Southern Flow Corridor Project Effectiveness Monitoring Plan

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Southern Flow Corridor project site: Dike along the Trask River. Photo by L. Brophy, Aug. 15, 2013

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Introduction

The effectiveness monitoring plan for the 646-acre Southern Flow Corridor (SFC) project is designed to allow evaluation of progress towards SFC project goals and expected benefits related to flood attenuation and improved ecological function. Effectiveness monitoring will also help identify any areas where adaptive management may be needed, and will provide data to guide those management actions. The SFC project is a large public investment, and effectiveness monitoring will provide accountability for the investment, allowing the project team to clearly communicate project results to funders, the scientific community, and the public. Finally, because of the SFC project's large size, monitoring will provide valuable information to help guide other projects in the region – information that is urgently needed (Burdick and Roman 2012, NOAA Restoration Center 2013).

In this plan, we first describe the overall goals, site conditions, and engineering plans for the SFC project. Then, we present goals and objectives for the monitoring program, along with rationale, parameters, and protocols.

SFC Project Goals

As stated in Tillamook County's proposal to the NOAA Restoration Center, the goals of the SFC project are to: 1) improve habitat for native fish and wildlife, 2) improve water quality and reduce sedimentation, 3) reduce flood hazards, and 4) enhance the overall ecological health of Tillamook Bay (Tillamook County 2013).

The specific flood attenuation benefit the project is expected to provide is reduced flood elevation and duration along the City of Tillamook's highway 101 business corridor.

The SFC project proposal (Tillamook County 2013) highlighted four ecological benefits the project is expected to provide:

1. Increased habitat complexity and availability, including low and high tidal marsh, forested tidal wetland and tidal channels;
2. Increased target species use, including increases in both species distribution and density within the project area. Target species include Chinook salmon (fall and spring races), coho salmon, chum salmon, and coastal cutthroat trout;
3. Enhanced water quality – specifically, reductions in temperature and turbidity, and increases in dissolved oxygen – in reconnected and constructed tidal channels; and
4. Increased climate change resilience through re-establishment of natural sediment accumulation and accretion processes, maximizing the opportunity for the site's wetlands to keep pace with sea-level rise.

Besides the benefits to target species (salmonids), the SFC proposal identified many other species that are expected to benefit from the project (Table 1).

Table 1. Other Species

The following species are expectyed to benefit from restored project area habitats			
Fishes	**Birds**	**Mammals**	**Amphibians**
Winter steelhead[1,2,3]	California brown pelican[3,4]	Townsend's big-eared bat[2,3]	Red-legged frog
Pacific lamprey[2,3]	American peregrine falcon[2,3]	Black-tailed deer	Pacific tree frog
white sturgeon	Olive-sided flycatcher[2,3]	Raccoon	Western toad
Top Smelt	American bald eagle[3]	Beaver	Northwestern salamander
Three spine stickleback	Aleutian Canada goose[3]	River otter	Long-toed salamander
Pacific staghorn sculpin	Band-tailed pigeon[3]	Muskrat	Roughskin newt
Shiner perch	American bittern		
English sole	Great blue heron		
Starry flounder	Green heron		
	Belted kingfisher		
	Rufous hummingbird		
	Miscellaneous waterfowl		

1- NOAA species of concern; 2- State sensitive species 3- Oregon Conservation Strategy key species; 4- State endangered species

SFC Site Conditions Summary

The SFC project proposal to NOAA (Tillamook County 2013) describes the site's land use history as follows: Earth levees surround nearly the entire 646 acre project area and have excluded the site's former tidal wetlands from tidal inundation for over 60 years (Figure 1). The area north of Blind Slough, which was not diked until the 1960's and appears to have never been farmed, has converted to a freshwater wetland with water levels regulated by tide gates. The northwest portion of the site along Hall Slough has naturally higher elevations and supports an area of Sitka spruce tidal swamp. South of, and adjacent to Blind Slough, a large area was managed for waterfowl after the cessation of agricultural activities, resulting in a series of excavated water features. Pasture production is active in the southeast area, and land is protected from the Trask River and Hoquarten and Dougherty Sloughs by levees. The easternmost portion of the project is dominated by historic spruce swamp with dike remnants along Hoquarten Slough limiting full floodplain connections. Numerous tide gates connect the project site to adjacent channels, but limit both juvenile salmon access and natural hydrological processes. Relict tidal channels are still clearly visible throughout the site. Typical interior land-surface elevations in the non-forested portions of the site are 1.9 to 2.1 m above NAVD88. Based on comparison with adjacent reference sites, subsidence of up to 0.5 m has occurred over large areas of the project site, particularly in pasture areas.

The project area is located at the terminus of a flood conveyance pathway for flows that leave the Wilson River valley. In recent decades flooding has increased in frequency and severity. Following the 1996 floods, a bank of ten, six-foot diameter tide gates were installed to discharge floodwaters that were trapped behind the dike. Most recently, a high capacity spillway consisting of four side-hinge 6x12 foot tide gates was installed to further increase flood drainage capacity.

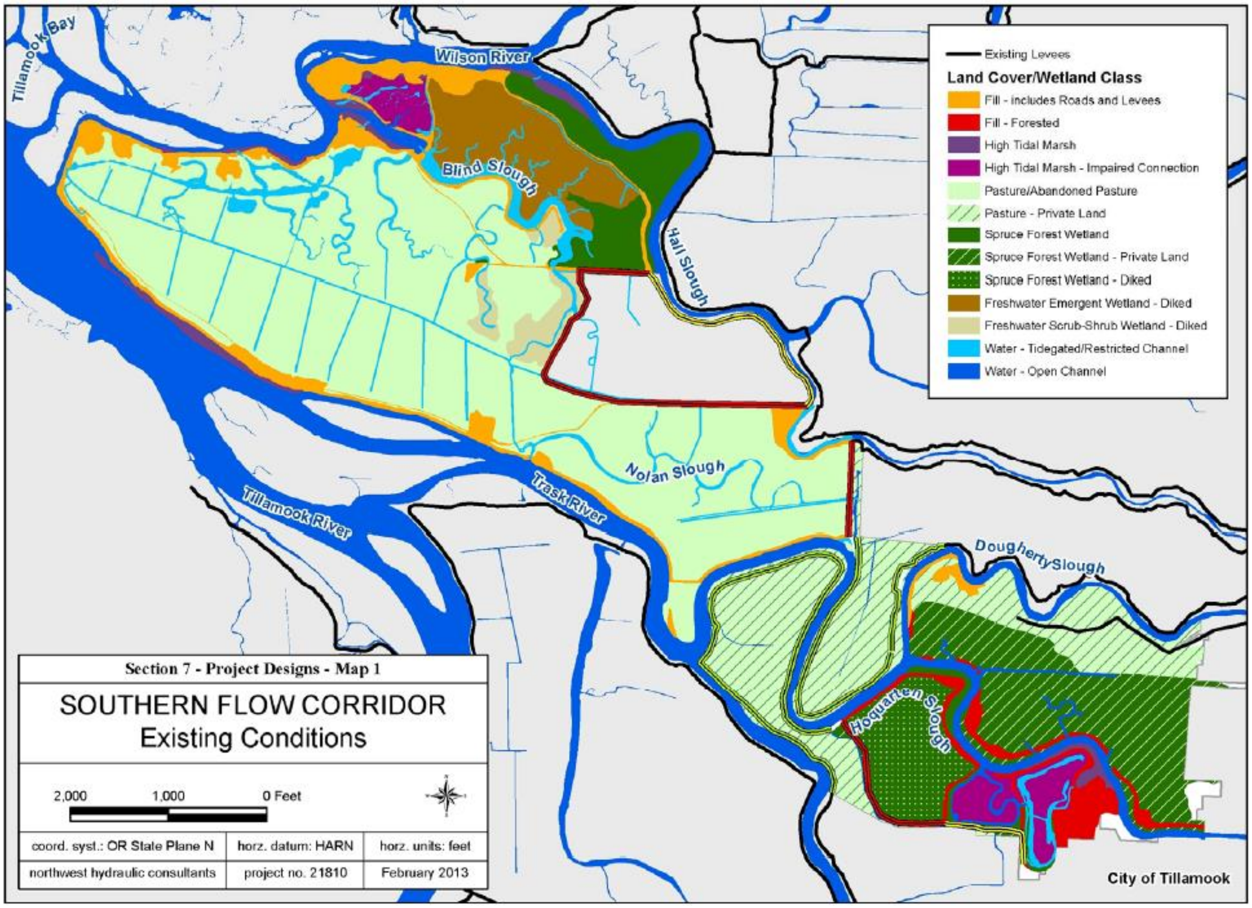

Figure 1. SFC project area: existing conditions

SFC Project Actions

By November 2015, construction contractors for the SFC project will implement the following actions (Figure 2):

- Remove 11 km of existing levees and 3 km of road
- Reconnect nine major tidal channels totaling 23 km in length
- Add large woody debris where logistically feasible to tidal channels
- Fill 5 km of drainage ditches to re-establish natural drainage regimes
- Lower over 3 km of existing levees
- Upgrade and construct over 3 km of dikes to protect adjacent landowners' property
- Remove and/or relocate seven tide gates and one floodgate
- Remove four buildings

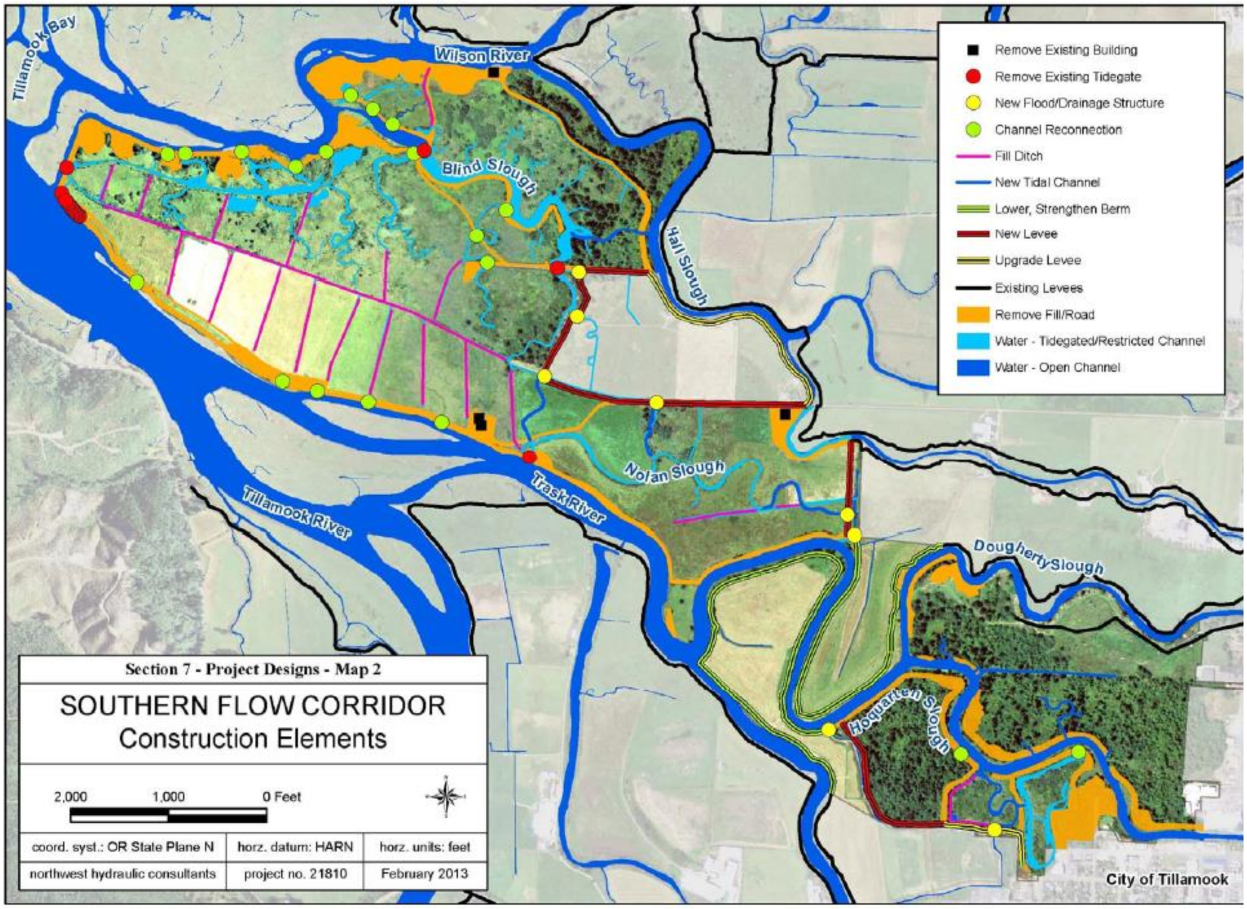

Figure 2. SFC project area: Construction elements

Effectiveness Monitoring Approach

Ecosystem Conceptual Model

Effectiveness monitoring at the SFC project site is based on a simple conceptual model of ecosystem function (Table 2). As shown in the conceptual model, stressors at this former tidal wetland (e.g. diking, ditching, grazing, and soil compaction) have altered the levels of ecosystem controlling factors (e.g. tidal hydrology, groundwater levels, and water quality). Those changes in controlling factors have affected ecosystem structures, processes and functions at the site. For example, diking has blocked most tidal inundation, and grazing and vegetation manipulation have led to dominance of reed canarygrass, considered an invasive species in wetlands. Actions at the SFC site are designed to remove or reduce those stressors, allowing the return of natural controlling factors such as tide levels, groundwater levels, soil characteristics, and water temperature. Re-establishment of natural hydrologic processes will in turn allow re-establishment of ecosystem structures, processes, and functions, such as support for juvenile salmonids, sediment detention, production of organic matter, and habitat suitable for native plant communities.

Table 2. Simple conceptual model of ecosystem function at the SFC site. This model focuses on factors related to the effectiveness monitoring plan; not all alterations, controlling factors, ecosystem structures, ecosystem processes or ecosystem functions are shown.

Alterations →	**Controlling → factors**	**Ecosystem → structures**	**Ecosystem → processes**	**Ecosystem functions**
Tidal restriction (dikes, tide gates)	Tidal hydrology	Emergent wetlands	Sediment accretion/erosion	Salmonid habitat
Ditching	Groundwater level	Shrub wetlands	Channel system development	Salmonid prey production
Grazing/veg manipulation	Water quality	Forested wetlands	Plant community succession	Native vegetation support
Soil compaction	Water temperature	Tidal channels		Organic matter production
Non-native and Invasive species		Soil characteristics		Sediment detention

Effectiveness monitoring will measure physical conditions and biological outcomes at all levels of the conceptual model (Appendix 1, Table A1). Monitoring reports will provide clear information on flood attenuation benefits achieved, the use of the site by target species, the trajectory of biological and physical changes at the site. By monitoring physical conditions as well as biological outcomes, monitoring will demonstrate not just that the project was built to specifications, but that natural processes have been re-established – maximizing sustainability of the project into the future (Simenstad and Bottom 2002).

Sample Design

Effectiveness monitoring will use a before-after/control-impact (BACI) sample design (e.g., Stewart-Oaten *et al.* 1986). Least-disturbed tidal wetland reference sites will be sampled to help evaluate the status of the project site and interpret trends in recovery trajectories of tidal wetland structure and function. Reference sites will represent both the habitat classes anticipated as shorter-term (5-15 yr) outcomes (e.g., low tidal marsh) and longer-term (50-100 yr) outcomes (e.g., high tidal marsh). Effectiveness monitoring will begin with pre-construction baseline data collection, followed by post-construction monitoring during the 2nd, 4th, and 6th years after project implementation is complete (Appendix 1, Tables A2 and A3). Additional data collection and analyses are recommended every five years thereafter.

Geographic Focus

Geographically, monitoring will focus on the 211 ha (521 acres) of pastures and lowlands being reconnected to tidal influence, west of the confluence of Dougherty and Hoquarten Sloughs (Figure 3). These areas are the central focus of the NOAA grant and will receive the bulk of the earthworks. The SFC project includes other actions that are more limited in area and scope. For example, discontinuous berms along the banks of Hoquarten and Dougherty Sloughs will be removed, enhancing connectivity to the existing forested tidal wetlands to help improve water quality in Hoquarten Slough. Monitoring associated with the Hoquarten berm removal will consist of the Tillamook Estuaries Partnership's (TEP's) ongoing water quality monitoring program, which will help track any changes resulting from the removal of the berms. The TEP water quality monitoring program is described at http://www.tbnep.org/programs/water-quality.

Target Species

To allow evaluation of the project's effectiveness in meeting its goals, monitoring of wildlife responses will focus on target fish species: Chinook salmon (fall and spring races), coho salmon, chum salmon, and coastal cutthroat trout. However, during fish monitoring, other fish species will be enumerated along with the target species and all species will be included in diversity indices. Fish monitoring will also include evaluation of habitat quality and prey resources, and measurements of fish, habitat and prey resources will be tightly linked, both spatially and temporally, allowing exploration of the relationships among components of the ecosystem conceptual model (Appendix 1, Table A1).

Linked Monitoring of Biological and Physical Parameters

The SFC project's ecological goals include increased complexity and availability of tidal wetland habitats. To evaluate this goal, we will conduct spatially and temporally linked monitoring of biological and physical characteristics that define those habitats and indicate their functions. Vegetation will be intensively sampled, since it provides a strong indicator of wetland condition (Adamus 2006). Within a randomly selected subset of vegetation sample sites, we will measure physical drivers that are strongly associated with wetland functions and prioritized in regional and national monitoring guidance (Roegner *et al*. 2008, Thayer *et al*. 2005, Simenstad *et al*. 1991, Rice *et al.* 2005, Zedler 2001): including groundwater levels, soil organic matter content, and soil salinity. Sediment accretion, which is strongly associated with climate change resilience (Cahoon *et al*. 2006), will be measured in the same locations as soil characteristics. This "co-location" of vegetation and physical conditions monitoring will allow analysis of the relationships illustrated in the ecosystem conceptual model (Appendix 1, Table A1). The tight links between biological and physical conditions in this monitoring plan will create a dataset that will be valuable in assessing the effects of climate change in the Tillamook Bay Estuary and along the Oregon coast.

Effectiveness Monitoring Goals and Objectives

The goals of SFC effectiveness monitoring are:

1) To determine the degree to which the project meets its overall goals (see *Southern Flow Corridor Project Goals* above), including evaluation of the level of structural and functional recovery taking place at the project site;
2) To help identify adaptive management needs (if any), and to provide data and interpretation to assist adaptive management if needed;
3) To provide the SFC project team with information that will be useful in communicating project results to funders, the scientific community, and the public;
4) To provide scientifically-sound data to help guide other similar projects and advance the understanding of estuarine wetland ecosystems; and to disseminate that information to other practitioners, resource managers, decision-makers, and scientists.

EM Objective 1: Vegetation. Quantify the development of vegetation communities within the SFC project site (including non-native and invasive species) and assess their degree of similarity to vegetation within reference wetlands.

Parameters: Plant species richness; percent cover (including non-native and invasive species); distribution and extent of plant communities

EM Objective 2: Wetland physical conditions. Quantify changes in hydrologic, topographic and edaphic parameters that support wetland functions and organisms using tidal wetland habitat.

Parameters: Wetland surface elevation, tidal inundation regime, groundwater regime, soil pH, soil salinity, soil % organic matter and carbon content, sediment accretion, channel morphology

EM Objective 3: Target fish species use, prey resources, and habitat. Quantify changes in target fish species use of the site, and the quality of target species habitat at the project site.

Parameters:
Fish: Fish presence, abundance, diversity, and species richness
Prey Resources: Benthic macroinvertebrate density and taxonomic composition
Habitat: Tidal exchange; channel water temperature; salinity; pH; dissolved oxygen; tidal channel morphology; in-stream habitat including large woody debris (LWD) abundance.

EM Objective 4: Flood attenuation. Quantify changes in flood levels in the vicinity of the project during flooding events.

Parameters: Water levels (stage recorders), maximum water levels (crest gages), floodplain structures and conditions

Effectiveness Monitoring Hypothesis

Monitoring at SFC is designed to evaluate the following two hypotheses:

1. *Implementation of the SFC project will result in reduction of flood levels.*
2. *Implementation of the SFC project will result in changes in the project site's physical and biological characteristics that show a statistically significant trend towards conditions at the reference sites.*

The first hypothesis will be evaluated by Northwest Hydraulic Consultants (NHC) by flood modeling using the off-site water level data and methods described in this plan.

The second hypothesis will be evaluated by comparing physical and biological data between the SFC project site and reference sites during each monitoring year. These comparisons, as well as trends over time, will be analyzed using the methods described in ***Data Analysis*** below. Data from other Oregon tidal wetland restoration and reference sites monitored by the SFC monitoring team (e.g. van de Wetering and French 2002, 2005; van de Wetering *et al*. 2007, 2009; Brophy 2009, Brophy and van de Wetering 2012, Brophy *et al.* 2011) will be used to assist interpretation and broaden the context for the project.

Tidal reconnection and removal of flow barriers, as planned at SFC, generally produce trends towards reference conditions. However, short-term results can differ from reference conditions. For example, opportunistic non-native species (or native colonizers not common at reference sites) may temporarily dominate plant communities during the early years after reconnection (e.g., Cornu and Sadro 2002). Such temporary conditions may or may not call for adaptive management. With each monitoring progress report, the monitoring team will evaluate observed trends and recommend adaptive management if needed.

Effectiveness Monitoring Sites

The SFC project site is located at the confluence of the Wilson and Trask Rivers. Monitoring will occur at the SFC project site, at two nearby reference sites (Figure 3).

SFC Project Site

Sampling will occur within wetlands and channels across the SFC project area. Sampling will be stratified into zones to reflect differences in conditions across the site. Stratification is recommended in estuarine and other habitat monitoring because it allows greater ability to detect change over time by compartmentalizing the variability inherent in variable natural systems (Elzinga *et al*. 1998, Simenstad *et al*. 1991). A common approach is stratification by elevation zone, but based on initial reconnaissance and review of background data, elevations at the site appear to be quite homogeneous (that is, the site is quite flat). However, land use history differs markedly across the site. Below, we list the planned sampling strata (wetland sample zones and fish monitoring zones); these are areas of relatively homogeneous land use history (Figure 3). Tides are currently blocked from all of these areas by dikes and tide gates.

Project Site Wetland Sample Zones

- **North Wetland Zone:** Less-intensively-altered, freshwater wetland area to the north of Blind Slough. This area appears not to have been farmed (Tillamook County 2013), although it was probably grazed.
- **Middle Wetland Zone:** Abandoned pastureland to the north of Goodspeed Road and south of Blind Slough. This zone has been actively managed as pasture in the past, but it has many intact remnant channels, in contrast to the South Wetland zone.
- **South Wetland Zone:** Farmed land south of the centerline ditch, adjacent to the Trask River. This zone is heavily ditched and intensively managed.
- **Nolan Slough Wetland Zone:** Active pasture surrounding Nolan Slough. The level of ditching in this zone is intermediate between the South Wetland Zone and the Middle Wetland Zone.

Fish Monitoring Zones

- **Blind Slough Mainstem:** Blind Slough and its tributaries are the primary channel system for the North and Middle Wetland Zones. Prior to construction of the centerline ditch, the Blind Slough system probably carried the majority of daily tidal flows into the South Wetland Zone. Reconnection of Blind Slough to tidal exchange will drive recovery of wetland functions across much of the SFC site.
- **Blind Slough Tributary:** This tributary connects to Blind Slough just downstream of the Blind Slough Mainstem tide gates; it is also currently tide gated. It is representative of the mid-sized tidal channels that predominate in the Middle Wetland Zone. The upper reach of this tributary is ditched, and is representative of the ditched channels found in the South Wetland zone.

- **Nolan Slough:** This channel system drains the eastern third of the main SFC project area. Historically, the middle and upper reaches of the Nolan Slough channel system were surrounded by Sitka spruce tidal swamp (Hawes *et al.* 2006).

Least-disturbed Reference Sites

Prior to diking, in the mid to late 1800s, the SFC site was predominantly high tidal marsh; the easternmost portions of the site were tidal swamp (shrub/forested tidal wetland) dominated by Sitka spruce (Hawes *et al.* 2006). However, due to subsidence, low marsh is likely to form on the majority of the site during the initial years after project implementation. Least-disturbed reference sites that contain both low tidal marsh and high tidal marsh are therefore particularly appropriate for interpretation and analysis of SFC monitoring data. The low marsh reference data will provide a useful yardstick for evaluating the SFC site's initial recovery trajectory. Over the longer term, as accretion progresses, the site may return to its pre-disturbance wetland type (high marsh). High marsh reference data will allow evaluation of the site's progress towards this original wetland class.

Reference sites in geomorphic settings similar to the SFC site are most likely to provide useful information on effects of past site alterations, and interpretation of future biological and physical changes after project implementation. The SFC site's geomorphic setting within the Tillamook Bay estuary is characterized by a strong river flooding regime (high fluvial influence), high riverine sediment loads (Philip Williams and Associates, 2002), and a strong salinity gradient (Lee and Brown 2009). The site's position on the tidal marsh/tidal swamp ecotone is also of strong interest for re-establishment of native vegetation and for selection of reference sites.

Reference Site Wetland Sample Zones

Three least-disturbed reference sites in geomorphic settings similar to the SFC site will complete the before-after/control-impact (BACI) design. Reference sites are used as a "yardstick" to measure the effectiveness of the SFC project, interpret the SFC site's post-implementation trajectory; and track overall changes in the vicinity (Thayer et al. 2005). The selected reference sites include both low marsh (the wetland class most likely to develop on the site in the short term, due to subsidence) and high marsh (the wetland class that was historically present on the SFC site). The reference sites will thus provide the appropriate comparisons for evaluation of short-term and long-term project effectiveness, as well as understanding of the effects of human manipulation of the site.

- **Dry Stocking Island:** This site includes both low and high tidal marsh; each will constitute a separate sample zone. The island is located at the confluence of the Trask and Tillamook Rivers. Based on historic vegetation mapping (Hawes *et al.* 2006), it has expanded considerably since the mid- to late 1800s. Similar marsh expansion (progradation) has occurred throughout the Tillamook Bay estuary, due to the high sediment loads carried by the estuary's five major rivers (Philip Williams and Associates 2002, Ewald and Brophy 2012). A dike was constructed near or on the island in the late 1800s in an attempt to improve navigation in Hoquarten Slough (Coulton *et al*. 1996). The dike's exact location is not known, but it probably influenced sediment deposition in the area. Despite the historic actions to improve navigation, channels on the island itself appear to be undisturbed, and were ranked in good condition by Ewald and Brophy (2012).
- **Bay Marsh:** This undiked low marsh site is located just west of the SFC site, within the extensive marsh that has accreted at the edge of Tillamook Bay since European settlement (Dicken 1961,

Philip Williams and Associates 2002). During the immediate post-project period, tidal inundation regime and other controlling factors are likely to be very similar at this site and the lower parts of the SFC wetlands.

- **Goose Point:** The Goose Point wetlands, about 3 km north of the SFC site, were identified as a least-disturbed tidal marsh in the Tillamook Tidal Wetland Prioritization (Ewald and Brophy 2012) and the Bay City Local Wetland Inventory (Wilson *et al.* 1997). The site contains mature high marsh, providing useful reference for pre-disturbance conditions at SFC as well as the site's longer-term trajectory.

Fish Monitoring Zones

- **Dry Stocking Island:** This site's channels will provide useful reference for fish use, habitat conditions, and macroinvertebrate communities. Selection of monitoring reaches will occur during field reconnaissance in mid-October 2013.
- **Wilson and Trask Rivers:** Fish monitoring will also be conducted in the Wilson River and Trask Rivers. These rivers provide the "supply" of species for a tidal wetland; data from the river systems will be used to interpret fish monitoring results in the recovering wetlands.

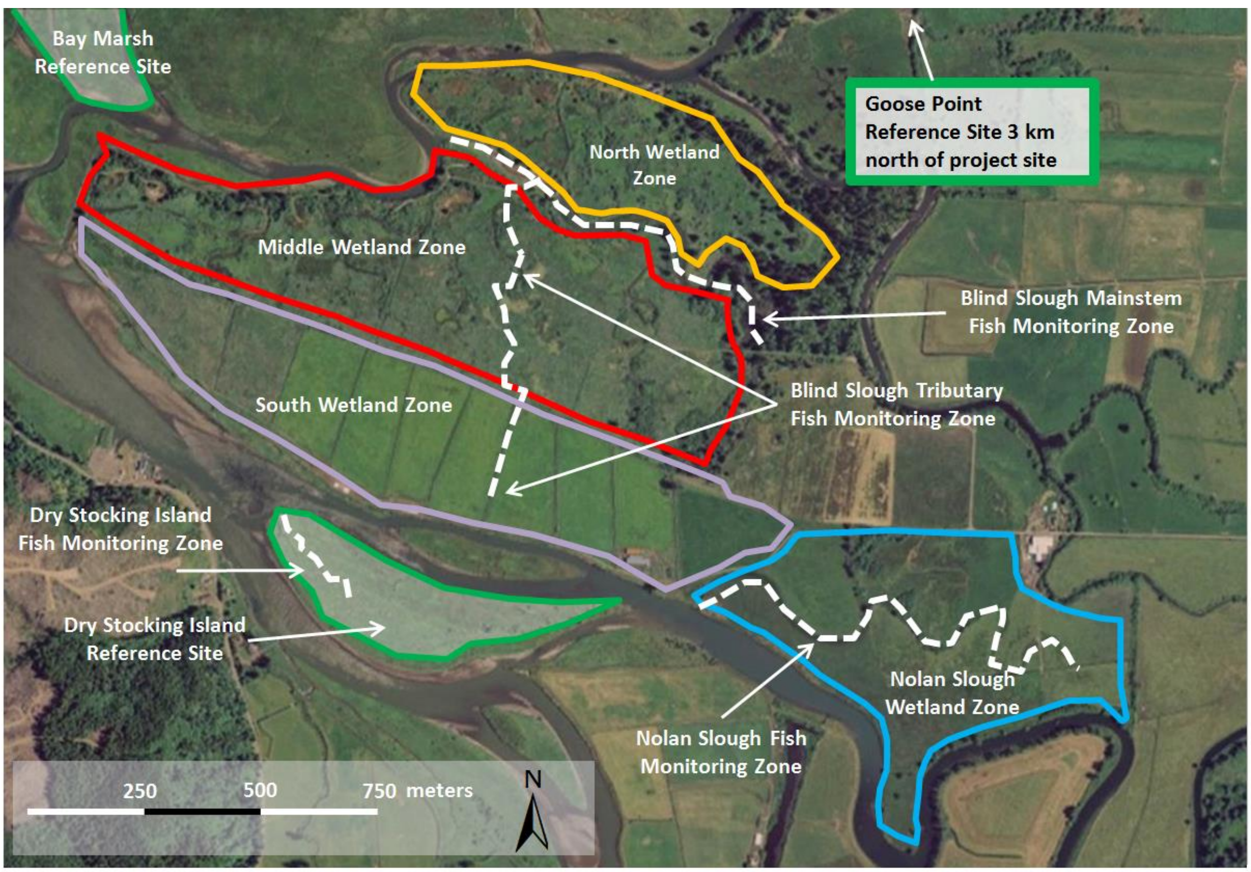

Figure 3. SFC project area: Wetland monitoring zones (sampling strata) and fish monitoring reaches

Effectiveness Monitoring Parameters and Protocols

The monitoring protocols described in this plan have been used in similar efforts in Oregon (e.g., Brophy and van de Wetering 2012, Cornu *et al*. 2011), and are recommended by regionally- and nationally-relevant sources (Roegner *et al*. 2008, Thayer *et al*. 2005, Simenstad *et al*. 1991, Rice *et al.* 2005, Zedler 2001).

Monitoring parameters and protocols are described below, and summarized in Appendix 1, Table A2. Sample locations and sample numbers are preliminary, and will be finalized during fall 2013 to summer 2014. The colored symbols below refer to the maps of monitoring locations (Figures 4 and 5). Relationships between the parameters and the conceptual model are shown in Appendix 1, Table A1.

Water level, water temperature and salinity, key ecological controlling factors in tidal wetlands (Thom *et al.* 2004), will be monitored in tidal channels on the SFC site and reference sites (Figure 4). Results will be used to:

- Document tidal restriction and water temperature and salinity fluctuations before project implementation;
- Document the degree to which SFC actions re-established tidal influence;
- Provide data on controlling factors, to assist interpretation of other monitoring results such as plant communities and fish populations. Changes in water level, salinity and temperature are expected to relate closely to post-implementation trajectory for these and other parameters (Appendix 1, Table A1).

We will follow protocols in Roegner *et al.* (2008), deploying automated water level loggers collecting data at 15 min intervals for a full year during the baseline period and during years two, four, and six after project implementation (Appendix 1, Tables A2 and A3). Water levels will be tied to a geodetic reference frame (NAVD88) via survey methods (see Vertical Control Monuments below), and tidal datums will be calculated. Water level data will be augmented by data from water level loggers deployed in groundwater wells, which will help describe differences in tidal inundation regimes across the site's extensive wetlands.

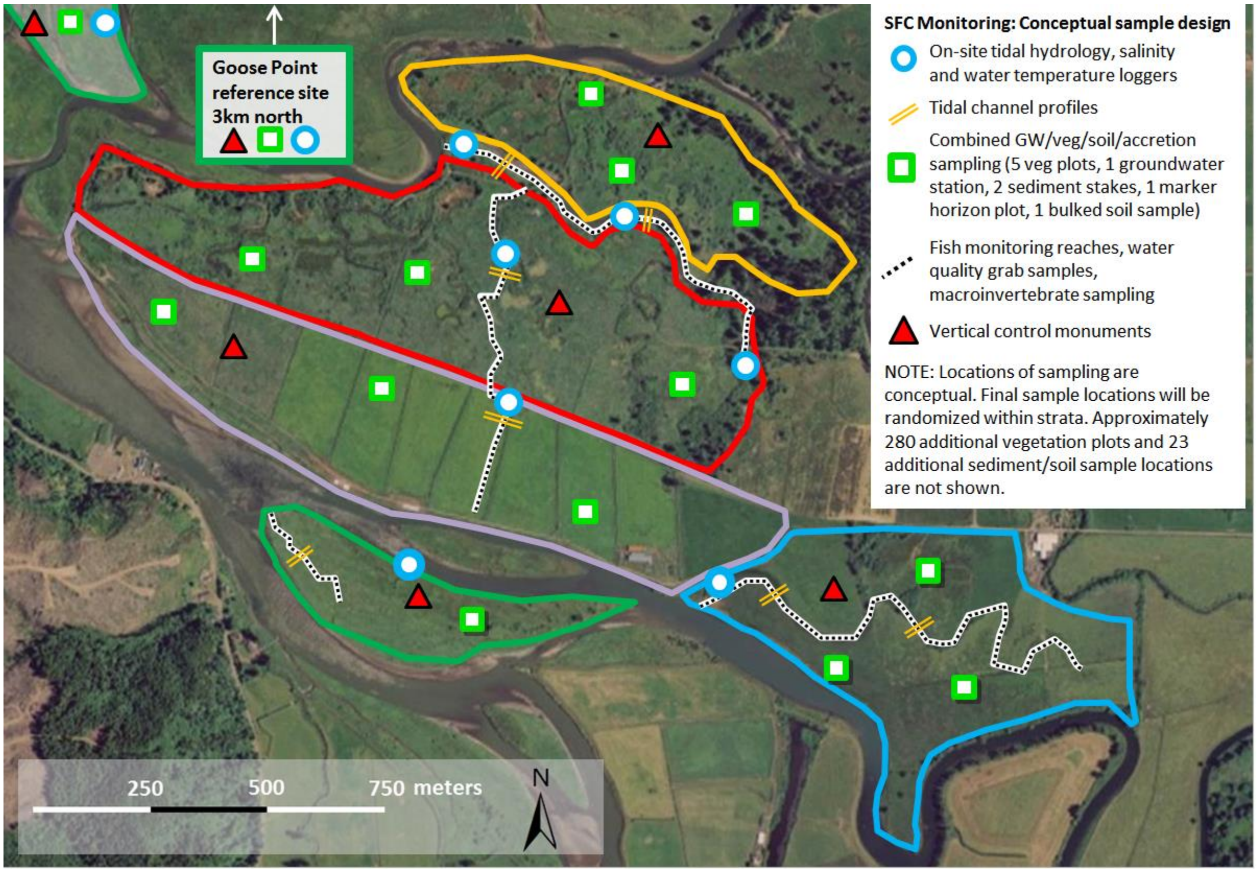

Figure 4. SFC project area: Conceptual sample design. Final sample locations will be randomized within strata (for physical drivers and vegetation), or based on field reconnaissance (for all other parameters). Approximately 250 additional vegetation plots and 23 additional sediment accretion/soil sample locations are not shown. Sampling strata are shown in Figure 3.

△ ***Off-site water levels*** will be monitored in key river channels and at the mudflat west of the project site (Figure 5). Results will be used to:

- Validate the flood reductions projected in hydraulic modeling during the project design phase.

Off-site water level monitoring will be conducted by NHC using water level recorders; the data collection interval will be the same as the on-site water level recorders (15min). Duration of off-site water level monitoring will be 5 years after project implementation is completed. Water levels will be tied to the geodetic datum through elevation surveys. Maximum water levels will be verified using independent crest stage gages co-located with each off-site water level recorder.

Flood modeling will be conducted by NHC for events above the 2-yr level during the 5-yr monitoring period. All recorded water level data, NOAA tide gage and USGS stream gage data will be loaded into a HEC-DSS database for use in the modeling effort. Data used, calibration and validation performed, and results of event simulation will be reported in a technical memorandum, which will provide comparisons of the simulated flood event under with- and without-project conditions, and comparisons with flood level reductions simulated during the design phase. Thus, modeling will document the degree to which actions at the SFC project site attenuated local flooding.

Off-site water level loggers will be multi-parameter devices that will also collect water temperature and salinity data, which will be used in combination with the on-site water temperature and salinity data to interpret other monitoring results, such as fish use and plant community development.

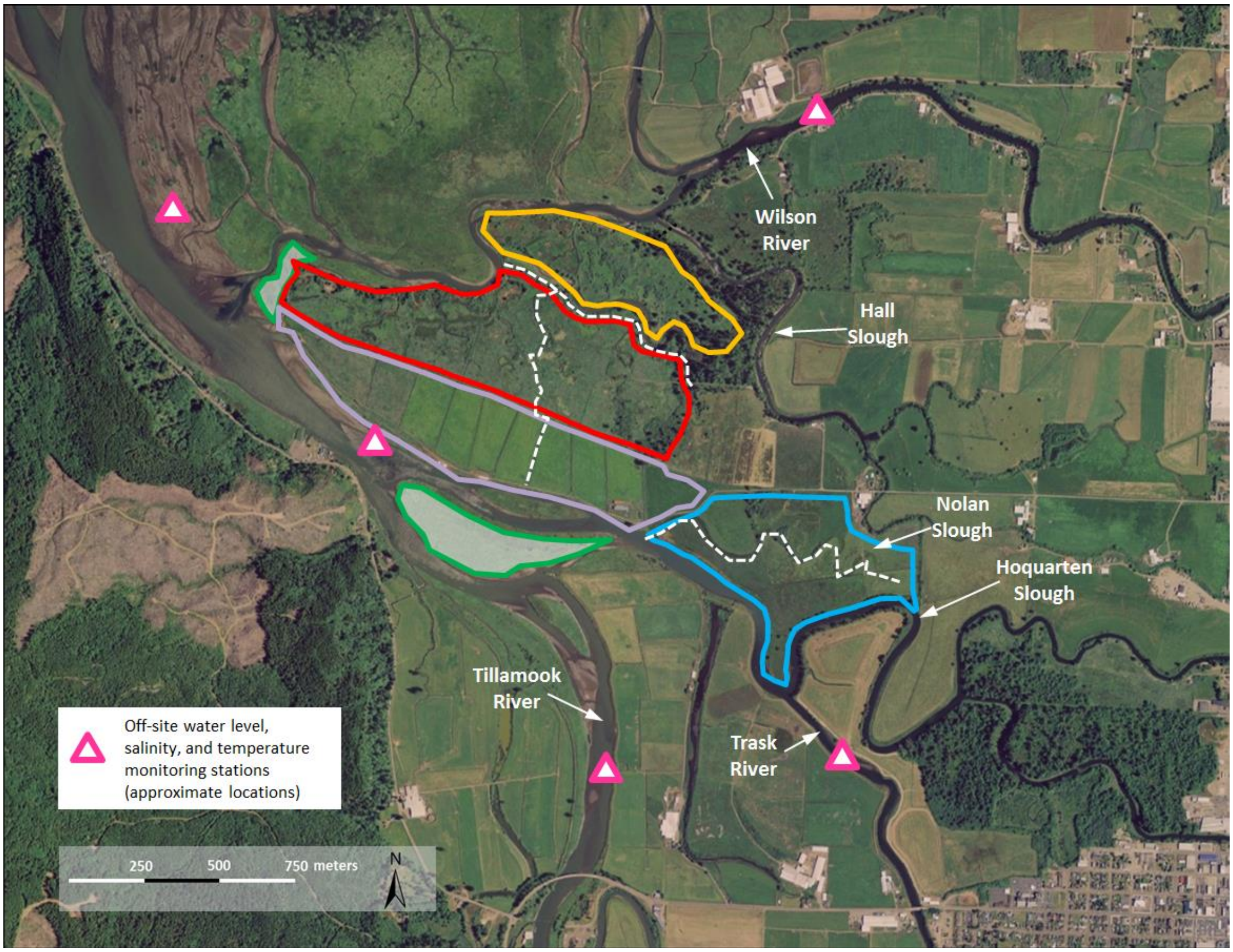

Figure 5. SFC project area: Approximate locations of off-site water level/salinity/temperature monitoring stations.

Vegetation will be monitored in 200-300 stratified random plots located within wetland sample zones at the SFC site, and in reference site wetlands. (For clarity, only fourteen of these plots – those co-located with groundwater sample locations -- are shown in Figure 4. A hypothetical sample layout is shown in Figure 6.) Results will be used to:

- Document changes in plant communities at the project site prior to and following project implementation, relative to reference sites;
- Document the degree to which native tidal wetland vegetation communities are re-established;

- Provide information on relationships between vegetation development and hydrologic, topographic and edaphic parameters including wetland surface elevation, tidal hydrology/inundation regime, water and soil salinity fluctuations, soil characteristics and groundwater level dynamics; and
- Document the presence and extent of invasive vegetation colonization, which will inform post-implementation adaptive management strategies, if needed.

Vegetation at the SFC project site and reference sites will be sampled using standard quadrats (1.0 m^2). Approximately 200-300 quadrats will be placed at random across the entire project, with numbers per stratum proportional to stratum area. Samples per stratum will range from 60 to 100 in the large South Wetland zone to less than 15 in low marsh at the reference sites. Computerized mapping (Geographic Information Systems) will be used to assign random locations within strata.

Vegetation measurements at each quadrat will include percent cover and species richness. Sampling will occur during the growing season during the baseline year and two, four and six years post-implementation (Appendix 1, Tables A2 and A3).

For sample points in forested areas, a rapid-assessment method may be substituted for the standard 1.0 m^2 cover quadrats. The method consists of brief (e.g., 15 min) timed-searches of woody, and herbaceous plants will be conducted by a single investigator within a predefined radius of the sample location (e.g., 20 m). Species lists will be used to determine differences in composition (e.g., ordination of species presence-absence lists), and species richness (species accumulation curves). Overall percent cover of canopy-forming trees, shrubs, and understory emergent vegetation will also be assessed in each rapid assessment area. This method will be refined based on time requirements in the field.

Physical conditions monitoring will be co-located with vegetation plots as follows (Figure 6):

- Groundwater sample stations (shallow observation wells) will be located at a randomly selected subgroup of 14 quadrats (3 in each wetland sample zone on the SFC project site, and 1 to 2 in high marsh at each reference site).
- Soil sampling and accretion/erosion sampling (feldspar marker horizon plots and sediment stakes) will be co-located with the 14 groundwater sample stations, and also at an additional 23 randomly selected vegetation plots.
- Of the remaining vegetation plots, 56 will be clustered around the combined vegetation/physical drivers sample sites (Figures 4 and 6) to provide greater ability to interpret linkages between groundwater regime and plant communities. These “clustered vegetation plots” will be placed at N-S-E-W bearings and at random distances from the groundwater well.
- The remainder of the vegetation plots (150 to 250 quadrats) will be not have associated physical conditions sampling.
- Elevation will be determined for every vegetation quadrat using RTK-GPS or leveling.

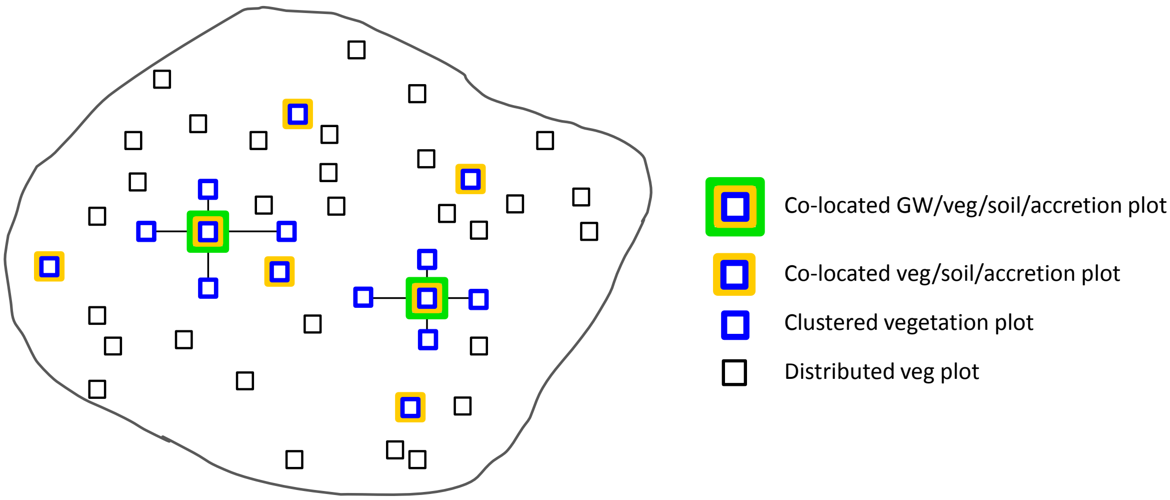

Figure 6. Diagram of a hypothetical sample layout for spatially linked vegetation and physical conditions monitoring. In this example, there are 2 combined GW/vegetation/soils/accretion sample locations, 8 clustered vegetation plots nearby, 5 co-located vegetation/soil/accretion sample locations, and 30 distributed vegetation plots.

Plant community mapping: In addition to the vegetation sampling described above, we will map plant communities within the wetland monitoring zones and reference sites (Figure 3). Mapping will use plot data along with aerial photographs (NAIP imagery) and field ground-truthing; plant community boundaries will be heads-up digitized with GIS software. Calculated metrics will consist of area of native-dominated and non-native-dominated communities, area of each vegetation alliance (major groupings of plant communities), and area of each mapped community.

Groundwater level will be monitored at a randomly selected subset of approximately 14 vegetation quadrats (12 at the SFC project site, and 3 in high marsh reference sites) (Figure 4). Results will be used to:

- Document groundwater level dynamics prior to tidal reconnection;
- Determine the degree to which the natural hydroperiod is re-established within project wetlands;
- Help interpret the results of other monitored parameters, including plant community development, water quality, water temperature, and soil characteristics.

We will follow the standard national protocol for shallow groundwater level monitoring (U.S. Army Corps of Engineers 2005), as modified by Brophy *et al.* (2009) for use in tidal wetlands. We will deploy automated water level loggers in each well and collect data at 15 min intervals for full year deployments prior to SFC project implementation. After project implementation, due to the low elevation of the majority of the SFC site's wetlands (apparently around 0.4m below MHHW, based on initial reconnaissance), we expect groundwater levels to equilibrate near the soil surface year-round, since inundation will occur daily. Groundwater will be monitored for strategic periods during Year 2 after implementation, and the extent and duration of further post-implementation groundwater monitoring will be based on the observed patterns during Year 2. Water levels will be tied to NAVD88 through elevation surveys (see Vertical Control Monuments below). During each monitoring year, groundwater depth relative to the soil surface will be calculated and compared to tidal water levels, and relationships between groundwater levels, associated tidal inundation period, and plant community composition will be described. Groundwater will not be monitored in low marsh at the reference sites, since past experience has shown that it generally remains at the soil surface year-round (Brophy 2009, Brophy *et al.* 2011, Brophy and van de Wetering 2012).

Sediment accretion/erosion will be monitored at approximately 37 sites co-located with a subset of randomized vegetation plots (Figures 4 and 6). Results will be used to:

- Quantify changes in vertical accretion or erosion after project implementation;
- Determine whether accretion rates in wetlands in the project site are comparable to, or exceed, projected rates of sea level rise; and
- Help interpret the results of other monitored parameters including plant communities, fish populations, and water quality (i.e., turbidity), which will help define relationships between sedimentation and the post-implementation trajectory for these and other parameters.

We will follow protocols provided in Roegner *et al*. (2008) and in Cahoon and Turner (1989) to measure changes in accretion or erosion, including deposition or erosion of organic and inorganic material, using sediment accretion stakes and feldspar marker horizon plots. Baseline measurements will be made prior to SFC project implementation, and two, four and six years post-implementation (Appendix 1, Tables A2 and A3). Elevation of sediment accretion stakes and feldspar marker horizon plots will be established through elevation surveys (see Vertical Control Monuments below).

Soil organic matter, pH and salinity will be monitored at approximately 37 sample sites co-located with a subset of randomized vegetation plots (Figures 4 and 6). Results will be used to:

- Evaluate differences in soil characteristics before and after project implementation, relative to reference wetland conditions; and
- Help interpret the results of other monitored parameters, particularly plant community development.

Soil characteristics are controlling factors for plant community development and relate closely to valued wetland functions like nutrient cycling, carbon storage, and water temperature moderation (through surface/subsurface flow connections). Soil samples will be collected during the baseline year and in Year 4 after implementation by pooling several subsamples in the vicinity of each co-located vegetation/soil/accretion plot (Appendix 1, Tables A2 and A3). Samples will be analyzed by the Oregon State University Central Analytical Lab following standard national protocols (USDA NRCS 1996, Dane and Topp 2002, Sparks 1996). Methods will include percent organic matter by loss on ignition, and pH and electrical conductivity of the soil solution (soil salinity). In addition, we will explore the potential of working with high school or community college students to collect more extensive data on soil salinity using field sampling methods (syringe and refractometer) (Callaway *et al*. 2001). Relationships between soil characteristics and plant community composition will be examined and will help interpret plant community data.

Tidal channel morphology (channel profiles and in-stream habitat) will be monitored in representative tidal channel reaches in fish monitoring zones (Figure 4). Results will be used to:

- Evaluate channel morphology characteristics before SFC project implementation, and changes after implementation, relative to reference site channels;

- Quantify in-stream habitat;
- Quantify effects of woody structure placements on in-stream habitat;
- Help interpret the results of other monitored parameters, including fish populations and plant communities.

We will follow protocols in Roegner *et al.* (2008), measuring channel cross sections prior to SFC project implementation and two, four and six years post-implementation (Appendix 1, Tables A2 and A3). Five permanent cross sections will be located in the upper and lower portions of the fish monitoring zones (Blind Slough Mainstem, Blind Slough Tributary, Nolan Slough, and Dry Stocking Island) and will be evaluated for changes. During this same period, longitudinal channel profiles will be described using permanent elevation markers and channel center line elevation measurements within the same fish monitoring zones. In-stream habitat, as defined by low tide fish refugia, pools, glides, bars, and presence of wood structures, will be mapped and used for analysis of fish distribution, diversity, abundance and migration. For the constructed channel system, cross-sections, longitudinal profiles, channel length and sinuosity will be used to describe newly formed salmonid habitats, and these characteristics will be compared to pre-implementation and reference data.

Fish distribution, diversity, abundance, and tidal migration patterns

will be measured in fish monitoring zones plus the Wilson and Trask Rivers (Figure 4). Results will be used to:

- Document pre-implementation fish use in remnant tidal channels and constructed ditches in the project area;
- Describe the degree to which salmonids and other fish species use reconnected and constructed tidal channels;
- Describe tidal migration patterns in reconnected and constructed tidal channels; and
- Describe fish use of channels before and after placement of large woody debris.

We will follow protocols in Roegner *et al*. (2008) and van de Wetering (2007). Fish monitoring zones will be stratified into habitat reaches using channel order, elevation, wood structure density, salinity and temperature. Sampling will occur during low tide to allow for a focus on low water refugia, generating species distribution, diversity and abundance estimates by habitat zone. Seine sampling will occur five times per year during each monitoring year (pre- implementation baseline, and two, four and six years post- implementation) (Appendix 1, Tables A2 and A3). We will use standard Catch per Unit Effort (CPUE) estimates to compare sites, reaches, habitat zones and time periods.

Tidal migration patterns will be measured using underwater video monitoring techniques during the peak use period of May and June (van de Wetering *et al*. 2007). Baseline monitoring will provide data on fish use before SFC project implementation (dike and tide gate removal as well as channel reconstruction and habitat enhancement - wood placement). Post-implementation monitoring will document potential shifts in fish use patterns across the restored marsh. The focus of this work will be to describe how, through daily migrations, fish use the mainstem river and the restored marsh as a series of optimal habitats.

Water quality grab sample data collected during fish monitoring activities will also assist interpretation of fish use (see Water Quality below). Interpretation of fish data will also be aided by other controlling factors described in this monitoring plan (e.g., on-site water level, temperature and salinity, and tidal channel morphology).

Fish prey resource communities (benthic macroinvertebrates) will be sampled in fish monitoring zones (Figure 4). Results will be used to:

- Compare benthic macroinvertebrate communities between the SFC project site and reference sites;
- Compare benthic macroinvertebrate communities in remnant tidal channels versus excavated ditches prior to SFC project implementation; and
- Describe the degree to which benthic macroinvertebrate communities recolonize reconnected channels *versus* constructed tidal channels in the project site. (Availability of this comparison will depend on whether final design includes tidal channel construction.)

We will follow protocols provided in the Estuarine Habitat Assessment Protocol (Simenstad *et al*. 1991) for benthic macroinvertebrates. Benthic macroinvertebrates will be sampled in September from channel sediments in the four of the fish monitoring zones (Figure 4) and in the Wilson River. Eight replicate core samples will be taken in each sampling zone. Sampling will take place prior to SFC project implementation and two, four and six years post-implementation (Appendix 1, Tables A2 and A3). Samples will be retained in labeled sample jars, and fixed in the field with a 7% solution of isopropyl alcohol. Samples will be washed through a 0.5 mm sieve and specimens counted and identified to the finest taxonomic resolution possible without dissection (generally to family).

Water quality parameters will be grab-sampled during fish monitoring activities in fish monitoring zones (Figure 4). Results will be used to:

- Document water quality conditions prior to SFC project implementation in remnant tidal channels and excavated ditches at the project site, and least disturbed tidal channels at reference sites;
- Quantify changes in water quality parameters in reconnected and constructed tidal channels; and
- Help interpret post-implementation changes in other monitored parameters, including fish populations and plant communities.

Grab sampling will be done using a Hach Hydrolab data logger, which collects temperature, dissolved oxygen, salinity, pH, depth, and turbidity data.

Monitoring by other groups: In addition to the grab samples described above, staff from the Tillamook Estuaries Partnership (TEP) will operate dataloggers in sloughs near the SFC project site as part of the Tillamook Estuaries Water Quality Monitoring and Analysis program (http://www.tbnep.org/programs/water-quality) following TEP's standard protocols. Temperature, salinity, pH, dissolved oxygen, depth and turbidity data will be collected at 15 min intervals using YSI multi-parameter data sondes. Duration of monitoring will span pre-implementation and post-implementation periods. Placement of the sondes will be coordinated with the SFC monitoring team to improve interpretation of SFC site conditions and project effectiveness. Time series data analysis will be conducted by TEP staff; the results will be reported in the TEP's periodic reports.

Vertical control benchmarks will be established at approximately four locations on the SFC project site, and at one location at each reference site. The monitoring team will use these benchmarks to ensure accurate and repeatable elevation measurements during monitoring activities. In addition, the monitoring team will establish local benchmarks at reference sites, tying to the survey benchmarks or to the geodetic reference frame using laser level, RTK-GPS, or other survey equipment. If possible, a subset of the monuments will be established as permanent deep-rod monuments following NOAA National Geodetic Survey protocols (e.g., Smith 2010). The remaining monuments will be established using re-bar or similar materials to ensure stability for approximately 5-10 years. Monument elevations will be determined to 1 cm (or greater) accuracy by GPS or total station leveling. Monitoring sites will be re-surveyed during each period of effectiveness monitoring (Appendix 1, Tables A2 and A3).

Data Analysis

Sampling of vegetation, ground water, sediment accretion and erosion, and soil characteristics uses a stratified random design with coupling of vegetation and environmental measurements in a subset of vegetation plots. As described above, all plots within the six "strata" in the study (North Wetland Zone, Middle Wetland Zone, South Wetland Zone, Nolan Slough, and high and low marsh at reference sites) will be randomly distributed.

Co-located physical and biological measurements will be conducted on the same plots during pre- and post-implementation periods. This sampling design will enable (i) direct comparison of conditions in wetlands with different land use histories, (ii) comparison of conditions between the SFC site and the reference sites (both low marsh and mature high marsh), and (iii) examination of linkages between vegetation development and environmental measurements such as groundwater, tidal elevation and soil organic matter.

Pre-implementation comparisons between the SFC project site and reference sites (total plant cover, native species cover, non-native species cover, species richness, tidal elevation, and additional environmental parameters) will be conducted with parametric and/or non-parametric ANOVA. Pre- and post-implementation metrics will be compared between the SFC wetlands and reference sites with repeated-measures ANOVA. Plant community composition will be examined by using similarity indices, multivariate ANOVA (PERMANOVA), and/or ordination (e.g., non-metric multi-dimensional scaling based on Bray-Curtis dissimilarity indices). Effect size analysis (Hedges *et al*. 1999) will be used to examine project effects across all parameters.

Time-series analysis (e.g., graphical display of data and trend analysis) will be conducted on temperature, salinity, and ground water time series. Water level data will be used to compute local tidal datums following standard NOAA procedures (NOAA 2003).

Relationships between biological parameters (e.g., cover of native plant species) and environmental variables (e.g., soil salinity) will be examined with simple or multiple regression. Additional statistical tools such as hierarchical partitioning (Chevan and Sutherland 1991) may be used to model relationships between environmental conditions and biological community structure.

For fish monitoring, seining will measure species presence, Catch Per Unit Effort (CPUE) (a measure of abundance), species diversity, and species richness. Fish metrics and habitat metrics will be compared between the SFC project site and the reference sites using parametric and non-parametric ANOVA. Pre- and post-implementation comparisons will be carried out using repeated measures ANOVA. Analysis will focus on describing changes in habitat availability (access), habitat types (tidal exchange rates/water availability, temperature, salinity, wood density), and habitat use by species and life history stages (young of the year, yearling and/or reproducing adults) of those same species.

Tidal migration monitoring measures movement of aquatic species i) along the river's corridor that acts as a "supply" of species for a tidal wetland, and ii) into and out of a given tidal wetland. This analysis is used to provide an understanding of rates of daily migration into and out of tidal wetlands relative to the river habitats, as well as the species present and their life history stage. Pre- and post-implementation migration profiles relative to changes in access (tide gate removal), tidal exchange rates, temperature and salinity will be compared.

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Appendix 1. Additional Tables

Table A1. Relationships between monitoring parameters and the SFC ecosystem conceptual model. A numeric code indicates which parameter(s) will be used to characterize each factor in the conceptual model (see the list of parameters below the table for the codes).

Alterations →	Controlling → factors	Ecosystem → structures	Ecosystem → processes	Ecosystem functions
Tidal restriction (dikes, tide gates) 1	Tidal hydrology 1	Emergent wetlands 2	Sediment accretion/erosion 4	Salmonid habitat 7
Ditching 6	Groundwater level 3	Shrub wetlands 2	Channel system development 6	Salmonid prey production 8
Grazing/veg manipulation 2	Water quality 1, 9	Forested wetlands 2	Plant community succession 2	Native vegetation support 2
Soil compaction 2 (elevation), 5	Water temperature 1, 9	Tidal channels 6		Organic matter production 5
Non-native and Invasive species 2		Soil characteristics 5		Sediment detention 4

Monitoring parameters:

1 = Tidal water levels, temperature and salinity (continuous dataloggers)
2 = Wetland vegetation (including elevation of each of 300 vegetation sample plots)
3 = Groundwater levels
4 = Sediment accretion/erosion
5 = Soil characteristics (% organic matter, pH, salinity)
6 = Tidal channel morphology
7 = Fish distribution, density, and tidal migration patterns
8 = Fish prey resources
9 = Water quality at fish monitoring sites (temperature, DO, salinity, pH, depth, turbidity)

Table A2. Effectiveness monitoring summary

Parameter	Method/equipment	Frequency / timing	Sample locations*	Protocol citation(s)
On-site water level, temperature and salinity	Water level via Onset HOBO datalogger; temperature and salinity logger via Odyssey datalogger	Interval: 15min Duration: 1 year duration in baseline and yrs 2, 4 and 6 post-implementation	Blind Slough (inside and outside tide gates, and upper reach); lower and upper reaches of Blind Sl. Tributary; Nolan Slough mouth (inside tide gate); Wilson River at west end of SFC site; 2 reference sites	Roegner *et al*. 2008, Rice *et al.* 2005
Off-site water level, temperature and salinity	Water level, temperature and salinity logger (Solinst or equivalent)	Interval: 15min Duration: 5 yr starting after project implementation	Wilson, Trask and Tillamook Rivers, tidal marsh near SFC site, and mudflat west of SFC site	Vaughn Collins, personal communication 2013
Vegetation	% cover by species in randomly placed quadrats; plant community mapping by heads-up digitization on orthophoto base	1x/yr in baseline and yrs 2, 4 and 6 post-implementation	200-300 1 sq-m quadrats randomized within strata. Mapping: All wetland sample zones and reference sites (Figure 4)	Roegner *et al.* 2008
Groundwater level	Continuous water level logger (Onset HOBO) in shallow observation well (approx. 1m depth)	15min interval for 1 year in baseline and at least 1 month in summer of year 2; then re-evaluate for yrs 4 and 6 post-implementation	Co-located with a subset of approx. 14 random vegetation quadrats at project site site and high marsh reference sites	Sprecher 2000; Brophy 2009a, Brophy *et al.* 2011
Sediment accumulation/ vertical accretion	Sediment stakes and feldspar horizon markers	1X/year in baseline andyrs 2, 4 and 6 post-implementation	Co-located with a subset of approx. 37 random vegetation quadrats	Roegner *et al.* 2008; Cahoon and Turner 1989
Soil organic matter, pH and salinity	%OM by loss on ignition; conductivity and pH of soil solution via laboratory analysis.	1x/yr in baseline and yr 4 post-implementation	Co-located with a subset of approx. 37 random vegetation quadrats. 1 core bulked from 10 subsamples, from shallow root zone (upper 30cm)	Dane and Topp 2002; Sparks 1996
Tidal channel morphology	Survey rod and level, laser level, or RTK-GPS	1x/yr in baseline and yrs 2, 4 and 6 post-implementation	Selected portions of fish monitoring reaches	Roegner et al. 2008, Rice *et al.* 2005
Fish distribution, density and tidal migration patterns	Seining and video monitoring techniques	1x/yr in baseline and yrs 2, 4 and 6 post-implementation	Fish monitoring reaches in Blind Slough, Blind Slough Tributary, Nolan Slough, and Dry Stocking Island; Wilson and Trask Rivers	Roegner et al. 2008; Van de Wetering *et al.* 2007
Fish prey resources (benthic macroinvertebrates)	Sediment cores in dewatered ditch/tidal channel sediments	1x/yr in baseline and yrs 2, 4 and 6 post-implementation	Sampling sites adjacent to tidal channel cross-sections in fish monitoring reaches	Simenstad *et al.* 1991
Water quality	Grab samples: Hach Hydrolab datalogger (temperature, DO, salinity, pH, depth, turbidity)	During fish monitoring activities	In fish monitoring reaches	Roegner *et al.* 2008, OPSW 2001
Vertical control benchmarks	RTK-GPS or total station	Establishment in baseline year; re-survey in yrs 2, 4 and 6 post-implementation	To be determined; 4 locations on project site, 1 location at each reference site	Roegner et al. 2008, Smith 2010

* monitoring for all parameters will occur at the SFC project site and reference sites

Table A3. SFC project timeline. [Year 6 monitoring is not shown, but will repeat the Year 4 timeline.]

	2013					2014												2015											
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
PHASE 1																													
Land and Easement Acquisition		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
Management Plan Revision																X	X	X	X	X	X								
Final Design		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X												
Geotechnical Investigation			X	X	X																								
Cultural Resources			X	X	X																								
Permitting								X	X	X	X	X	X	X	X	X													
Bid Process																		X	X	X									
PHASE 2 - CONSTRUCTION																													
Site Preparation																						X	X						
Interior Perimeter Work																							X	X	X	X			
Interior Restoration Work																								X	X	X			
New Levee Construction																								X	X	X	X		
Final Breaching																											X		
Project Closeout (As-built documentation by contractor)																											X	X	
Monitoring																													
Monitoring Plan Development																													
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Fish at LWD (Yr 4 post implementation only)																													

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2013-15 Monitoring Plan Development and Baseline Monitoring

2016-17 Year 2 Post-Construction Effectiveness Monitoring

2018-19 Year 4 Post-Construction Effectiveness Monitoring