South Slough NERR
Sentinel Site Application Module 1 Plan

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I. Introduction

This document outlines a detailed plan for the South Slough National Estuarine Research Reserve (SSNERR) to establish a Sentinel Site Application Module 1 (SSAM-1) monitoring program for understanding climate change impacts on estuaries, following the protocols of the National Estuarine Research Reserve System (NERRS) Sentinel Sites Program Guidance for Climate Change Impacts (NERRS 2012). Hidden Creek marsh is SSNERR's "primary" SSAM-1 location. Hidden Creek's size (the largest study marsh in the estuary at 43,000 m^2), location (mesohaline region), accessibility, environmental condition, and geomorphology (unmodified pocket marsh) contributed to its selection as the Reserve's primary sentinel site. Biomonitoring at Hidden Creek marsh follows NERRS protocols of perpendicular marsh vegetation transects as outlined in Moore (2011). Many of the tidal marshes in the Reserve are small, fringing marshes or modified pocket marshes, some occurring behind failed dikes (Rumrill 2006), which present challenges for both comparing sites (e.g., modified vs unmodified) and following NERRS vegetation protocols (large enough marshes to set up required perpendicular transects). SSNERR has been establishing 13 additional "secondary" sites at least-disturbed wetlands along the estuarine gradient of the South Slough. Infrastructure at these secondary sites is identical to the primary site with the exception that their vegetation (tidal marsh, eelgrass, or Sitka spruce tidal swamp) transects are parallel to the channel (see "Biomonitoring" under *V. Sentinel Site Infrastructure* for more).

<u>Goals and Objectives</u>

The goal of the SSNERR SSAM-1 program is to provide a foundation to assess impacts of changing climate conditions (e.g., changes in sea level, tidal inundation, erosion rates, and storm surges), to emergent marsh habitat and provide a basis for comparing changes to coastal habitats locally, regionally, and across the NERRS. Our objectives are to: 1) Establish a permanent monitoring network (vegetation, sediment, elevation, water level, soil salinity, and groundwater) along the salinity gradient and tied to vertical control; 2) Quantify change in vegetation patterns and sediment dynamics across spatial gradients and over different timescales; 3) Determine relationships between vegetation patterns and environmental factors; 4) Communicate our findings to coastal communities and decision-makers to help inform adaptation planning, potentially including a sea level rise vulnerability assessment; and 5) Demonstrate marsh monitoring techniques to educators and students.

<u>Environmental Stressors</u>

Wetlands in the Coos estuary (inclusive of South Slough) have been highly modified historically and often permanently converted for human uses (e.g., diked and drained); however, surviving wetlands host diverse and relatively stable plant communities (Cornu and Souder 2015). However, in the face of changing climate conditions (e.g., increased frequency and severity of winter storm events and dryer summers), tidal wetland habitats will be responding to new stressors such as increased tidal inundation periods, sediment accumulation or erosion, evapotranspiration, storm water inundation, and erosion from increased wave energy (Scavia et al. 2002; USGS n.d.). For example, native eelgrass (*Zostera marina*) beds that are relatively exposed in the South Slough may be jeopardized as more frequent and intense storms cause larger storm-generated waves to propagate through the lower estuary (Cornu et al. 2012).

Our local NOAA National Water Level Observation Network (NWLON) tide station in Charleston (Station ID 9432780) has documented an average rate of sea level rise (SLR) of 1.05 $\pm$ 0.80 mm per year averaged over the past 47 years (1970-2017); however, the rate of SLR is expected to accelerate over time

(NOAA Tides and Currents 2013). For example, the National Research Council (NRC) (2012) predicted a worst case scenario of sea levels increasing up to 23 cm by 2030; 48 cm by 2050; and 143 cm by 2100 for the area to the north of California's Cape Mendocino (the study's closest site to the Coos estuary). SLR may be intensified by cyclical long term climatic patterns such as El Niño Southern Oscillation. Barnard et al. (2011) note that El Niño events may increase regional sea level by as much as 30 cm for several months at a time. Historically, these events have been associated with increased coastal erosion and flooding and are likely to periodically intensify the effects of SLR in the future (Dalton et al. 2013).

Cornu and Souder (2015) suggest substantial change may occur to tidal wetlands on southern Oregon's coast due to moderate and extreme sea level rise scenarios. For example, research from US Geological Survey (USGS) predicts that high, mid, and low marsh emergent plant communities on nearby Bull Island in the Coos estuary could convert entirely to a low marsh plant community under moderate SLR scenarios (+ 63 cm), and convert entirely to unvegetated mudflat under extreme SLR scenarios (+ 142 cm) (Thorne et al. 2015).

Primary End-Users

End-users of SSAM-1 data will include SSNERR and other NERRs, coastal natural resource managers, city and county planners, and researchers at other government (including both local tribes), academic and nonprofit institutions. Information from SSAM-1 data could inform the following planning processes: a sea level rise vulnerability assessment for the Coos estuary; revision of the outdated Coos Bay Estuary Management Plan; and a community visioning process. Other applications have included estuary ecology classes at Oregon State University and University of Oregon, various blue carbon-related research (by USGS, Institute for Applied Ecology, and the Commission for Environmental Cooperation), comparison with SeagrassNet sites (a global seagrass monitoring network), and Master Naturalist classes. Future applications could include habitat restoration by Coos Watershed Association, hydrodynamic modeling work by Oregon State University and University of Oregon, and comparison with marsh habitats studied by USGS.

Prior Monitoring Activities

SSNERR has been operating System-Wide Monitoring Program (SWMP) water quality stations since 1995 and a meteorological station since 2001. Habitat mapping using the NERRS classification scheme for the South Slough estuary was begun in 2011 and is in the process of being upgraded with 2016 imagery, accuracy assessed, and finalized.

II. Local Management Issues Addressed by SSP Plan

Local Management Issues

SSNERR used a collaborative process to engage coastal decision makers, regional educators, and natural resource managers during the development of the Reserve's 2016-2021 Management Plan to identify three priority management areas: climate change, habitat protection, and invasive species – each of which can be informed by the SSAM-1 monitoring program. The Oregon coast is vulnerable to many climate related changes, including sea level rise. Tidal marshes and eelgrass beds that are constrained on the landward side (e.g., due to dikes or steep terrain) will be unable to migrate in response to rising sea levels. These habitats will be squeezed until they potentially "drown", with ecological and economic repercussions (e.g., nursery habitat that supports local fisheries). In the Coos estuary, rises in sea level may influence habitat and species distributions as well as infrastructure related to the local economy, coastal accessibility, and human safety. For example, as much of 70-95% of the historical extent of tidally-influenced wetlands in the project area has been converted to terrestrial-based land uses (e.g., urban development and agriculture) by the historic construction of levees, tide gates, and other structures that control water flow (CoosWA 2006; Hofnagle et al. 1976). The effects of rising sea levels, including increased erosion rates and inundation periods, will be exacerbated by storm-driven high tides, which are predicted to increase in frequency in Oregon (OCCRI 2010).

The South Slough Site Profile (Rumrill 2006) identifies invasive species as one of the largest threats to the biodiversity and ecological integrity of the estuary. Over 60 non-native aquatic species and nearly 40 invasive terrestrial species are established in the Coos estuary and lower watershed (Cornu and Souder 2015). Invasive species cause damage to both the economy (e.g. tree mortality from Port Orford cedar root-rot) and natural systems (e.g. displacement of native wetland plant communities with reed canary grass). The presence of many species will be captured and quantified by the biomonitoring efforts detailed below.

<u>Regional and National Management Issues</u>

The SSNERR is primed to contribute to greater understanding of climate change, habitat protection, and invasive species through regional and national networks. As the only Sentinel Site in Oregon and one of two sites in the Pacific Northwest that is studying emergent marsh habitat, SSNERR's Sentinel Site will provide critical information for understanding the effects of changing climate conditions on coastal wetlands in the region. For example, Oregon's Coastal Management Program (OCMP) has identified sea level rise as a major risk to estuaries. Likewise, SSNERR and regional partners (e.g., Padilla Bay NERR; Oregon State University; Pacific Northwest National Laboratory) recognize the increasing importance of managing carbon sequestration rates in wetland soils and are interested in determining the resilience of coastal wetlands to increases in sea level – both of which can be informed by SSNERR's Sentinel Site data. As part of the NERRS, SSNERR shares SSAM-1 protocols and data products that can be compared nationally (NERRS 2012).

<u>NOAA Sentinel Site Cooperative</u>

SSNERR is not a member of NOAA's Sentinel Site Cooperative, but is open to becoming part of a cooperative in the future as that program expands.

III. Communication and Outreach to Appropriate Audiences

<u>Audiences</u>

SSNERR staff have identified the following audiences for SSAM-1 dissemination: local and regional teachers and students, wetlands and estuarine ecologists (e.g., USGS, Oregon State University, Oregon Climate Change Research Institute, Institute for Natural Resources, Institute for Applied Ecology), local decision makers and planners (e.g., cities and counties), local and regional coastal managers (e.g., Coquille Indian Tribe, Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians, Bureau of Land Management, Oregon Department of Fish and Wildlife), community and business groups (e.g., Connect the Boardwalks), and other NERRs. These audiences have either already expressed interest in the products and opportunities the SSAM-1 program provides, or have been identified in the SSNERR 2016-2021 Management Plan.

<u>Communication and Outreach Approach</u>

Working with Science staff, the Education and Outreach staff are installing a demonstration sentinel station at Hidden Creek marsh, including a SET sampling station, vegetation transects, and feldspar marker horizon plots, in order to reduce disturbance to the official sentinel station in the same marsh. The SSNERR Education Coordinator plans to introduce the SSAM-1 model to middle and high school teachers through Teachers on the Estuary (TOTE) workshops and other K-12 Estuarine Education Program (KEEP) activities. Teachers will participate in SSAM-1 monitoring data collection and be trained on how to use SSAM-1 and SWMP data with their students. Teachers and students will be able to collect their own data using SSAM-1 protocols at the demonstration site.

The SSNERR 2016-2021 Management Plan includes an objective to incorporate climate change research into informal education activities. Hidden Creek marsh is visible from our most used hiking trail as well as our water trail. Informal education about SSAM-1 will include interpretation on SSNERR-led hikes and paddle trips. Dependent on funding, a new interpretive sign will also be created and installed on the platform trail overlooking Hidden Creek marsh. Education and outreach staff will create a one page information sheet geared toward a public audience that highlights the SSAM-1 objectives and outcomes, which will be made available to general public at the Interpretive Center, to students and teachers, and to interested individuals during festivals and group presentations. In addition, the education and research staff will create PowerPoint slides and Storymaps about SSAM-1 that can be included in staff presentations about SSNERR and added to online educational portals. Outreach staff will occasionally highlight stories related to SSAM-1 in the South Slough newsletter.

The Coastal Training Program (CTP) provides needs-based training and information for coastal managers and decision makers in the lower Columbia biogeographic region, with emphasis on issues of concern for Coos and Curry counties and the Coos Bay metropolitan area. An assessment of training needs of community organizations conducted in 2016 identified a number of concerns for the Coos estuary that could be addressed with reference to sentinel sites and climate change. These include sea level rise and the fate of wetlands; reduced fresh water supplies and degraded water quality; impacts of severe weather, coastal hazards and resiliency planning; vegetation changes and invasive species; and public health and safety. In addition, training would be helpful for specialized audiences (e.g., habitat restoration practitioners, computer mapping specialists, watershed councils and associations) to increase their understanding of sentinel site monitoring data collection methods.

Initial training will be geared towards methodology and uses while later trainings can be modified based on early monitoring results. The Reserve anticipates that over the long term there will be opportunities to collaborate with other west coast research reserves to expand the network of sentinel site monitoring stations to key locations along the entire coast. To this end the CTP will from time to time re-evaluate this strategy and adapt training and outreach as necessary to meet the changing needs of coastal managers.

SSNERR Education, Outreach, and CTP staff will participate in SSAM-1 infrastructure installation, maintenance, and data collection activities, as time permits, to maintain their knowledge of the project and better inform their programs and activities. As data are synthesized, Science staff will work with Education, Outreach, and CTP staff to translate it into stories that can be used to communicate results with end audiences.

IV. Programmatic Capacity

Staffing Capacity and Training

The Watershed Monitoring Coordinator (WMC) is responsible for coordinating the planning and implementation of the Sentinel Site Program. The WMC and the Estuarine Monitoring Coordinator (EMC) are the staff primarily responsible for carrying out SSAM-1 related tasks with the following breakdown: WMC is responsible for marsh, spruce swamp, sediment, groundwater, and soil salinity monitoring and establishment of the vertical control network; EMC is responsible for eelgrass monitoring, tidal station (with technical support and recommendations provided by the Center for Operational Oceanographic Products and Services (CO-OPS) and Aquatrak instrument manufacturer), SWMP stations (including tying to vertical control), and submitting all SSAM-1 data to the CDMO; both WMC and EMC complete outreach, education and data synthesis tasks. Communication tasks are supported by education, outreach, and coastal training staff. SSNERR has three trained science staff dedicated to implementing SSAM-1 monitoring. All three staff have been trained by NOAA in the use of Static and Real-Time Kinematic (RTK) GPS survey equipment and its use in establishing vertical control. The WMC attended training in 2016 and 2017; the other two were trained in April 2008 and will seek to update their training in upcoming years. Several staff have been trained on biomonitoring protocols, groundwater wells, and sediment dynamics techniques by NOAA and NERRS staff. Two staff receive annual NERRS SWMP Technician Training through the Centralized Data Management Office (CDMO).

Current and Anticipated Needs, and Potential Funding

Due to the ambitious monitoring plan at multiple sites, a continuous need for seasonal monitoring staff is expected. Currently, staffing capacity is supported during the monitoring-intensive summer months by paid interns through Friends of South Slough. In addition, SSNERR takes advantage of opportunities with other intern programs (e.g., NOAA's Hollings Scholar program; NOAA's Center for Coastal Ocean Science college-supported internship program, Oregon's SeaGrant Summer Scholar program). Other anticipated needs are regular RTK trainings (to ensure staff are current on equipment use and concepts), and OPUS Projects trainings. Eventually, training on analyzing monitoring data, including processing water level data to derive local tidal datums and statistical analyses for vegetation and sediment datasets (e.g., using R) will be necessary. Anticipated resource needs involve sustaining and building out infrastructure (e.g., R-SETs, groundwater wells, feldspar marker horizons, etc.,), and replacing equipment (e.g., regular replacement of groundwater well depth and salinity loggers). We will need to find funding to maintain the tide gauge station (e.g., Aquatrak head and calibration tubes have a maximum two-year replacement interval). We will need resources to contract leveling survey work outlined below in the Vertical Control plan, as leveling is currently beyond the capacity of staff. We would also like to find additional Trimble antennas to use, in order to do concurrent static surveys at vertical control stations.

Monitoring site prioritization

With our large number of monitoring sites, we have prioritized our build-out effort in the following order:

1. Hidden Creek marsh (primary sentinel station)
2. Mainland marsh sites (Metcalf marsh, Valino Island marsh, Hidden Creek marsh (secondary station) Danger Point marsh, Fredrickson marsh, Winchester marsh)
3. Island marsh sites (Metcalf Islands, Valino Island Island)
4. Eelgrass sites
5. Sitka spruce swamp

This order considers which sites can best answer each of our research questions (see sidebar next page). Each marsh and spruce swamp site will be sampled on a three-year rotation schedule depending on the research question it is a part of (see Table 1 for schedule). For example, staff are interested in understanding changes to marsh communities relative to changes to estuarine gradient, so six secondary sites (Metcalf Marsh, Valino Marsh, Hidden Creek Marsh, Danger Point Marsh, Fredrickson South Marsh, and Winchester Marsh) are all sampled in the same years to help answer that question. Similarly, staff want to understand how island marshes will change differently relative to nearby mainland marshes. Therefore, Metcalf Marsh, Metcalf Islands, Valino Island Marsh, and Valino Island-Island Marsh are sampled the same years. Differences in results using the perpendicular vs. parallel transect orientation are also of interest, so the primary Hidden Creek transects are sampled the same years as the secondary transects. The staggering of timing the sampling different sites across different years is to allow limited staffing capacity to collect all necessary data to answer these questions. Eelgrass sites will be sampled every year because monitoring is less intensive while changes to the eelgrass community can happen more suddenly.

SSNERR Sentinel Site Research Questions

- How will tidal marshes respond* differently along the estuarine gradient to changes in sea level?
- How will marsh islands respond differently from mainland (pocket or fringing marsh) marshes?
- Does the orientation of the vegetation transect matter when analyzing changes to marsh plant communities over time?
- Do high marsh plant communities respond differently than low marsh plant communities to changing climate conditions?
- Will eelgrass beds respond sooner than marsh habitats to climate-related issues?
- Do eelgrass beds respond differently along the estuarine gradient?
- How will spruce swamp tidal forests respond to changes to climate?

** Responses include changes to vegetation community, sediment dynamics, elevation, water table regime, and soil salinity.*

V. Sentinel Site Monitoring Infrastructure

i. Location of Infrastructure

As mentioned in the introduction, Hidden Creek marsh is the location of SSNERR's primary station. Hidden Creek marsh and seven other marshes, along with four eelgrass beds and one forested swamp comprise the secondary stations. Infrastructure for all stations is described below. Table 2 summarizes current and final build-out monitoring elements at all sites. Figure 1 provides a detailed map of Hidden Creek marsh primary biomonitoring plots, R-SETs, sediment rebar stations, feldspar marker horizon plots, groundwater wells, benchmarks, and anticipated dedicated tide gauge. Figure 2 provides the same detail of infrastructure for the secondary sentinel stations. Figure 3 shows the locations of SSNERR's boundaries, SWMP water quality stations, established and proposed vertical control marks (including R-SET stations), and NOAA's NWLON station.

Table 1: *Vegetation, sediment dynamics, and groundwater infrastructure installation and baseline sampling dates, along with planned sampling intervals. Sites are ordered north (most marine) to south (fresh). Infrastructure code abbreviations: PT = Perpendicular Transect; T = Vegetation Transect; RSET = R-SET; R = Rebar Station; F = Feldspar Marker Horizon; G = mudflat accretion grid; GW = groundwater wells; * = Not yet installed*

Site	Installation	Baseline Sampling	2016	2017	2018	2019	2020	2021	2022	2023	2024
Metcalf Marsh	2010 (T, RSET); 2011 (R, F); 2016 (GW)	2010, 2015 (T); 2011 (RSET, R); 2016 (F)	X	X		X	X		X	X	
Metcalf Islands Marsh	2010 (T, RSET); 2011 (R, F)	2010 (T); 2011 (RSET, R); 2017 (F)		X			X			X	
Collver Point Eelgrass	2010 (T); *(G, R)	2010 (T)	X	X	X	X	X	X	X	X	X
Valino Island Marsh	2010 (T, RSET); 2011 (R, F); 2017 (GW)	2010 (T); 2011 (RSET, R); 2016 (F)	X	X		X	X		X	X	
Valino Island Eelgrass	2004 (T); 2011 (R)	2007-2015 (T); 2011 (R)	X	X	X	X	X	X	X	X	X
Valino Island-Island Marsh	2010 (T, RSET); 2011 (R, F)	2010 (T); 2011 (RSET, R); 2017 (F)		X			X			X	
Hidden Creek Marsh	1994 (F, G); 2010 (T, RSET, GW); 2011 (R, F); 2015 (PT, GW); 2016 (GW); 2017 (RSET)	2010 (T); 2011 (RSET, R); 2015 (T, F, G, RSET, R); 2016 (PT, G GW)	X			X			X		
Hidden Creek Eelgrass	2010 (T); 2011 (R); *(G)	2010 (T); 2011 (R)	X	X	X	X	X	X	X	X	X
Danger Point Marsh	2004 (GW); 2010 (T, RSET); 2011 (R, F); 2016 (T)	2005 (GW); 2010 (T); 2011 (RSET, R, GW); 2016 (F)	X			X			X		
Danger Point Eelgrass	1994 (G); 2010 (T); 2011 (R)	2010 (T); 2011 (R); 2016 (G)	X	X	X	X	X	X	X	X	X
Fredrickson South Marsh	2011 (T, RSET); 2015 (T); 2016 (F, GW); 2017 (RSET)	2016 (T, RSET)	X			X			X		
Winchester Spruce Swamp	2017 (RSET); * (T, F)				X			X			X
Winchester Marsh	2012 (T, RSET); 2016 (T, F)	2016 (T, RSET)	X			X			X		

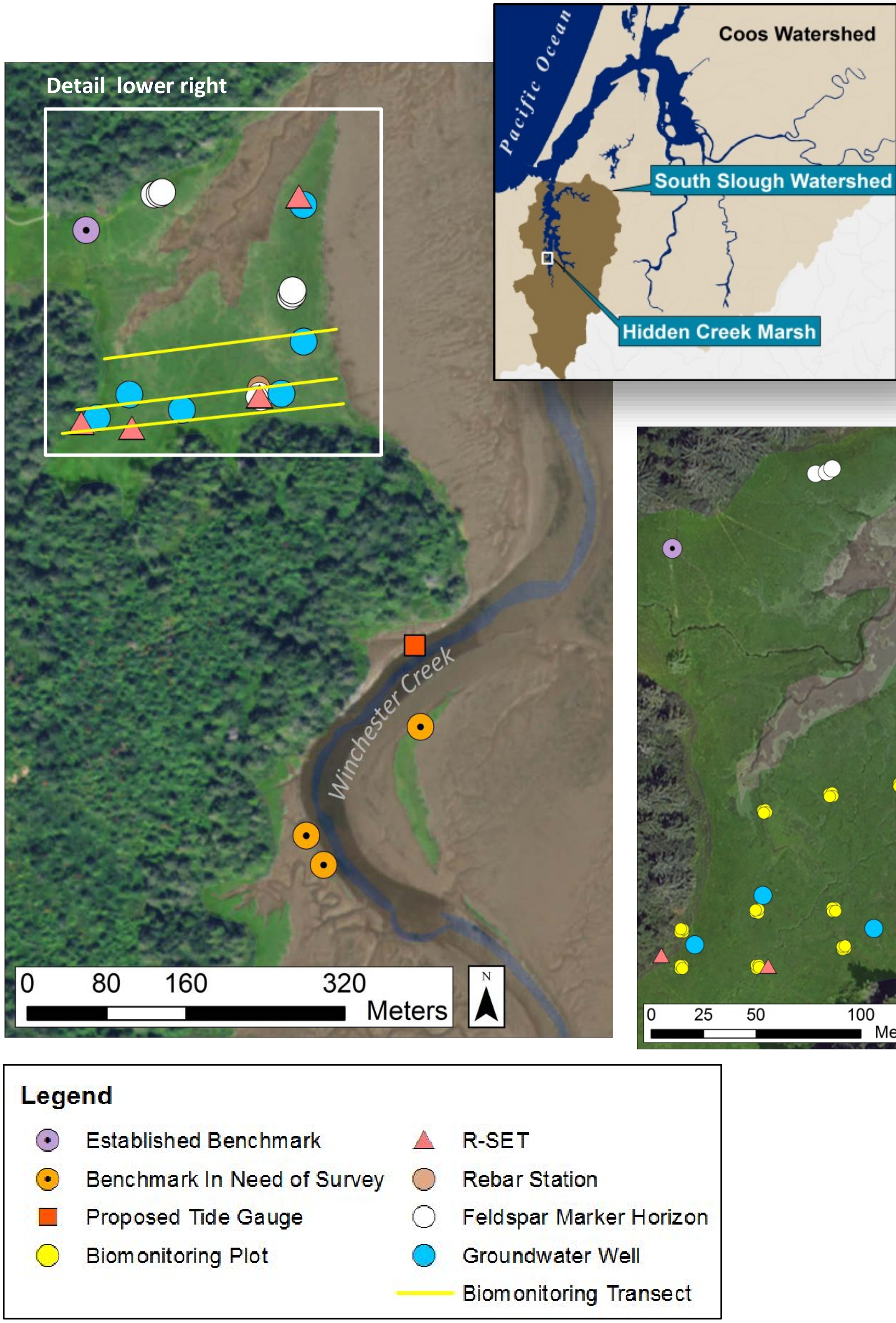
Table 2: *Summary of current and final build out of monitoring infrastructure at all sentinel stations including emergent marsh, eelgrass and tidal swamp types. Infrastructure includes vegetation transects, R-SETs, marker horizon plots, vertical control marks, groundwater wells, and soil salinity tubes.*

Type	Site Name	Vegetation Transects[1]				Sediment Dynamics				Vertical Control Marks		Elective Parameters		Nearest SWMP or Tide Station name/distance (river km)
		Marsh Par.	Marsh Perp.	Eelgrass	Swamp Forest	R-SET[2]	Feldspar Plot[2]	Rebar Station	Mudflat Grid	Installed[2]	Surveyed[3]	Soil Salinity[2]	Groundwater Wells[2]	
Marsh	Metcalf	4/20				1 (4)	3 (12)	1		1 (3)	1/0	0 (20)	2 (4)	Charleston/0.9
Marsh	Metcalf Islands	3/20				1 (3)	3 (12)	1		1 (3)	0/0	0 (20)		Charleston/0.4
Marsh	Valino Island	5/20				1 (4)	3 (12)	1		3 (3)	1/0	0 (20)	2 (4)	Valino/0.5
Marsh	Valino Is. - Is.	4/20				1 (3)	3 (12)	1		2 (3)	0/0	0 (20)		Valino/0.7
Marsh	Hidden Creek	4/20	3/21			4 (4)	9 (18)	1	3	2 (3)	1/0	0 (40)	6 (6)	Hidden Tide/0.2
Marsh	Danger Point	3/21				1 (3)	9 (18)	1	3	2 (3)	1/0	0 (20)	7 (7)	Winchester/0.3
Marsh	Fredrickson South	4/20				1 (4)	3 (12)	1		1 (3)	1/0	0 (20)	2 (4)	Winchester/1.5
Marsh	Winchester	4/20				1 (4)	3 (12)	1		1 (3)	1/0	0 (20)	0 ()	Winchester/2.3
Eelgrass	Collver Point			2/20					0 (6)					Charleston/0.9
Eelgrass	Valino (Eelgrass)			3/30				1	0 (9)					Valino/0.2
Eelgrass	Hidden (Eelgrass)			2/20				1	0 (6)					Hidden Tide/0.1
Eelgrass	Danger (Eelgrass)			2/20					0 (6)					Winchester/0.1
Tidal Swamp	Winchester Spruce Swamp				5/10/25	0 (3)	0 (9)			0 (3)	0/0	0 (11)	0 (11)	Winchester/2.0

[1] For Marsh (parallel and perpendicular) and eelgrass, values indicate number of transects/total number of plots. For Forested Swamp, values indicate number of transects/total number of tree and shrub plots/total number of herbaceous plots.

[2] Final build-out total in parenthesis

[3] Values indicate marks surveyed to local site/marks surveyed to entire SSAM-1 network



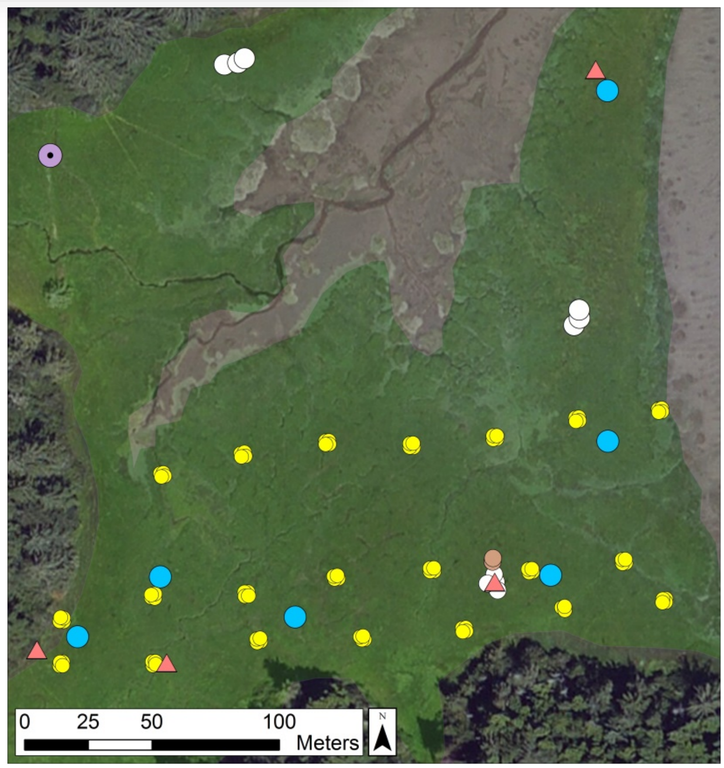


Figure 1: *Hidden Creek Marsh primary sentinel station infrastructure (far left) within the context of the Coos Watershed (near left). Detailed marsh infrastructure shown below.*

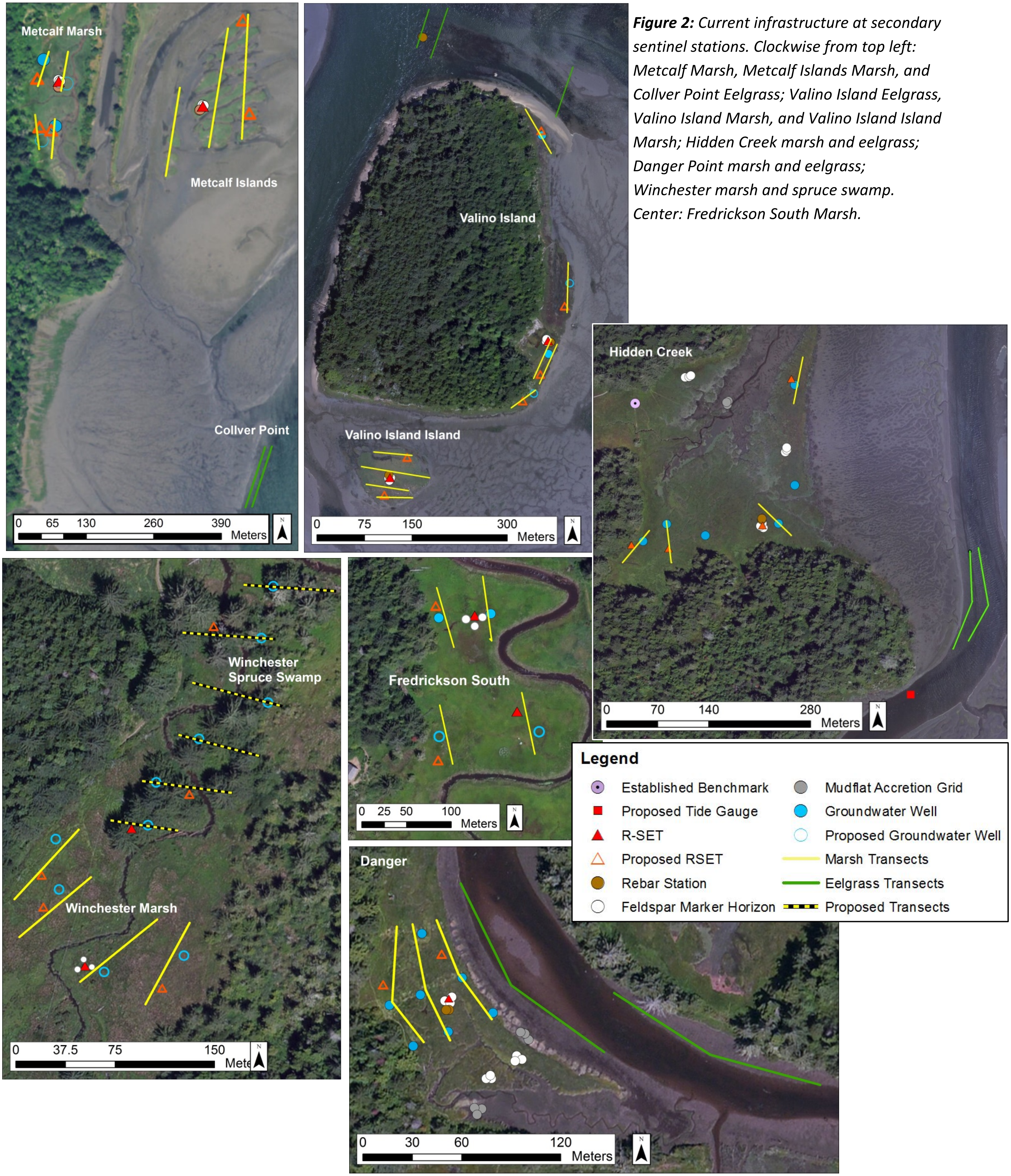


Figure 2: *Current infrastructure at secondary sentinel stations. Clockwise from top left: Metcalf Marsh, Metcalf Islands Marsh, and Collver Point Eelgrass; Valino Island Eelgrass, Valino Island Marsh, and Valino Island Island Marsh; Hidden Creek marsh and eelgrass; Danger Point marsh and eelgrass; Winchester marsh and spruce swamp. Center: Fredrickson South Marsh.*

i. Biomonitoring

Rationale

In comparison to salt marshes found on the east coast of the Unites States, which generally are dominated by large, flat expanses of *Spartina alterniflora* salt marshes, marshes on the west coast are often more diverse, smaller in distribution and less abundant due to higher wave energies and sharp coastal elevations. Due to this diversity of plant species (e.g., 45 species found in South Slough marshes out of 70 species in Oregon according to Rumrill (2006)), SSNERR staff set up tidal emergent marsh transects that were oriented parallel to the main channel (as compared to the typical perpendicular transects used on the East Coast). The parallel orientation of transects allows for higher replication at each elevation gradient (e.g. low marsh or high marsh zones) and provides greater statistical strength to detect significant changes in diverse plant communities (where elevation is a factor) (Roegner et al. 2009). This is especially important given the natural community composition changes that occur along the elevation gradient from submerged aquatic vegetation, to emergent low and high marsh, to scrub shrub wetland, to forested wetlands (e.g., Sitka spruce swamp), and finally sloped, forested uplands. We consulted two wetlands experts (L. Brophy, Institute for Applied Ecology; C. Janousek, USGS) who work in Pacific Northwest salt marshes about the transect orientations, and they highly recommended using the parallel orientation.

However, to comply with NERRS Sentinel Site biomonitoring transect methods (and after consulting with K. Wasson (ESNERR) and K. Raposa (NBNERR)), SSNERR staff set up Hidden Creek with additional transects oriented perpendicular from the low marsh edge to the high marsh edge as our "primary" SSAM-1 site. Therefore, at Hidden Creek, we are monitoring a total of seven transects (three perpendicular and four parallel) in order to both meet NERRS protocols and be included in System-Wide analyses, and to monitor marsh vegetation for our own research purposes.

Site Descriptions

The sites are described in order of their location along the estuarine salinity gradient from marine (north) to freshwater (south) (Figures 1 and 2). Each site has a description of the habitat, its physical and abiotic conditions, including proximity to the nearest SWMP station, and concludes with reference to the driving research question(s) it is monitored for.

Metcalf Marsh: Metcalf is a marine-dominated marsh approximately 14,400 m^2 in size, located just south of the end of Roosevelt Road in Charleston, OR and owned by the University of Oregon Institute of Marine Biology. Access is by road, with a brief crossing of private property to reach the marsh. The site has numerous small hidden channels and is divided roughly in half by a larger channel 2-3 m wide. The marsh is bordered to the east by a main channel which is, in turn, bordered by a wooded dike; mature forested uplands border the south and west, and a private lawn edges the marsh to the north. The low zone is dominated by *Distichlis spicata* and *Sarcocornia perennis*, intermixed with *Triglochin maritima*, *Jaumea carnosa* and occasionally *Atriplex prostrata* and *Plantago maritima (*Keammer 2011, Hamilton 2011). The high zone is more diverse and predominately *Carex lyngbyei*, *Juncus balticus*, and *Deschampsia caespitosa*. There appears to be a freshwater seep near *C. lyngbyei*-dominated Transect 2, and considerable down wood overlaying Transect 4, both in the high marsh zone.

Metcalf Marsh is located about 0.7 km west of the Charleston Bridge SWMP station, where the maximum tidal range is 3.9 m, daily mean water temperatures range from 7-18 ^{o}C, and the monthly mean salinities fluctuate seasonally from 22 in winter to 35 in summer, with a mean annual salinity of 29.5. Freshwater input is limited to seasonal rainwater and a small transient salinity/density signal from Joe Ney Slough (a tributary to South Slough). The marsh is situated across the primary channel from Joe Ney Slough, which has a decade-long history of tributyltin pollution. The area was voluntarily cleaned up in the mid-1990s and passed DEQ site review. Occasional high bacterial levels have been noted (NOAA NERRS 2016).

Metcalf Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, 2) island marshes, 3) high marsh/low marsh comparisons, and 4) eelgrass beds in close proximity.

Metcalf Islands Marsh: The Metcalf Islands are a series of 24 low (~1m elevation), silty marsh islands situated on the large mud/sand flat east of Metcalf marsh. The area covered by marsh plants totals approximately 0.016 km^2, and individual islands range in size from approximately 100 to 2000 m^2 (Hamilton, 2011). The islands are surrounded by water at tides > 1.5m, and are submerged at tides in excess of 2.5 m. The bulk of island area consists of a roughly oval assemblage of 16 islands separated by NE-SW-running channels; the remaining eight islands are generally smaller and form a landward archipelago with a north to south orientation. Channels separating islands are mostly shallow (approximately 1 m depth from marsh surface to channel bottom), ranging in width from approximately 2-15 m. Human use in the area is greater than at other sites, with frequent recreational clam digging occurring on the large mud flats to the east of Metcalf Islands. Plant communities at Metcalf islands are typical of brackish low marsh environments in South Slough, with *S. perennis*, *J. carnosa*, and *P. maritima* comprising the vast majority. Additionally, *Puccinellia* sp. is found in profusion interspersing the succulents. *Distichlis spicata* is dense on one of the southernmost islands of the archipelago; it is found in low numbers on other southern archipelago islands but is absent to the north. The listed species *Chloropyron maritimum palustre* (salt marsh bird's beak), is also found on the southern end of the westernmost archipelago. Salt marsh bird's beak is considered endangered by the state of Oregon and is federally listed as a species of concern (Cornu and Souder 2015).

Metcalf Islands are located about 0.4 km west of the Charleston Bridge SWMP station (see physical description under Metcalf Islands, above).

Metcalf Islands are monitored for comparisons with: 1) mainland marshes.

Collver Point Eelgrass: Collver Point is a sandstone headland with adjacent mudflats, eelgrass beds, a cobble terrace, and a fringing, low, silty salt marsh (Rumrill and Sowers, 2008). The Collver Point eelgrass bed is located in the marine-dominated region of the South Slough estuary, approximately 0.6 km southeast from neighboring Metcalf marsh, and approximately 100 m north of Collver Point. The Charleston SWMP water quality monitoring station is approximately 1.1 km to the northeast, and the Valino Island SWMP station is 1.5 km to the southeast. The eelgrass bed is narrow and discontinuous, but in 2010 measured about 3,000 m^2. It is situated on the transitional slope from a large mudflat to the west to the channel proper. Access is by boat at most tides or by foot from Metcalf marsh at negative tides. This eelgrass site was chosen to optimize maximum size and continuity with separation from a heavily-used clam digging area to the north. This eelgrass bed was used in the biomonitoring pilot study by Rumrill and Sowers (2008) where transects were oriented perpendicular to shore. Current biomonitoring transects bisect those original transects.

Collver Point is located about 0.9 km southwest of the Charleston Bridge SWMP station (see physical description under Metcalf Islands, above).

Collver Point Eelgrass is monitored for comparisons with: 1) marsh habitats in close proximity, and 2) other eelgrass beds along the estuarine gradient.

Valino Island Marsh: Valino Island Marsh has a total area of approximately 9,800 m^2 and is located in the middle region of the South Slough estuary. It has a narrow fringing marsh that extends from the southwest corner to the northeastern side of the island. The south side is predominantly high marsh then transitions into predominantly low marsh along the eastern side of the island. The high marsh is dominated by *D. caespitosa* and *J. carnosa*, with substantial *S. perennis* and *D. spicata.* The low marsh is typically dominated by *S. perennis* (forming exclusive stands in some places), *D. spicata* and *J. carnosa.* However, low marsh in the southeastern section contains numerous individuals of the federally listed species of concern *Chloropyron maritimum palustre* (salt marsh bird's beak). Access is by boat at moderate tides, on foot from Crown Point Rd at good low tides, or by kayak in any condition.

The Valino Island SWMP water quality monitoring station is located approximately 0.3 km from the northernmost transect and 0.7km from the southernmost transect. The Valino SWMP station is 3.6 km from the mouth of the South Slough estuary. Maximum tidal ranges at the SWMP station can reach 3.8 m while daily average water temperatures range from 5-20 °C. Monthly mean salinities fluctuate seasonally from 18-34, with a mean annual average salinity of 27. Freshwater input is mainly from rainfall and small adjacent tidal creeks. Additional freshwater enters this region indirectly from the Winchester and Sengstacken arms of the estuary during ebb tides. There are no known point source pollutants although high bacterial levels cause frequent regulatory problems for commercial oyster growers (NOAA NERRS 2016).

Valino Island Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, 2) island marshes, 3) high marsh/low marsh comparisons, and 4) eelgrass beds in close proximity.

Valino Island Eelgrass: Valino Island is located in the polyhaline region of the estuary and is surrounded by expansive eelgrass beds over sand and mudflat substrates, and fringing, low, sandy salt marsh primarily on its east and south sides. The Valino Island eelgrass bed is located just off the north end of Valino Island, on a broad, flat, shallow shelf housing an extensive eelgrass bed of approximately 38,000 m^2 (Hamilton, 2011). Access is by boat or kayak at tides > 0.0 m or by foot from a steep trail at the end of Crown Point Road.

The Valino Island eelgrass transects double as a SeagrassNet (www.seagrassnet.org) monitoring site, established July 2004 and sampled nearly quarterly for *Zostera marina* (native) and *Zostera japonica* (non-native) percent cover, shoot density, canopy height, and number of flowering shoots. Three transects were established in July 2004 to reflect the small elevation change present in this bed, from the highest extent of the bed to the main channel edge (though eelgrass continues into the subtidal region of the channel). The highest transect was re-located in 2005. A secondary channel, Day Creek, meanders through the middle region of the bed, and since 2010, this channel has been migrating south, consuming plots in the northern ends of the two low-elevation transects. Each transect is 50 m long with 12 permanent plot locations that were randomly assigned during initial set-up. In April 2016, additional random plots were added to the two low elevation transects to replace the plots that have succumbed to the channel, in order to meet the 20 plot requirement.

The Valino Island SWMP water quality monitoring station is located approximately 0.2 km from the eelgrass site. See summary of physical attributes of this station under *Valino Island Marsh*, above.

Valino Island Eelgrass is monitored for comparisons with: 1) marsh habitats in close proximity, and 2) other eelgrass beds along the estuarine gradient.

Valino Island- Island Marsh: This marsh is a small (approximately 4,000 m^2) tidal island marsh located approximately 40 m due south of Valino Island, separated from the main island by a shallow channel. Elevation on the small island changes only slightly, primarily from south to north, and a small peninsula-like section on the northernmost end is partially separated from the rest of the island by a small (max 3 m wide), shallow, muddy inlet that is dominated by *S. perennis*. The remaining half of the island (between the peninsula and the south end) is a dense expanse of *D. spicata*, with *J. carnosa* and *S. perennis* interspersed throughout. Elevation increases slightly in the southern third of the island, with the marsh plant community becoming increasingly dominated by *S. perennis*, *Puccinellia pumila*, *D. caespitosa*, and *D. spicata*. Access is by kayak at all tides; by foot from Valino Island proper at tides < 1.0 m; and by motor boat at tides > 1.7 m.

The Valino Island SWMP water quality monitoring station is located approximately 0.75 km from this marsh site. See summary of physical attributes of this station under *Valino Island Marsh*, above.

Valino Island-Island Marsh is monitored for comparisons with: 1) mainland marshes.

Hidden Creek Marsh is SSNERR's largest study marsh (43,000 m^2). It is a highly diverse (27 marsh plant species identified), unmodified high, mature tidal marsh (Rumrill 2006). The low elevation marsh is generally dominated by *Triglochin maritima*, *Sarcocornia perennis*, *Jaumea carnosa*, and *Deschampsia caespitosa* while high elevation marsh tends to be dominated by *Agrostis stolonifera*, *Carex lyngbyei*, *Lysimachia maritima*, *T. maritima*, and *J. carnosa.*

Data from the Winchester Creek SWMP water quality monitoring station (approximately 1.9 river km south) show an average tidal range of 1.82 m (maximum 2.6 m) and mean salinity of 12 that fluctuates seasonally (monthly means 2-25 depending on season). Water is nearly fresh in the winter months when it is dominated by the freshwater influence of Winchester Creek, the largest freshwater tributary to South Slough (winter discharge peaks measured 2011-2013 were around 120 cfs) (Cornu and Souder 2015; Cornu et al. 2012, Rumrill 2006). Freshwater inputs vary seasonally between 1-23 cfs, depending on precipitation events. Salinity becomes much higher in the summer months (monthly averages in the low to mid 20's) when Winchester Creek's flows diminish (base flow of 2.57 cfs) and oceanic drivers dominate. Other freshwater input is minimal although some fresh water drains into the marsh from the Hidden Creek watershed through an intermittent creek during the wet season. Stressors occur mainly in the summer dry season with high water temperatures, and low dissolved oxygen (DO) levels. Daily mean water temperatures range from 1.6-23 ^{o}C, depending on the season. The median dry season temperature at Winchester station is 16.2 ^{o}C; however, the highest 25% temperatures are above 20 ^{o}C (Oregon Department of Environmental Quality (ODEQ) considers temperatures higher than 18^{o}C as impaired for aquatic life, and temperatures above 23 ^{o}C inhibit salmon rearing) (Cornu and Souder 2015). There is high daily variability in DO at the Winchester SWMP station with median summertime levels of 8.4 mg/l (Cornu and Souder 2015). The lowest 25 % of DO values are 7.4 mg/L or lower, frequently falling below the ODEQ standard of 6.5 mg/L for impaired estuarine waters. In addition, Winchester station exceeds ODEQ criterion for bacteria *Escherichia coli* (*E. coli*). Monthly dissolved inorganic nitrogen averages at Winchester station are considered healthy in summer months (below EPA's 0.5 mg/L criteria), and fair (EPA's criteria 0.5-1.0 mg/L) in winter months (with highest levels occurring in January) (Cornu and Souder 2015).

A tide gauge closer to Hidden Creek marsh will be installed 2018, about 0.3 km south of the marsh (See Tide Gauges and Tidal Benchmarks below for more detail).

Hidden Creek Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, 2) nearby eelgrass beds, 3) high marsh/low marsh comparisons, 4) analysis of vegetation transect orientation, and 5) high resolution water level near the primary SAM1 site compared to Charleston NWLON station water levels.

Hidden Creek eelgrass: The Hidden Creek eelgrass bed is located approximately 200 m southeast of Hidden Creek marsh. Movement within the site is somewhat difficult with very soft mud characterizing the entire eelgrass bed. Eelgrass beds occupy about 2,000 m^2 of the transitional slope between marsh and deeper channel in a narrow, discontinuous band, with larger expanses forming in eddy zones of channel meanders. *Zostera japonica* is present at the highest elevations. Access is on foot from Hidden Creek marsh or by boat on tides > 0.5m.

Hidden Creek eelgrass beds are approximately 1.9 river km north of the Winchester Creek SWMP station (see description of physical conditions under Hidden Creek marsh, above).

Hidden Creek Eelgrass is monitored for comparisons with: 1) marsh habitats in close proximity, and 2) other eelgrass beds along the estuarine gradient.

Danger Point Marsh: Danger Point is located in the riverine/mesohaline region of the South Slough estuary and consists of a mature high salt marsh, transitioning to mudbanks and a fringing eelgrass bed along the length of a narrow tidal channel. Danger Point marsh is a relatively small (approximately 6,300 m^2) but a diverse and undisturbed site. The site is accessed by boat at tides > 0.5 m or by foot from Hinch Road's bridge. This marsh differs from many others in its elevation profile with the middle of the marsh lower in elevation than the upland or channel interface, but overall the marsh is higher in elevation than other Sentinel stations in the South Slough estuary. The plant community follows different distributional patterns horizontally from the upland to the channel with *Agrostis stolonifera*, *T. maritima*, and *C. lyngbyei* dominating (and *Potentilla anserina* and *D. caespitosa* consistently present) the plant community near the upland and channel edges. The middle portion of the marsh consists primarily of *C. lyngbyei*, *T. maritima*, *D. caespitosa*, and *D. spicata*.

Winchester Creek SWMP station (see description from "*Hidden Creek*" above) is about 300 m from the closest Danger Point marsh transect.

Danger Point Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, 2) high marsh/low marsh comparisons, and 3) eelgrass beds in close proximity.

Danger Point Eelgrass: The Danger Point eelgrass site is the southernmost established eelgrass Sentinel station, and parallels Danger Marsh along a relatively narrow (approximately 30 m wide, edge-to-edge), tidally-influenced section of lower Winchester Creek. Only 10 m separates the eelgrass plots from the marsh plots at their closest point. The higher elevations of the channel are characterized by relatively narrow but dense and continuous eelgrass, while the middle of the channel (1.1 m deep at a zero tide) has dense patches of eelgrass. The channel bottom is firm sand compared to the extremely soft mud of the intertidal eelgrass beds. The southeastern transect is directly across from an experimental marsh restoration area, where dikes were removed from a 5.1 ha area in 1996 and 1998 (Cornu 2005b). About 4.2 hectares of natural marsh are directly across from the southeastern end of that transect. The non-native *Z. japonica* occurs in the higher elevations, particularly at the north end of the western transect. Access at lowest tides is by foot from Hinch Road bridge.

Winchester Creek SWMP station (see description from "*Hidden Creek Marsh*" above) is about 100 m from the closest eelgrass transect.

Danger Point Eelgrass is monitored for comparisons with: 1) marsh habitats in close proximity, and 2) other eelgrass beds along the estuarine gradient.

Fredrickson South Marsh: Fredrickson South marsh is a 28,000 m^2 tidally-influenced brackish high sedge marsh located on the western side of Winchester Creek at the southern end of the Reserve near the upper limits of tidal influence. The marsh elevation is about 2.7 m above mean lower low water. The dominant vegetation is *C. lyngbyei*, *P. anserina* and *J. balticus*.

The Sentinel station is located just south of Fredrickson marsh, which was a two-hectare wetland restored in 1998 as part of the larger Winchester Tidelands Restoration Project (Cornu 2005b). Restoration included removal of a dike to restore tidal flooding. Two tidally influenced ditches were also enhanced by adding coniferous root wads to restore channel complexity. Hydrology changed dramatically at this site because of the restoration work, including full restoration of tidal flooding and freshwater spring flows. The marsh vegetation changes included new freshwater plant communities at the upland edge including the invasive reed canary grass (*Phalaris arundinacea*).

The Winchester Creek SWMP station, located approximately 1.5 river km north of Fredrickson South marsh, is the closest SWMP water quality station (see description from "*Hidden Creek Marsh*" above). There is a long-term NOAA climate reference network station at this site described in the main document above (Section V, v.).

Fredrickson South Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, and 2) high marsh/low marsh comparisons.

Winchester Spruce Swamp: This site has approximately 8,000 m^2 of Sitka spruce swamp forest. Once common in the Pacific Northwest, forested swamps (such as Sitka spruce swamp) are now one of the rarest wetland types in the region (Cornu and Souder 2015). This site is not yet established, but plans are underway to have RSETs and biomonitoring transects established prior to summer 2018 sampling. The site encompasses an adult Coho salmon trap monitored by Oregon Department of Fish and Wildlife.

The nearest SWMP water quality station is Winchester Creek (see description from "*Hidden Creek*" above), located 2.0 river km north.

Winchester Spruce Swamp is monitored for response over time to climate-related changes.

Winchester Marsh: Winchester marsh is a tidally-influenced freshwater high marsh, with a study area of approximately 30,000 m^2 located directly adjacent to Winchester Creek. The study site is located between two major tributaries to Winchester Creek (Wasson Creek to the north, and Anderson Creek to the south), both of which are drainages where major lowland restoration work has (Anderson (Cornu 2005a)) or will (Wasson) take place. It is the southernmost Sentinel station and the last marsh site to be established (all biomonitoring transects fully established July 2016). The dominant vegetation is *Carex obnupta*. Just beyond the study area to the south, there is a small rural, residential dwelling outside the South Slough Reserve's boundary (NOAA NERRS 2016). The watershed south of the Reserve boundary is owned by Coos County forestry department and actively harvested for timber.

The nearest SWMP water quality station is Winchester Creek (see description from "*Hidden Creek*" above), located 2.3 river km north.

Winchester Marsh is monitored for comparisons with: 1) other mainland marshes along the salinity gradient, and 2) high marsh/low marsh comparisons.

Vegetation Monitoring Plans

Marsh - Primary Station: Hidden Creek's three perpendicular vegetation transects were established in September 2015 (Table 1). Each transect has seven permanent 1m^2 plots (totaling 21 plots) that were established using protocols adopted by NERRS (Moore 2011; Roman et al. 2001). Transects span the elevation gradient with the first plot in each transect randomly assigned within the first 10 m of either the marsh edge or the forest edge. Remaining plots were evenly distributed along the remainder of each transect (~25 m apart). Plots were randomly located north or south, 1 m away from the center of the transect. Four corner stakes were installed at each plot and marsh surface elevation adjacent to each stake was collected. Percent cover of each plant species is quantified using the point-intercept method from Roman et al. (2001) where a vertically-held 5 mm-diameter fiberglass rod is lowered through the plant community to the ground at each of 50 points in a 1 m^2 quadrat. All plant species contacting the rod are recorded at each point and the total number of "presence" scores are tallied and converted into percent cover. Percent cover recorded in this way ensures that understory species and canopy species are represented appropriately and minimizes observer-induced variability. Based on the percent cover sampling, the three species with the highest percent cover from the following list are sub-sampled for number of stems and canopy heights: *Plantago maritima, Triglochin maritima, Distichlis spicata, Juncus balticus, Carex lyngbyei,* and *Potentilla anserina.* These species are the best indicator species for low/mid marsh habitat (first three) and mid/high marsh habitat (last three). Stem counts and canopy heights are sampled in permanent 0.0625 m^2 plots, randomized within the 1 m^2 plot the initial year. In each subplot, all individuals of each top three species are enumerated, and stem height is measured for the three tallest individuals. Percent cover, density, and elevation data at each vegetation plot will be taken during the summer (June-July) every three years, to understand trends that may be linked to regular climatic cycles and to capture temporal variation.

Marsh – Secondary Stations: Secondary marsh sites consist of 3-5 transects (overall linear distance ~200m) and a total of twenty 1 m^2 (1 m x 1m) plots. Generally, sites are set up as four transects (two high marsh, two low marsh) with five plots per transect. Most sites were originally set up in 2010, where transects were assigned both permanent and random plots. Random plots were kept as permanent in subsequent sampling years following conversations with regional wetland experts. Each marsh transect was randomly assigned its first permanent plot within the first 10 m by use of a random number generator, and subsequent permanent plots were systematically located along the remainder of the transect in 20 m increments. Random plots were then interspersed throughout, their locations determined by a random number generator. Metcalf Islands was set up differently with both permanent and random plot locations randomly assigned. Plots are located 1 m to either side of each transect.

Plot sampling methods and measurements are identical to those described in the main document (see Vegetation Monitoring Plan section V, ii).

Eelgrass – Secondary Stations: In 2010, eelgrass stations were established at three sites (Collver, Hidden, and Danger), each with two transects oriented parallel to the main channel. Transects at these sites are 100 m long with 10 permanent plots placed 10 m apart from a randomly-chosen starting point (totaling 20 plots per site) (Moore 2011). The two transects are separated by 10 m. Transect ends at all four sites are marked with screw anchors and PVC/rebar stakes. At Hidden and Danger, transects are angled in a V-shape to follow the eelgrass bed as it curves along the channel; at these sites the center of each transect is also marked with PVC/rebar. Eelgrass transects are oriented north (start) to south (end) except for Valino Island where the start and ends are reversed, following SeagrassNet protocols. The Valino Island eelgrass site was established in July 2004 following SeagrassNet protocols, with three 50 m long transects (randomized across the bed) each with 12 plots (randomized permanent plots). Data from two transects (the two closest to the channel) double as the Sentinel station.

Eelgrass plots are sampled with 0.25 m^2 quadrats (50cm x 50cm) placed on the transect tape, flipped toward the channel at most sites (Collver, Hidden, Danger) except Valino Island, where the quadrat is flipped away from the channel (per SeagrassNet protocols (Short et al. 2015)). Quadrats at all sites are placed with the lower right corner of the quadrat on the sampling number of the meter tape, while facing the channel (Collver, Hidden, and Danger) or shoreward (Valino). At each plot the following data is collected: 1) photo of each plot with label of plot transect and quadrat number location; 2) spatial cover of *Z. marina* and *Z. japonica*, visually estimated as percent cover in 5% increments and corroborated by two observers; 3) shoot density, where all plants rooted within the quadrat are counted; 4) maximum canopy height, estimated by measuring the longest shoot present in the plot; and 5) the number of flowering shoots found within the plot (Short et al. 2015).

In addition to biomonitoring, sediment dynamics are quantified in the eelgrass habitat with mudflat accretion grids and rebar stations. Mudflat accretion grids allow measurement of accretion and erosion rates in soft sediment habitats (Kairis and Rybczyk 2010, Pasternack and Brush 1998). Square plastic grids (0.016 m^2) are placed at the mudflat surface level with the ground, marked on diagonal corners by rebar/PVC stakes. Sediment accretion is measured by sampling accumulation of sediment on top of the grid with a ruler pushed down until it touches the grid. Grids will be installed at the three eelgrass monitoring sites in summer 2016 (Danger Point has grids installed from a different monitoring project).

Like marsh rebar stations (see Methodology in the Surface Elevation section below), mudflat rebar stations consist of two rebar stakes (3 m length, 2 cm diameter) one meter apart, leveled and driven 2.25 m into the substrate (Hamilton 2011). Rebar stations were installed and sampled in 2011 at Valino Island, Hidden Creek, and Danger Point and will be installed and sampled at Collver Point in 2016 (Table 1). Rebar stations are sampled identically to the marsh rebar stations (Section V, iii).

Sitka Spruce Swamp – Secondary Station: The South Slough NERR has been developing and describing methods and protocols for sampling spruce swamp transects in 2018 after consultation with Laura Brophy (Institute for Applied Ecology) and Chris Janousek (Oregon State University) and others who work in this now-unique habitat type. Methods primarily follow Roegner et al. 2009 and include guidance from ODSL 2009, Peet 1998, and Brophy 2005. In brief, six 50m transects will be established, roughly parallel to each other (randomly assigned first transect, and equally distributed throughout remainder of spruce swamp habitat, see proposed transects in Figure 2). Transects will be generally oriented perpendicular to Winchester Creek channel. Most transects will have two shrub/forest plots (10 m diameter) and five herbaceous plots (1 m^2) for a total of 11 shrub/forest plots and 28 herbaceous plots. Each shrub/forest plot will have one herbaceous plot within it; remaining herbaceous plots will be randomly located along each transect outside of shrub/forest plots. Sampling methods for forest/shrub plots will incorporate separate methods for sampling trees and shrubs. For trees, all trees (live and dead) within the plot will be identified to species and diameters of each tree will be measured at breast height (dbh). Height measurements will be taken and canopy cover estimated for each tree. Shrubs will be sampled within a 1 m wide "belt" within each forest plot. On initial setup, the belt will be randomly assigned N-S or E-W direction. All shrubs rooted within the belt will be identified to species. For each species, stems will be tallied by diameter class (at 1.4m height) following Peet (1998): 0–1 cm, 1–2.5 cm, 2.5–5 cm, 5–10 cm, 10–15 cm, 15–20 cm, 20–25 cm, 25–30 cm, 30–35 cm, and 35–40 cm; stems greater than 40 cm will be measured at breast height. Multiple stems arising from a common root system will be recorded separately if they branch below 0.5 m above ground level (stems branching above 0.5 m but below 1.4 m will be measured at the narrowest point below the branch). Methods for herbaceous plots will follow marsh biomonitoring protocols above.

Habitat Mapping and Change Plan

In 2011, SSNERR science staff began and nearly completed a Reserve habitat map following the Habitat and Land Cover Classification Scheme for the NERRS (Kutcher 2008). However, an accuracy assessment was never completed for those habitat maps and the imagery (2005) was considered too old to complete an accuracy assessment when staff re-evaluated the maps in 2016. In 2017, science staff began the process of creating new habitat maps for the South Slough estuary. Staff worked with Nate Harold at NOAA's Office for Coastal Management, who used e-cognition software to delineate habitat boundaries based on NAIP 4-band 2016 aerial imagery. The project area boundary was based on the lower watershed hydrologic unit boundary for the South Slough in addition to South Slough managed lands that extend just outside the watershed boundary. NOAA's 50% exceedance boundary was used to delineate the estuarine bounds. Total delineation resulted in 161,004 GIS polygons delivered to SSNERR in June 2017. SSNERR staff then began the process of refining, aggregating, and classifying the polygons in accordance with the NERRS classification scheme (Standard Operating Procedures for Mapping Land Use and

Change in the National Estuarine Research Reserve System (May 2015, v 2.0)). Estuarine habitats were classified to the "subclass" level, while upland habitats were classified to the "class" level. In early fall 2017, staff collected data at 385 accuracy assessment points for the estuarine habitats; the accuracy assessment for the uplands portion is still needed. Staff are finalizing modifier data for estuarine habitats, developing metadata, and crosswalking the NERRS classification map to Coastal and Marine Ecological Classification Standard (CMECS) with the goal of having complete maps by end of 2017.

Other related habitat mapping efforts that the Reserve was directly involved in include a 2014 and 2016 partnership with the Oregon Department of Land Conservation and Development. For this project, SSNERR science staff began to refine and validate Oregon's Coastal and Marine Ecological Classification Standard (CMECS) habitat classification for the Coos estuary. Prior to this, the Reserve was involved with a revision of the Oregon Estuarine Habitat Classification Scheme in 2007, which reviewed existing habitat classification systems and recommended guidelines for adopting a new framework for estuarine habitat classification based on Bottom et al. (1979).

ii. Surface Elevation

Rationale

Sediment accretion or erosion rates are a key factor in determining sea level rise impacts on tidal marshes. Marsh elevation is affected by a variety of processes including sea level, local subsidence, decomposition, surface sediment compaction, surface sediment accumulation, and organic matter from local plant production. In order to understand the spatial and temporal variation in sediment dynamics and the processes contributing to elevation change, SSNERR has employed a variety of methods at each marsh including, deep Rod Surface Elevation Tables (R-SETs), marker horizons, rebar stations, and sediment plates/grids. The R-SET provides precise, accurate, repeatable, and non-destructive measurements of elevation change in wetland sediments relative to orthometric height (Lynch et al. 2015). The marker horizon plots provide measurements of surface accretion rates that are inexpensive, easily sampled, and at mm level resolution. The rebar stations provide an inexpensive method for measuring sediment elevation relative to the top of the rebar and will be useful in comparison with the R-SETs. Rebar stations measure shallow subsidence monitoring (~2.25m) as opposed to the RSETS, which measure slightly deeper subsidence processes (10-12m) (see *Methodology* below for more on rebar stations). The difference between vertical accretion (from marker horizons) and changes in relative sediment elevation (from R-SET or rebar stations) provides a measure of shallow subsidence or uplift.

Location

At least one R-SET has been established at each marsh site, located adjacent to a vegetation transect, within an area representative of that transect (Figures 1 and 2; Table 1). Each R-SET is marked by four PVC stakes driven 2m from the center of the benchmark. Three RSETs will be installed at the Spruce Swamp site, at random locations and adjacent to three randomly selected transects. At marsh sites, a rebar station was also established several meters from the R-SET area.

At each R-SET station, three 0.25 m^2 marker horizon (feldspar) plots have been established adjacent to corners of the R-SET area. In addition, six marker horizon plots in two mid marsh locations were established at Hidden Creek and Danger Point marshes in June 1994 (Figures 1 and 2). New marker horizon plots will be installed every 10 years, adjacent to the R-SETs. Future installations will be colored with construction chalk to easily identify year of installation.

Science staff hope to add additional R-SETs and marker horizon plots adjacent to each transect to provide replicates to compare across sites; however, this will depend on future funding and staffing.

Methodology

R-SETs and marker horizons were installed following USGS Patuxent Wildlife Research Center and National Park Service protocols (Cahoon et al. 2002b, Lynch et al. 2015) along with training and recommendations from Philippe Hensel (NOAA), Scott Lerberg (CBNERR-VA), and Dr. John Rybczyck (Western Washington University). Each R-SET station is attached to a deep rod mark, established by manually driving stainless steel, threaded, sectional rods into the ground until “refusal” was reached. The last rod was driven completely and or cut at the marsh surface. A stainless-steel SET receiver was attached to the benchmark rod with four steel bolts, with the cap approximately 4” above a 6” PVC pipe. Concrete was poured over the rod and receiver until level with the top of the PVC pipe and a brass monument marker was placed into the concrete.

R-SET sampling consists of attaching a rotating arm that extends horizontally over the marsh surface to the SET receiver, lowering the sliding, vertical pins to the marsh surface, and taking readings at nine points in each of four sampling directions (for a total of 36 elevation readings). The R-SET are sampled in June or July, during summer low tides (generally +1m or better) before wet season rains have begun (see Table 1 for sampling interval for each station).

Marker horizons are sampled by cutting out a small square core and measuring the distance from marsh surface to the top of the feldspar layer on all four sides to determine the vertical thickness of sediment accretion.

Mudflat accretion grids, sediment plates and sediment pins have been used short term (weeks to months) to estimate sediment accretion rates in highly variable mudflat habitats over a seasonal temporal scale (Turner et al. 2012). Mudflat areas are subject to scour and materials sink easily; therefore, we will determine if sediment grids or pin methods work at South Slough mudflat sites for estimating short term mudflat accretion rates. Mudflat accretion grids/sediment plates are hard plates placed below the sediment surface with sediment accumulation measured on top of the plate. These have been used successfully in the past at several sites in the South Slough. Sediment pins are tall PVC poles pushed into the sediment with the height of the pole measured repeatedly over time to estimate sediment accretion or erosion.

Rebar stations were installed based on Roegner et al. 2009 methods and consist of two rebar stakes, 3 m long driven into the substrate 2.25m deep, 1 m apart and leveled. PVC tubes were installed over the rebar for visibility. To sample, a level is placed across the top of the rebar stakes and the distance from the bottom of the level to the substrate is measured at 10 cm intervals across the level. This provides relatively standardized data collection points over time. Each time the rebar station is sampled, it is checked to ensure it is still level.

iii. Vertical Reference System

Vertical Control Marks

Each SSAM-1 station, SWMP station, and the Hidden Creek Tide Gauge will have three vertical control marks associated with it once build-out is complete (Figure 3). For descriptions of each mark including type, year installed, sites tied to it, and survey data, see Table 3. Of the three marks for each site, one is designated "primary" and will be established by Static GPS observations (leveling from an existing level line is not feasible). Static surveys are accomplished in accordance with NGS specifications (NGS 2015) (e.g., continuous four-hour minimum static GPS data collection at each benchmark). The other two marks at each site are designated "secondary" and established through leveling surveys from the primary mark. SSNERR currently has primary marks installed for all sites (11 total marks). Of those, all but the Hidden Tide Gauge have been surveyed to North American Vertical Datum 1988 (NAVD88), in accordance with the National Spatial Reference System (NSRS). This provides vertical context at the station scale. In order to pull all stations into one local network (i.e., estuary scale), SSNERR staff will do simultaneous occupations at all primary marks. This will tie all stations together (since leveling between stations is not feasible), and allow for comparisons across stations. Ideally, simultaneous occupations on each primary mark will occur multiple times, several days apart, to take advantage of different satellite configurations. All data from simultaneous occupations will be tied together using OPUS Projects. Full build-out will also include 24 secondary vertical control marks. Of these, 11 have been installed and two (Charleston 1 and 2) have been surveyed to their primary mark. Once the entire network is established and tied to a local network, secondary marks will be re-leveled on a regular basis (three to six years as staff time and equipment use permits). In addition, primary vertical control marks will be checked for stability each year they are used for RTK survey work by conducting a two-hour static survey during the RTK survey. If the vertical offset of the two-hour survey is 4-6cm or greater, staff will check the OPUS report for obvious problems with the short survey (e.g., fixed ambiguities, number of observations used, etc.). If the report checks out then the mark may have moved. This will trigger staff to complete another simultaneous occupation of all primary vertical control marks. Vertical control marks are a combination of deep rod, concrete embedded brass markers, and R-SETs (Figure 3). Deep rod marks are driven to resistance (~12m deep but varies by site) with the top 0.5 m either surrounded by a capped PVC sleeve filled with sand or fitted with an R-SET adapter and filled with concrete, to minimize horizontal movement.

Five Continuously Operating Reference Stations (CORS) are in the vicinity of South Slough ranging from 53-87 km from Hidden Creek marsh (Figure 4; Table 4). These stations are used to improve the precision of GPS survey positioning. However, as South Slough is on the west coast, there is a gap in CORS coverage to the west (i.e., Pacific Ocean), reducing the potential for triangulation corrections (Figure 4).

Tide Gauges and Tidal Benchmarks

The local NWLON station is in Charleston and approximately 5.8 river km from Hidden Creek marsh. A tidal benchmark tied to this station (943 2780 Tidal 9 (PID: OA0651)) is the benchmark we plan to use during simultaneous occupations at primary vertical control marks at all stations (see above). In 2011, the NWLON station water level data was used to compare water levels at the Winchester Creek and Valino Island SWMP stations and calculate tidal datums for the SWMP stations depth/water level elevations relative to NAVD88 (US Dept. of Commerce 2003; COASTAL Team 2007, Figure 5). Tidal datums were also calculated at Hidden Creek Marsh in 2009 as part of a Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) project (Brophy et al. 2011; Figure 5).

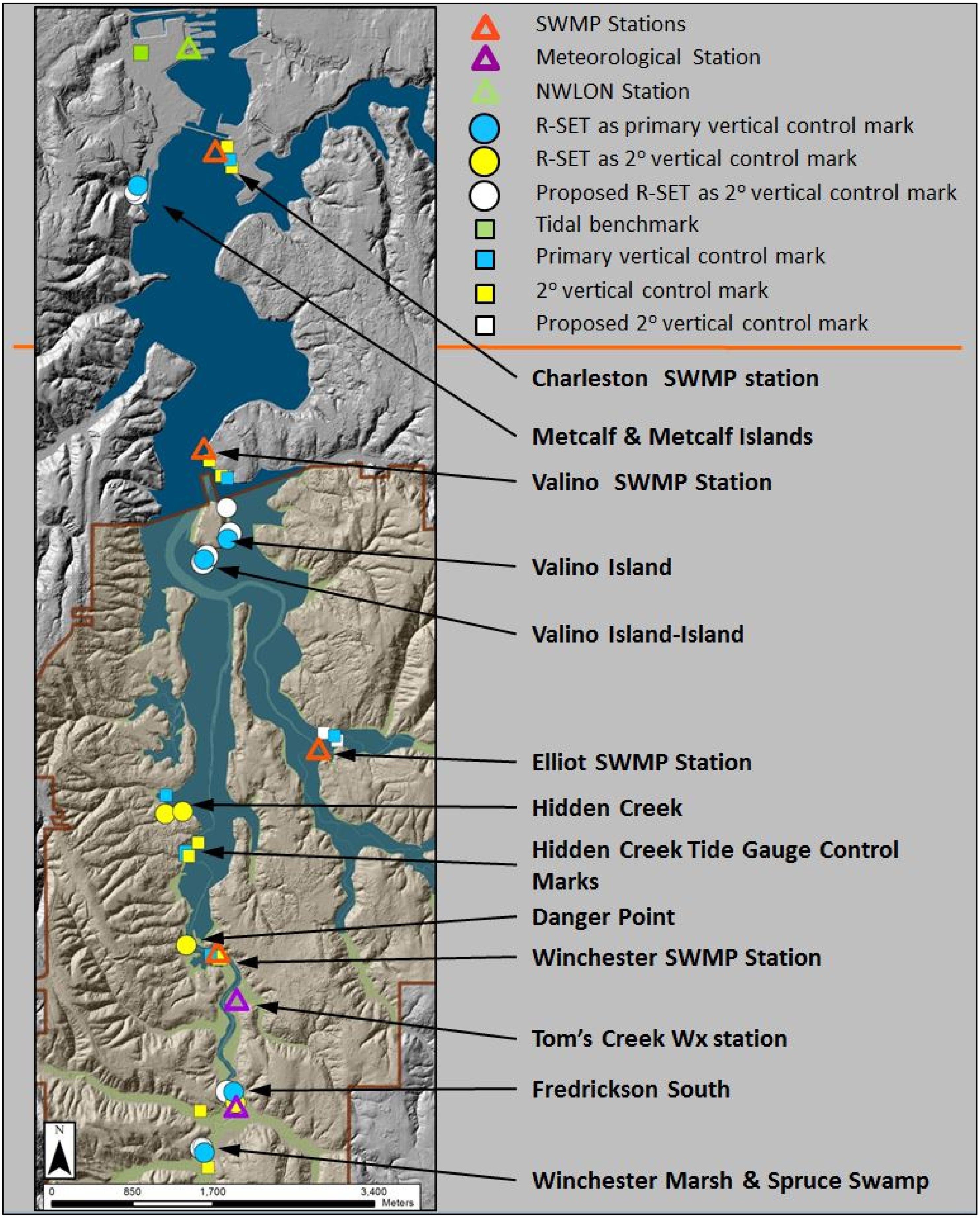


Figure 3*: South Slough Reserve boundaries (outlined in brown), established and proposed vertical control marks, SWMP stations, NOAA NWLON station, and tidal benchmark. Primary vertical control stations are those that will have simultaneous GPS observations completed. Secondary vertical control stations are those that will be leveled to from the primary station for that site.*

Table 3 (continued on next page): *Primary and secondary vertical control marks in the South Slough estuary. Nearly all marks are to support the SSAM-1 and SWMP stations. However several marks are also included that are tied to restoration projects. Proposed sites, that have not yet been installed have no information under Type/Install Year. Grayed out cells mean "no data".*

Name	Relevant Site(s)	Primary/ Secondary[2]	Type/Install Year (if known)[3]	Static Duration (h)/ Survey year	UTM_N UTM_E[4]	Ortho Height (m)[5]	Obs. Used (%)	Fixed Amb. (%)	RMS Error (m)	Peak-to-Peak Accuracy (m)
943 2780 Tidal 9 (PID:OA0651)	All sites		Tidal Benchmark on concrete slab/ 1970	Differential leveling, adjusted	4799923.21 5	4.849				
Charleston 1[1]	Charleston SWMP, Metcalf Islands	Secondary	Deep rod mark	24 / 2013	4799093.46 4	2.318	96	92	0.013	0.023
Charleston 2	Charleston SWMP, Metcalf Islands Marsh	Secondary	Deep rod mark/2013	Differential leveling/2016		2.746				
Charleston 3	Charleston SWMP, Metcalf Islands	Primary	Concrete foundation (dock ramp)/ 2010	4.7/ 2010	4799032.59 1	3.818	95	95	0.013	0.02
Crown Point S	Valino SWMP	Primary	Deep rod mark/ 2011	24/ 2013	4796641.63 4	2.304	71	86	0.018	0.021
Crown Point SW	Valino SWMP	Secondary	Deep rod mark/2013							
Crown Point W	Valino SWMP	Secondary	Deep rod mark/2013							
Danger RSET	Danger Point Marsh; Winchester SWMP	Secondary	Deep rod R-SET/ 2010							
Elliot Dike 1	Sengstacken SWMP	Primary	Brass marker in concrete/2007	4.5/ 2010	4794670.36 4	4.252	50	70	0.022	0.254
Elliot Dike 2	Sengstacken SWMP	Secondary								
Elliot Dike 3	Sengstacken SWMP	Secondary								
Fredrickson South Marsh RSET (T4)	Fredrickson South Marsh	Primary	Deep rod R-SET/ 2011	6.2/ 2015	4791947.77 392966.2	2.7	96	91	0.012	0.018
Fredrickson South Marsh RSET (T2)	Fredrickson South Marsh	Secondary	Deep rod R-SET/ 2017							
Fredrickson South Marsh RSET (T3)	Fredrickson South Marsh	Secondary								
Hidden RSET (T2)	Hidden Creek Marsh	Secondary								
Hidden RSET (T4)	Hidden Creek Marsh	Secondary								
Hidden Tide Gauge 1	Hidden Tide Gauge	Secondary	Deep rod mark/2015							
Hidden Tide Gauge 2	Hidden Tide Gauge	Primary	Deep rod mark/2015							
Hidden Tide Gauge 3	Hidden Tide Gauge	Secondary	Deep rod mark/2015							

[1] This is the average of two different static surveys in the same season

[2] Primary sites will have static GPS, secondary sites will be leveled to from primary site

3 All RSET marks surveyed using a kendapter (i.e., elevation is to top of rod)

[4] All UTM coordinates are in Zone 10

[5] Ephemeris was Precise for all OPUS calculations and all heights were computed using GEOID 12B

Table 3 continued: *Primary and secondary vertical control marks in the South Slough estuary. Nearly all marks are to support the SSAM-1 and SWMP stations. However several marks are also included that are tied to restoration projects. Proposed sites, that have not yet been installed have no information under Type/Install Year. Grayed out cells mean "no data".*

Name	Relevant Site(s)	Primary/ Secondary[2]	Type/Install Year (if known)[3]	Static Duration (h)/ Survey year	UTM_N UTM_E[4]	Ortho Height (m)[5]	Obs. Used (%)	Fixed Amb. (%)	RMS Error (m)	Peak-to-Peak Accuracy (m)
Kunz	Danger Point Marsh; Winchester SWMP	Primary	Deep rod mark/ 2013	26/ 2013	4793006.36 4	3.209	96	93	0.014	0.023
Kunz Dike Island	Danger Point Marsh; Winchester SWMP	Secondary	Concrete post							
Metcalf RSET (T1)	Metcalf Marsh	Primary	Deep rod R-SET/ 2010	4.3/ 2011	4798917.38 8	2	96	88	0.013	0.018
Metcalf RSET (T3)	Metcalf Marsh	Secondary								
Metcalf RSET (T4)	Metcalf Marsh	Secondary								
SS 2 (PID: DK6367)[1]	Hidden Creek Marsh	Primary	Brass marker in concrete/2007	10.6 / 2015	4794231.45 1	2.64	94	96	0.015	0.035
Upper Winchester	Anderson Restoration	Secondary	Deep rod mark	4.5/ 2010	4791379.27 4	2.912	92	84	0.014	0.061
Valino Is.-Is. RSET (T2/3)	Valino Island-Island Marsh	Primary	Deep rod R-SET/ 2010	3.8	4796035.92 5	2.191	99	100	0.01	0.018
Valino Is.-Is. RSET (T4)	Valino Island-Island Marsh	Secondary								
Valino Is.-Is. RSET (T1)	Valino Island-Island Marsh	Secondary								
Valino Island RSET (T3)	Valino Island Marsh	Primary	Deep rod R-SET/ 2010	3.9/ 2016	4796191.62 7	2.414	96	93	0.012	0.042
Valino Island RSET (T5)	Valino Island Marsh	Secondary								
Valino Island RSET (T4)	Valino Island Marsh	Secondary								
Wasson Creek Marsh	Wasson Restoration	Secondary	Concrete post	4.6/ 2010	4791813.12 1	7.176	87	81	0.016	0.03
Winchester Marsh RSET (T1)	Winchester Marsh and Spruce Swamp	Primary	Deep rod R-SET/ 2011	4.1/ 2016	4791494.40 2	2.72	96	98	0.012	0.02
Winchester Marsh RSET (T3)	Winchester Marsh and Spruce Swamp	Secondary								
Winchester Marsh RSET (T4)	Winchester Marsh and Spruce Swamp	Secondary								

[1] This is the average of two different static surveys in the same season

[2] Primary sites will have static GPS, secondary sites will be leveled to from primary site

3 All RSET marks surveyed using a kendapter (i.e., elevation is to top of rod)

[4] All UTM coordinates are in Zone 10

[5] Ephemeris was Precise for all OPUS calculations and all heights were computed using GEOID 12B

The nearest SWMP station (Winchester Creek) to Hidden Creek marsh is 1.9 river km away. Due to the distance and lesser accuracy of the EXO depth sensor used at SWMP stations compared to other instruments, SSNERR staff decided to install a dedicated tide gauge adjacent to Hidden Creek. A new tide station using similar instrumentation as the CO-OPS water level stations (Aquatrak5002 acoustic sensor) will be established by Reserve staff in the main channel adjacent to Hidden Creek marsh (planned Fall 2016). The AquaTrak instrument was selected for its ± 1 mm resolution, ± 0.025% calibration accuracy, ± 0.01% precision and repeatability, and 0 drift after 1 year. Water level is a function of tidal range and with a tidal range ≤ 5 m at Winchester Creek, CO-OPS recommended a sensor resolution of 1 mm or better. The instrument will be mounted on a 10" diameter steel piling driven approximately 10 m deep adjacent to the channel. Like NWLON stations, the logger will continuously record water depth on a six-minute averaging interval.

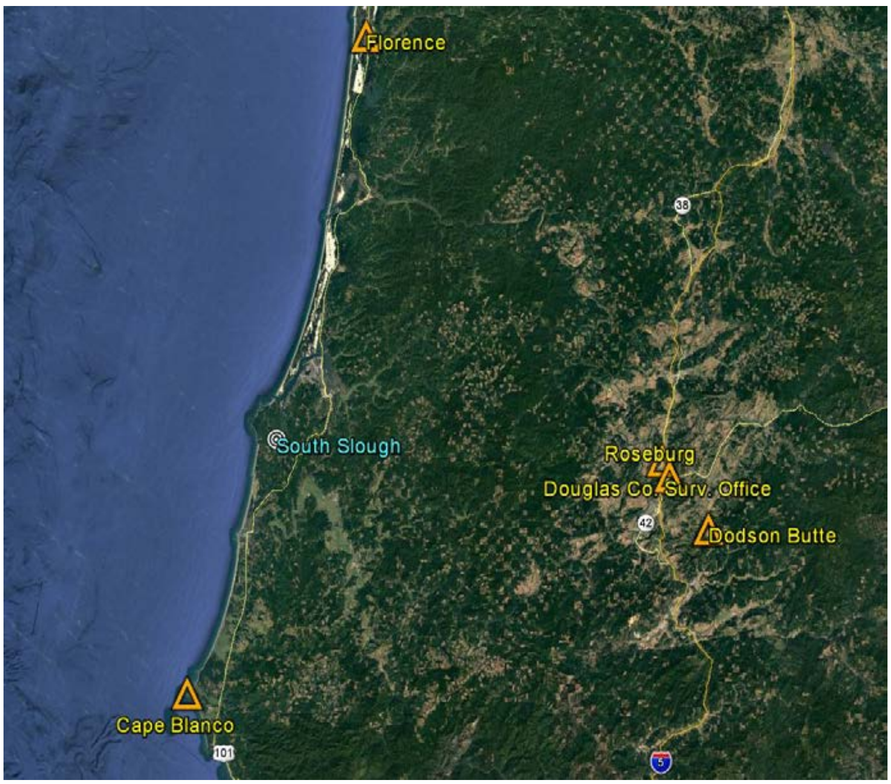


Figure 4: *Closest CORS stations (orange triangles) to the South Slough estuary. Note the absence of any stations west of South Slough due to proximity to ocean.*

CORS Station	Distance From Hidden Creek Marsh (km)	Station ID	Latitude (N)	Longitude (W)
Cape Blanco	53	AF9662	425009.939	1243347.989
Florence	80	DI0946	435900.964	1240627.692
Roseburg	80	DO8790	431406.05	1232133.727
Douglas County Surveyor's Office	80	DG9304	431239.617	1232029.39
Dodson Butte	87	AJ7211	30707.633	1231439.212

Table 4*: The closest Continuous Operating Reference Stations (CORS) to the South Slough estuary.*

Connecting SSAM-1 to Vertical Control

Vertical control will be connected to SSAM-1 components at marsh and spruce swamp stations using Trimble RTK surveys (1-5 cm precision relative to local network). Survey components currently include vegetative points (four per plot), groundwater wells, and R-SETs. Future components will include a tide gauge near Hidden Creek Marsh (which will be leveled in upon installation and then every five years following). Rover elevations at control points (first and last point in survey), and groundwater wells will be made when vertical and horizontal precision is ≤ 1 cm for a minimum of 120 seconds. Vegetation plots will have a minimum 15 second data collection period. A Kenadapter will be used on R-SET measurements. Vertical control surveying of SSAM-1 components will be done in September/October following each summer that biomonitoring sampling takes place (i.e., at the end of the dry season before any heavy rains occur). This will provide a consistency to reduce possible error related to seasonality at the wetland sites.

Responsible Parties

A timeline for completion of the vertical control network is shown in Section VII below. The Watershed Monitoring Coordinator and the Estuarine Monitoring Coordinator are primarily responsible for finishing the establishment of the geodetic network in accordance to NSRS standards, with the help of other Reserve staff. They will also be responsible for ensuring NOAA guidelines are followed to connect SSAM-1 components to the same vertical datum.

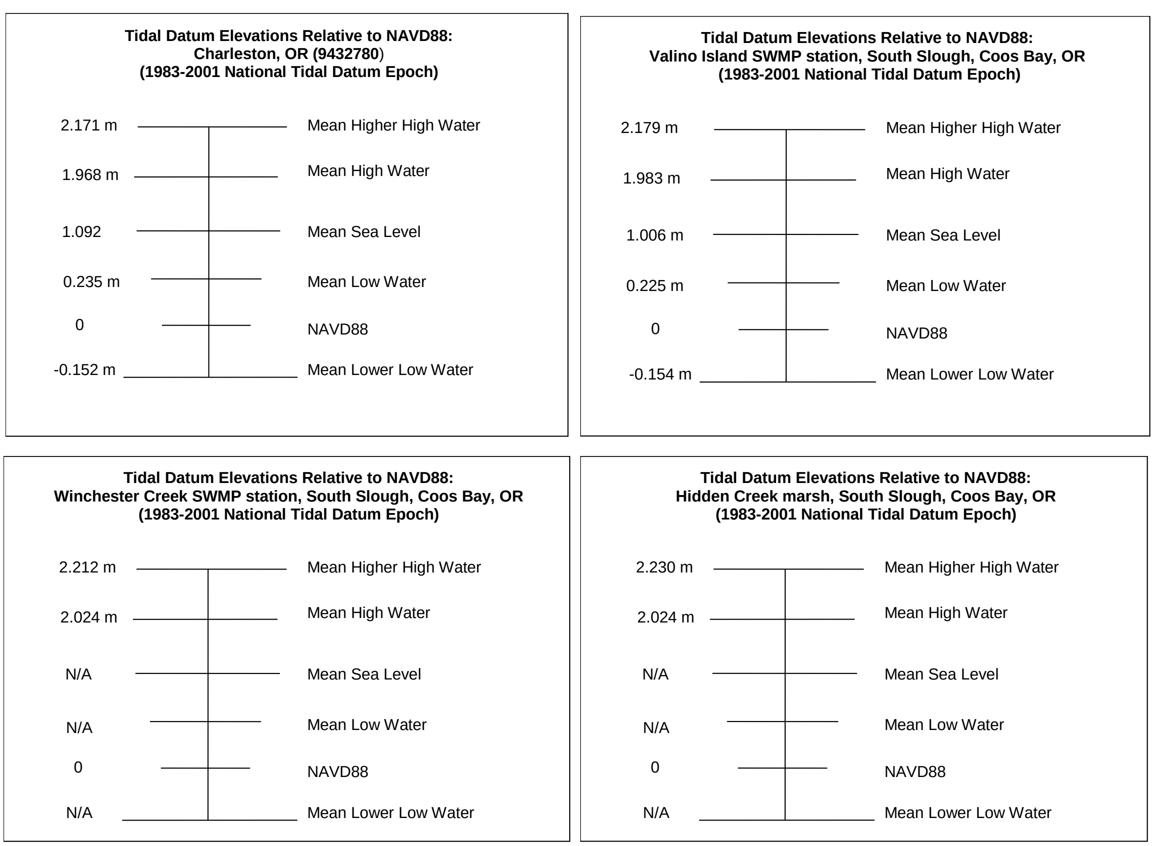


Figure 5: *Tidal Datums relative to NAVD88 at (clockwise from top left): Charleston, OR NWLON station, Valino Island SWMP station, Hidden Creek marsh, and Winchester Creek SWMP station.*

Products

High resolution elevation data will help us understand how changes in wetland elevations and tidal inundation are related to changes in vegetation composition and quality of coastal habitat over time. Elevation data products will include: 1) 35 vertical control benchmarks in NAVD88; 2) wetland (R-SET, vegetation plots) and groundwater elevation data on the same vertical datum; 3) a tidal datum adjacent to Hidden Creek marsh; and 4) four SWMP water quality stations with water levels tied to a local tidal datum. Data generated will meet our goals of accurately measuring changes in sea level, tidal inundation rates, and storm surges at a local scale. Relating this data to biomonitoring, surface elevation, groundwater levels, and water quality, we can better understand responses of wetland habitats to those stressors and identify vulnerabilities.

iv. Water Quality and Meteorological Data

The Winchester Creek SWMP water quality station is located approximately 1.9 river km south of Hidden Creek marsh and is the closest SWMP station to the site (Figure 3). There are three additional SWMP stations within the South Slough estuary (Figure 3). The SWMP water quality stations collect water temperature, specific conductivity, salinity, dissolved oxygen (% saturation and concentration), turbidity, and depth at fifteen-minute intervals. Stations are telemetered and data are available in near real-time through http://nerrsdata.org and http://nanoos.nvs.org. Nutrient and fecal indicator bacteria data are also collected monthly at three water quality SWMP stations; nutrients are also collected at a fourth station "Boathouse". Nutrient parameters include ammonium, nitrate, nitrite, dissolved inorganic nitrogen, orthophosphate, silicate, and chlorophyll *a*. Bacteria parameters include total coliforms and *E. coli* estimates.

SSNERR's SWMP meteorological station is located at Tom's Creek marsh, which is about 1.6 km south of Hidden Creek marsh (Figure 3). The station was relocated to this site June 2016. It provides real-time data on air temperature, relative humidity, barometric pressure, wind speed and direction, photosynthetically active radiation (PAR), and precipitation at fifteen-minute intervals. The station is also telemetered and data are available through http://nerrsdata.org and http://nanoos.nvs.org.

The NOAA Climate Reference Network/SSNERR maintains a weather station at Frederickson South marsh, which is approximately 2.4 km south of Hidden Creek marsh (Figure 3). This station was installed in July 2008 and collects air temperature, precipitation, wind speed, solar radiation, relative humidity, surface (infrared radiation) temperature, soil moisture, and soil temperature data at five-minute intervals. Data from this station are transmitted hourly in near real-time and available at https://www.ncdc.noaa.gov/crn/.

Total Suspended Solids (TSS), a second tier SWMP nutrient parameter, will be collected at the Winchester SWMP station in summer 2016 (NERRS 2015). TSS will also be collected at three additional SWMP stations (Boathouse, Charleston Bridge, and Valino Island). TSS data were collected previously at SWMP stations from August 2002-June 2004.

v. Elective Parameters

<u>Groundwater wells</u>

The Reserve is adding hydrological monitoring through a network of groundwater wells to collect information on water table dynamics, tidal inundation, and groundwater level (Table 2). Fluctuations in groundwater levels can affect vegetation species distribution, range and density. Groundwater wells have been or will be installed near each vegetation transect at marsh sites (see Figures 1 and 2 for current and proposed locations) following NERRS protocols, which are modified from USACE (2005) and Roman et al. (2001). Danger Point had seven groundwater wells installed in 2004 for the NERRS Biomonitoring Pilot project (Rumrill and Sowers 2008). The wells were reused for a marsh reference/restoration site project (Dionne et al. 2012) and again for the Sentinel Sites project. Two groundwater wells each at Metcalf Marsh (2016), Valino Island (2017), and Fredrickson South (2016) and six wells at Hidden Creek Marsh (2010, 2015) have also been installed. Groundwater wells will also be installed at Winchester Spruce Swamp where on each transect, the centroid of one forest/shrub plot will have a groundwater well.

Sensors to monitor water temperature and depth (Onset Hobo) and salinity (Solinst or AquaTroll) will deployed between March-December in the years when summer biomonitoring will occur (recording data at 30-minute intervals). One barometric pressure sensor will be deployed near the top of one well at the site furthest from the SWMP weather station. Marsh surface elevations at each groundwater well will be recorded near the end of the dry season in September or October of sampling years.

<u>Soil salinity</u>

Soil salinities can provide information about the distribution patterns of plant communities as well as inundation patterns (Zedler 2000), which are important for understanding potential shifts and changes in the distribution of vegetation species and the hydrologic regimes that influence their distribution. Soil salinity data was collected at two sites (Kunz Marsh and Danger Point) in the South Slough estuary as part of the NERRS Reference Site project (Dionne et al. 2012). Of the five reserves that participated in the study, SSNERR found strong correlations between porewater salinities and plant community assemblages at restoration sites while other Reserve sites did not; therefore, soil salinity may be a useful parameter for understanding current baseline conditions and how they may change with future stressors at specific sites.

During summer monitoring, soil salinities will be measured adjacent to each marsh vegetation plot using a pore-water equilibrator method developed by Erik Smith at North Inlet-Winyah Bay NERR. In brief, a modified groundwater well is installed adjacent to the plot. The well has an outer PVC sleeve with slits that allow groundwater to permeate. It has an inner PVC sleeve where two vials are physically separated and sit at the upper and lower root zones. Each vial has a permeable membrane and is inverted to expose it to soil pore water for one month. This equilibrates the soil pore water salinity conditions over that period. To sample, the inner PVC sleeve is lifted out and water from each vial is dropped onto a refractometer and recorded. At SSNERR stations, soil salinity will be sampled monthly during the year of biomonitoring. Groundwater salinities will also be measured by Aquatroll or Solinst conductivity and temperature loggers placed in groundwater wells; however, groundwater salinity measurements are only useful for characterizing general trends at a site and do not provide information for specific vegetation plots. Soil salinities will also be recorded at the Winchester Spruce Swamp site where forest/shrub plot will have a soil salinity collection installed on the northern edge of the plot for a total of 11 soil salinity locations.

VI. Data Archiving, Synthesis and Translation

Data management

Sentinel site monitoring data are collected on waterproof field datasheets with templates designed for each of the monitoring elements. The sediment dynamics template was adapted from the National Park Service (Lynch et al 2015). After fieldwork is completed, datasheets are scanned and vegetation data are entered into Access databases (one for marshes, one for eelgrass) or excel spreadsheets (sediment data, water level, groundwater level, soil salinity) and reviewed by another science staff member for quality assurance/quality control (QA/QC). Access databases for Sitka spruce swamp transects, sediment, water level, groundwater level, and soil salinity monitoring elements will be created by summer 2017. All information is saved on the SSNERR server, which is backed up daily.

During elevation surveys, field notes are recorded with receiver used (e.g., Trimble or Epoch), start and end times and antenna height. A photo of each base station or static survey is taken and archived. RTK elevation data is processed using Trimble Business Center where base station elevation can be checked and corrected if needed (based on field notes and OPUS solution from the two-hour static occupation conducted during RTK survey). Control points (1st and last RTK points in survey) are also checked to ensure they match. Data are then exported as a shapefile.

The marsh biomonitoring data along with the metadata document will be formatted into the NERRS templates by science staff and then submitted to the CDMO approximately annually. Once reviews are complete and concerns addressed, data will be incorporated into the Vegetation Monitoring Application. SSNERR staff member Ali Helms will be responsible for data submission to the CDMO.

Data Syntheses

Any elevation data used for synthesis will be checked to ensure all data are using the same Geoid model, collected during the same month, using the same elevation for the base station (when making temporal comparisons within the same site), and if possible using the same CORS stations for correction (using OPUS Projects).

Data analyses will consist of a variety of methods including linear regressions, t-tests, multi-factor Analyses of Variance (ANOVAs) and/or Multivariate Analyses of Variance (MANOVAs) depending on sample sizes and research questions addressed. Also, staff will seek help with statistical analyses from others including regional experts (e.g., Laura Brophy, Institute for Applied Ecology) and NERRS staff. For example, marsh biomonitoring and vegetation plot elevation data will be analyzed and synthesized for trends focusing on comparisons between high and low marsh elevations and compared to the 2010 datasets where applicable (i.e. vegetation plots from parallel transects, high or low, will be useful to compare to highest and lowest elevation plots of the perpendicular vegetation plots to increase replication). Comparing vegetation and vegetation elevation data from parallel and perpendicular transects will also be useful for the science staff and west coast NERRS to understand differences provided by these two transect orientations. For vegetation data, mean plant metrics (i.e. percent cover, number of plant species, densities of indicator species, and canopy heights) may be compared across elevation, groundwater level, and soil salinity factors. At secondary sentinel sites, similar analyses will be completed for plant metrics from parallel transects. In future monitoring years, data will be analyzed comparing trends across years. For example, percent cover of one or more indicator species could be tracked over time and across sites (Roegner et al. 2009).

Spruce Swamp data will be analyzed in various ways. Herbaceous cover will be analyzed similar to marsh biomonitoring data above. Shrub data will be analyzed according to number of stems of each species while trees will be analyzed for basal area, density, and percent frequency by species.

Sediment dynamic information will also be analyzed for trends and will be compared to 2011 datasets (R-SET, feldspar marker horizons) and older datasets where applicable (e.g., Hidden 1994 feldspar marker horizons, 2012 soil salinity Danger Point). For R-SET and marker horizon data, sediment trends will be combined across sites and analyzed for change throughout the system. When full build out is complete and sample sizes are sufficient, ANOVAs may be used to determine if mean surface elevation change and mean vertical accretion rates are different between sites (both primary and secondary sites). Surface elevation and accretion rates will also be analyzed with a two-way ANOVA with site and salinity as factors. Depending on these results, sediment data may also be analyzed by grouping sites by salinity zones (using data from SWMP stations) to increase replication.

Hidden Creek water levels and Elliot Creek and Charleston Bridge SWMP water levels will be used to calculate tidal datums for these sites (US Dept. of Commerce 2003; COASTAL Team 2007; Wardwell 2016). Tidal datums will be updated for Valino Island and Winchester Creek SWMP stations by recalculating datums with more data.

Groundwater level and temperature data will first be corrected for atmospheric pressure and converted into elevation relative to NAVD88. Inundation period will be calculated along with percent inundation (i.e., amount of time flooded at that location).

Additional analyses will be decided upon and completed as more data are collected and as any changes may arise with a long-term monitoring program.

Data summary reports will be produced on approximately a triennial basis during the winter season. Smaller annual reports may be produced documenting monitoring trends for the sampling year. Data summary reports will be modified into one-two page documents highlighting information for the education, outreach and coastal training program staff as well as public and stakeholder communities.

NERRS System-Wide SSAM-1 Synthesis

The SSNERR contributed and analyzed sentinel site data from 2010 and 2015 at Hidden Creek marsh to the NERRS Marsh Resilience Synthesis. Data included marsh elevations from vegetation plots (parallel, perpendicular, and NGS survey points), elevation change from one R-SET station, short-term and long-term accretion rates from marker horizons and cores, turbidity, total suspended solids concentrations, and short-term changes in water level measurements from the Winchester Creek SWMP station, and long-term changes in water level from the Charleston NWLON station. Data from 16 reserves and ten marsh metrics were compiled and analyzed to create tidal marsh indices that may influence marsh resilience to sea level rise. A manuscript reporting on these indices has been accepted for publication by Biological Conservation, due out in late Fall 2016.

VII: Timeline

Project Task/Activity	Timeline	Staff Lead(s)*
Trainings		
RTK/Leveling Training	Annually (rotated between staff)	WMC/EMC/SC
SWMP Technician Training	Annually (one-two staff)	EMC/MT
OPUS Projects	By 2020 (one-two staff)	WMC/EMC
Infrastructure Installation/ Maintenance		
Biomonitoring - Permanent transects/plots		
Emergent Marsh	Completed 2015	WMC
Eelgrass	Completed 2010	EMC
Spruce swamp	By 2018	WMC
Surface Elevation		
Marsh R-SET stations	Primary station completed 2017. Secondary stations in progress, building out all stations as funding permits.	WMC
Feldspars (3 plots) adjacent to R-SET station	In progress: each emergent marsh station has one set installed 2011/2016. Continuing to build out all stations as funding permits.	WMC
Feldspar reapplications at R-SET station	Every 10 years (next reapplication will be 2021)	WMC
Vertical Reference System		
Primary vertical control marks installed (11 marks)	Completed 2015	WMC/EMC
Secondary vertical control marks installed (24 marks)	Primary station complete 2017. All sites, 11 marks installed by 2017. Will continue to add marks as funding permits.	WMC/EMC
Tide station piling installation	Completed 2016	EMC
Tide station logger instrument installation	2017	EMC/MT
Tide station logger maintenance	Monthly	EMC/MT
Water Quality/Meteorology		
SWMP water quality station maintenance	Monthly	EMC/MT
SWMP meteorological station maintenance	Monthly	EMC/MT
NOAA Climate Reference Network maintenance	Monthly to Quarterly	EMC
Elective Elements		
Groundwater wells	Primary site completed 2010 and 2015. Continuing to build out secondary stations as funding permits.	WMC
Soil salinity tubes	Primary site by 2019. Secondary sites as funding permits.	WMC
Data Collection		
Marsh biomonitoring	June/July: nearly annually, rotated among sites	WMC
Eelgrass biomonitoring	June/July: annually	EMC
Spruce swamp biomonitoring	June/July: 2018 then every three years	WMC
Elevations of marsh and spruce swamp biomonitoring plots, groundwater wells, and RSETs	September/October: years biomonitoring takes place	WMC
R-SET measurements	June/July: years biomonitoring takes place	WMC
Feldspar cores	June/July: years biomonitoring takes place	WMC
Groundwater levels/salinity	March-December: same year biomonitoring takes place; loggers record at 30 min intervals; data downloaded every 3 months; salinity loggers calibrated every 3 months	WMC
Soil salinity	Monthly, March-December: year biomonitoring takes place	WMC
SWMP water quality data	15 minutes continuous for abiotic; nutrients and bacteria	EMC/MT
SWMP meteorological data	15 minutes continuous	EMC/MT
NOAA Climate Reference Network station	5 minutes continuous	EMC
Habitat Maps	By 2018	WMC/SC
Vertical Reference System		
Primary vertical control marks surveyed	Eleven marks completed 2017; Hidden Tide Gauge by 2018	WMC/EMC
Initial leveling to secondary vertical control marks	By 2020	WMC/EMC
Vertical control mark stability check	Two hour minimum static survey on primary marks during regular survey years; RTK survey on secondary marks same years; leveling survey to secondary marks every 3-6 years	WMC/EMC
Simultaneous static observations at all sentinel stations, SWMP stations, Hidden tide level marks, and NWLON	By 2020	WMC/EMC

** Staff position acronyms: WMC = Watershed Monitoring Coordinator; EMC = Estuarine Monitoring Coordinator; SC = Stewardship Coordinator; MT = Monitoring Technician; CTP = Coastal Training Program Coordinator; EC = Education Coordinator; PIC = Public Involvement Coordinator; ES = Education Specialist*

Timeline Continued

Project Task/Activity	Timeline	Staff Lead(s)*
Data Management		
Access database creation	Biomonitoring data completed 2010; groundwater level, water level, soil salinity, R-SET, feldspar data by 2019	EMC/WMC
Data entry and QA/QC	Biomonitoring, R-SET, feldspar, soil salinity, groundwater wells = within one week of data collection; water quality and meteorological data follow SWMP protocols	EMC/WMC
CDMO submission	Fall of years biomonitoring data collection occurs	EMC
Vertical Reference System		
Static GPS surveys	"Precise" OPUS reports filed by station within one month of data collection; data for all sites resubmitted in years of	WMC
RTK elevation data	QA/QC using Trimble Business Center, then stored as a GIS shapefile within one week of data collection	WMC
Leveling data	Entered and QA/QC within one week of data collection	WMC
Data Syntheses		
NERRS System-Wide SSAM1 Synthesis	2014-2016, manuscript 2017	EMC/WMC
Primary Vegetation and elevation data	2016, 3-6 year intervals	WMC/EMC
Secondary sites vegetation and elevation data	2016; 3-6 year intervals	WMC/EMC
Soil salinity	2020, 3-6 year intervals	WMC/EMC
Ground water level	2019, 3-6 year intervals	WMC/EMC
Sediment dynamic data (primary and secondary sites)	2018; 3-6 year intervals	WMC/EMC
Hidden Creek Water level data	2018-2019, can be updated with additional years of data	EMC/WMC
SWMP Water level data (Winchester, Valino, Charleston)	2018-2019, can be updated with additional years of data	EMC/WMC
Communication and Outreach		
Work with SSNERR staff to identify audiences	Completed as of February 2016. Will reassess as needed.	CTP/EC/PIC/WMC
Develop one-pager	2016	PIC/WMC/EMC
Sentinel Site write up - South Slough Newsletter	Summer 2016, followed by biennial write ups	PIC/WMC/EMC
Demonstration Sentinel Site installation	2016-2017	EC/WMC
Oregon State University - Estuarine Ecology class	Annually (October)	ES/EMC/WMC
TOTE workshop	By 2018	EC
Develop KEEP activities	By 2018	EC
Identify coastal mgmt training needs relevent to SSAM1	Ongoing	CTP
Develop workshops/trainings to address training needs	By 2019	CTP/EC/WMC/EMC
Engage regional audiences	2020 +	CTP/WMC/EMC
Offer trainings: infrastructure installation; monitoring protocols	2020 +	CTP/EC/WMC/EMC

** Staff position acronyms: WMC = Watershed Monitoring Coordinator; EMC = Estuarine Monitoring Coordinator; SC = Stewardship Coordinator; MT = Monitoring Technician; CTP = Coastal Training Program Coordinator; EC = Education Coordinator; PIC = Public Involvement Coordinator; ES = Education Specialist*

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