Sites Working Group in consultation with staff at reserves that are operational NERRS Sentinel Sites. When this template is available, these data will be submitted to the (CDMO) for archiving according to procedures that are being piloted for Biological Monitoring data. Reserves will be required to track and maintain their local geodetic networks and associated elevations, and publish static GPS observations of the local control network to OPUS-DB. Reserves will develop periodic syntheses and data products to meet management needs and the needs of the users as identified in their Sentinel Sites Program Plan. The Sentinel Sites Working Group will be responsible for developing data translation and synthesis protocols and the Sentinel Sites Oversight

Committee will be responsible for monitoring reserve compliance.

Elective Protocols. Elective protocols may be implemented by a single or a subset of reserves as part of their Sentinel Sites Program, but are not required and currently will not be funded at the system-wide level. These protocols may address issues that are associated with specific management issues, and provide data or other ancillary information that complements the suite of required protocols and may contribute important information to address specific management issues. For example, measurements of ground water levels and pore-water salinity along vegetation transects are useful in predicting vegetation zonation changes, and water column suspended sediment concentrations are critical to understanding net accretion rates. By adding the same elective protocols, groups of reserves facing similar issues can coordinate their activities. The rationale for these activities should be identified in the reserve's Sentinel Site Program Plan. As reserve Sentinel Site Program Plans are developed, a library of elective elements and their associated protocols will be compiled and attached to this document.

# Developing an Implementation Plan for the NERRS Sentinel Sites Program



As stated above, reserves (or individual components of a single reserve) that have installed the essential infrastructure and established programmatic support for monitoring and collecting the relevant information are operational as NERRS Sentinel Sites, but to become a fully operational NERRS Sentinel Sites Program, a reserve must also develop strategies for synthesizing information, reaching intended audiences, and making results relevant to coastal managers. The NERRS Sentinel Sites Program has been initiated at a group of reserves by integrating existing components of SWMP such as vegetation monitoring and associated SETs with other capacity and infrastructure (e.g., a local geodetic network that is tied to tidal datums through the National Water Level Observation Network, and to the National Spatial Reference System).

Reserves that currently have a complete complement of NERRS Sentinel Sites required monitoring infrastructure components, as listed in Part V. of the following Program Plan Template, are operational sentinel sites. These reserves will be prioritized for initial augmentation to operational Sentinel Site Program status, as NERRS funding and resources become available. Additional monitoring capacity may also be obtained by any reserve through partnerships with other NOAA offices, through the broader NOAA Sentinel Sites

Program, and through partnerships with other federal and state agencies. Before receiving federal funding from NOAA ERD that explicitly supports the establishment of a NERRS Sentinel Site, the candidate reserve must have a Sentinel Sites Program Plan (SSP Plan) in place that has been reviewed by the NERRS Sentinel Sites Working Group. The SSP Plan should incorporate input from potential end-users to ensure that the data collected and the associated analyses can improve understanding and inform decisions affecting coastal watersheds and communities. Ideally, a reserve's SSP Plan should be developed prior to installing observational infrastructure and establishing geodetic control networks. However, many reserves are at different stages in the development of their sentinel site infrastructure and program planning, and therefore, these reserves will create their reserve SSP Plans retroactively.

A reserve can establish sentinel site monitoring infrastructure at a single or multiple components of the reserve, or at single or multiple locations within a component, but the reserve SSP Plan should include all sentinel site activities. The SSP Plan should articulate the relevance of the sentinel site data to reserve management needs, and should explicitly list the coastal management priorities addressed by the sentinel sites monitoring that is taking place. Another key component of the reserve's SSP Plan is "Communication and Outreach to Appropriate Audiences". To fully implement a NERRS SSP, it is critical that reserve SSP Plans consider key audiences and how these audiences or stakeholders might use the reserve's sentinel sites data. The reserve SSP Plan must identify a strategy for including target audiences in development, use, and dissemination of sentinel site data and/or derived products, and the potential utility of the information for local and national NERRS education and CTP programs.

## **NERRS SSP PLAN TEMPLATE:**

### **I. Introduction: (1/2 Page to 1 Page).**

- Describe the primary goals and objectives for sentinel site monitoring at the reserve, including the primary environmental stressors that provide a focus for the sentinel sites monitoring efforts, and the primary users of sentinel site monitoring data.
- Provide a brief list of prior sentinel sites monitoring at the reserve that support these activities, including foundational activities such as Biological Monitoring and Restoration.

### **II. Local Management Issues Addressed by SSP Plan: (1/2 to 1 Page) – with Links to Other Plans.**

- Identify local research and management issues addressed by the SSP Plan, including references to these issues in the reserve's Management Plan, where appropriate.
- Briefly describe the relevance to regional and national management issues.
- Describe the relevance of reserve sentinel sites activities to NOAA Sentinel Sites Cooperatives (if appropriate).

### **III. Communication and Outreach to Appropriate Audiences (1- 2 pages):**

- Working with other staff at the reserves (e.g., CTP, EC, and SC), identify the audiences (including NOAA and the NERRS) who will use the reserve's sentinel site monitoring data, and the rationale behind the inclusion of these audiences.
- Describe an approach for including these audiences in development and use of products, including a strategy for communicating outcomes, and the potential utility of the information for local and national NERRS education and CTP programs.

### **IV. Programmatic Capacity (1-2 Pages)**

- Identify existing staffing capacity to conduct and sustain sentinel sites monitoring.
- Describe any staff training that has been accomplished to support implementation of this SSP Plan at the reserve.
- Identify current and anticipated gaps and needs for staffing, training, and resources.
- Provide a plan and a timeline (see VII) for completing additional staff training, if needed.
- Identify potential funding sources, staff resources, and partnerships to support long-term implementation of sentinel site monitoring.

### **V. Sentinel Site Monitoring Infrastructure (5- 10 pages, not including map products).**

- Location of Infrastructure: Provide a map of reserve or reserve component boundaries that

identifies locations of vegetative communities that are the targets of this sentinel site monitoring and the location of transects, boardwalks, and other infrastructure (e.g., SETs, SWMP data-loggers, groundwater wells, nearby geodetic and tidal benchmarks, CORS).

(Note: If a habitat map has been produced per the NERRS SOP, preferably use the map as a backdrop for the infrastructure map described above. If a NERRS compliant map has not been produced, use a habitat map that is available of your reserve)

■ Tidal Marsh, Mangrove, and/or SAV Monitoring

- For each site within the reserve where vegetation monitoring will be done, describe:

- habitat type
- tidal range
- salinity range
- type and amount of freshwater input
- potential pollutants and other stressors

(Note: Relevant pages and sections of the reserve's Site Profile may be referenced here)

- Attach a research plan for vegetation monitoring that follows SWMP protocols for vegetation mapping, including methodology, experimental design, and sampling methods. (Note: a copy of the Biological Monitoring Work Plan from 2010 or 2011 funding can be attached, if relevant).

- Describe any habitat mapping and associated mapping protocols, and/or high resolution imagery that will be collected. If this information is contained in the reserve's Habitat Mapping and Change Plan, then the plan may be referenced here and attached.

■ Wetland Surface Elevation Change Measurements

- Indicate where SETs will be installed in relationship to the permanent vegetation transects and other infrastructure.

- Describe methodology and rationale for installation of SETs, including how SET data will be used to address research or monitoring questions, and at what frequency measurements will be taken.

- Describe any constraints or complicating factors that may interfere with SETs being read on an ongoing basis.

■ Vertical Reference System for Sentinel Site Infrastructure (Alternatively, a full vertical control network plan may be developed, approved by NGS, referenced here, and attached)

- Describe the local network of existing geodetic and tidal benchmarks, nearby water level stations, and Continually Operating Reference System (CORS) stations by indicating the type, Permanent Identification and Designation (where appropriate), and location of this infrastructure on the reserve and or a regional map. Identify on the map where additional infrastructure is desired.

- Include a timeline (see VII) and identify the responsible parties for completing and maintaining the local network, and for ensuring that the local network is tied into both

local tidal datums and the National Spatial Reference System (NSRS). If the reserve is in a National Water Level Observing Network (NWLON) gap, then describe the procedures that will be put in place and any equipment that will be installed to estimate relative sea level and water level trends over time.

- Describe a timeline (see VII) and identify responsible parties for ensuring that NOAA guidelines and procedures for establishing high accuracy local geodetic control networks are followed to connect SETs, SWMP stations, vegetation transects, ground water wells, and digital elevation models on the same vertical datum.
- Identify the elevation products generated by the vertical control network and the temporal and spatial resolution of the data generated from the network needed to produce the products. Describe how these products address the Plan's goals and stakeholder needs.
- **Water Quality and Meteorological Data:**
  - Describe core SWMP water quality and weather data monitoring that will be conducted at stations adjacent to or in ecologically relevant proximity of sentinel site vegetation transects.
  - Describe any other water quality or weather data that will be collected in the vicinity of sentinel site vegetation transects.
- **Elective (Optional) Parameters and Protocols:**
  - Describe any ancillary monitoring data or other information that will be collected to address issues specific management concerns, the rationale for collecting these data, and their applicability to similar issues faced by other reserves (if appropriate).
  - Provide references for standardized protocols that will be followed to collect the information.

## **VI. Data Archiving, Synthesis and Translation (one page)**

- Describe how sentinel sites monitoring data will be retained and archived at the reserve.
- Include a timeline (see VII) and identify the responsible parties for:
  - submitting the data to the NERRS Centralized Data Management Office (CDMO) for archiving;
  - tracking and maintaining data associated with local geodetic networks and associated elevations, and publishing static GPS observations to OPUS-DB, and
  - developing periodic data syntheses and other products that meet management needs, and evaluating their utility among end- users, as identified in Section III.

**VII. Timeline (1 -2 pages):** Include a timeline of the major milestones for sentinel site project implementation, including training, installation of infrastructure, and data collection, synthesis, translation, development of products, and communication of outcomes and products to appropriate audiences.

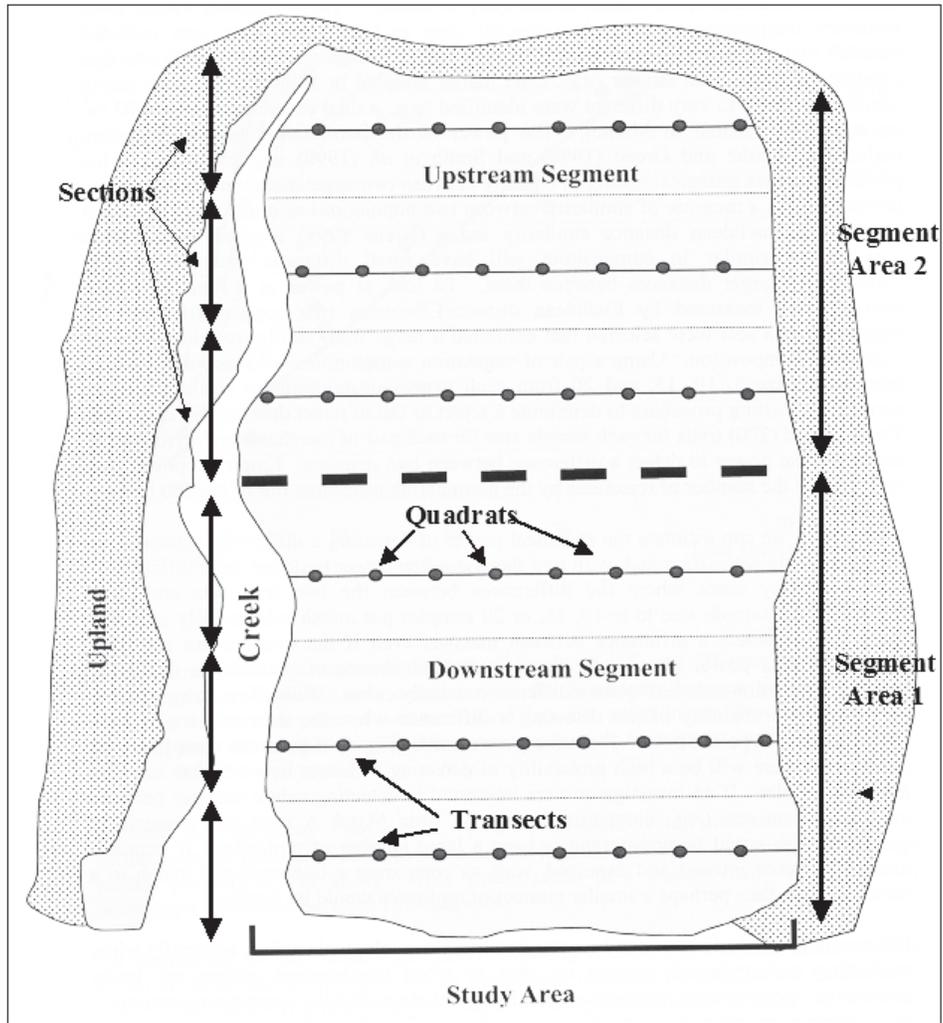
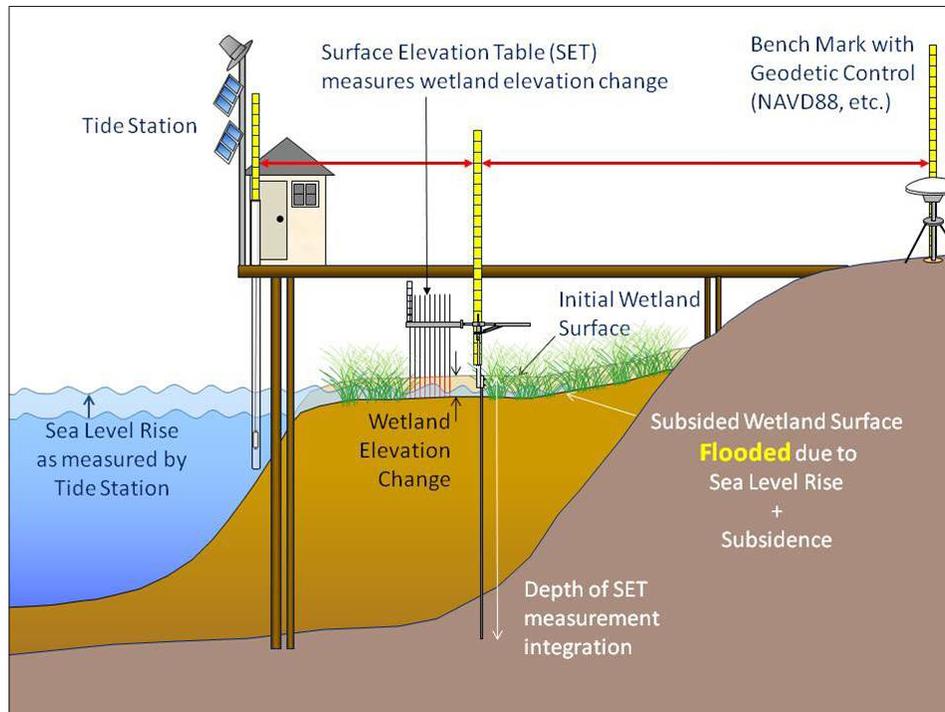


Figure 2: Emergent Marsh Sampling Design (from Moore 2009)



*Figure 3. An example of a Sentinel Sites Geospatial Infrastructure Conceptual Model designed to study impacts of increasing water levels. This geospatial infrastructure will be tied to vegetation transects.*

## SUPPORTING DOCUMENTS

1. NOAA Sentinel Site Program Report: [www.nerrs.noaa.gov/Doc/PDF/Research/NOAA\\_SSP\\_PPISubmission.pdf](http://www.nerrs.noaa.gov/Doc/PDF/Research/NOAA_SSP_PPISubmission.pdf)
2. National Estuarine Research Reserve System System-wide Monitoring Program Plan (2011). NERRS SWMP Guidance Committee. <http://www.nerrs.noaa.gov/Doc/PDF/Research/2011SWMPPlan.pdf>
3. Moore, K.R. (2009) NERRS SWMP Bio-Monitoring Protocol: Long-term Monitoring of Estuarine Submersed and Emergent Vegetation Communities. NERRS Technical Report. <http://www.nerrs.noaa.gov/Doc/PDF/Research/TechReportSWMPBio-MonitoringProtocol.pdf>
4. NERRS Sentinel Sites Program Plan Template (see page 14 of this document)
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