Section 5: Project Description

1. ***Project Objectives*****:** The primary purpose of the proposed pilot project is to demonstrate that thin-layer sediment augmentation is an effective sea-level rise adaptation tool for ensuring the long-term preservation of coastal salt marsh habitat along the California coast, along with the protection of the ecosystem services provided by this habitat including the valuable carbon sequestration and carbon storage capacity of California's tidal salt marshes. We intend to demonstrate that the implementation of sediment augmentation along the California coast can provide net greenhouse gas (GHG) benefits along with benefits to other ecosystem services, including listed and sensitive species conservation.
   The objectives of this project include:

   - Enhance 10 acres of subsiding tidal salt marsh habitat by applying 10,000 to 13,500 cubic yards [CY] of clean dredge material as a fairly uniform thin layer of sediment, about 8 to 10 inches (20.32 to 25.4 centimeters [cm]) deep, to achieve and maintain a minimum three-inch increase in the marsh plain elevation within the project site two year after sediment augmentation;

   - Within one year of sediment augmentation, provide foraging opportunities for migratory birds and the light-footed Ridgway's rail within the project site;

   - Within two years of sediment augmentation, achieve a diversity and abundance of benthic invertebrates within the project sediments that are similar to the selected reference site;

   - Within two years of sediment application, achieve stem heights and stem densities of Pacific cordgrass (*Spartina folisa*) equal to or greater than pre-project conditions, and within five years of sediment application achieve stem heights, stem densities, and below-ground root structures that exceed pre-project conditions and thereby result in a net increase in the carbon sequestration capacity within the site, as well as enhanced habitat quality to support the endangered light-footed Ridgway's rail (formerly called the light-footed clapper rail [*Rallus longirostris levipes*]) and other salt marsh-dependent species;

   - Within five years of sediment application, demonstrate that enhancing the vegetative cover within this tidal salt marsh site has produced net GHG benefits that can be duplicated in other tidal salt marsh habitat along the California coast that is threatened by sea-level rise and/or subsidence.

   - Produce and disseminate a thin-layer sediment augmentation guidance document that describes this "proof-of-concept" project, including a description of the procedures and techniques employed to achieve uniform sediment depths and minimize movement of sediment offsite (including the effectiveness of all tested procedures and lessons learned) and a discussion of the biological and physical monitoring results (including estimated carbon sequestration and carbon storage rates at the project site prior to and after sediment augmentation), to facilitate future thin-layer sediment augmentation projects along the California coast, and hold a workshop/webinar to present interim results two years post application and final results five years post application.

2. ***Background and Conceptual Models:***
   Overview. Tidal marshes accumulate and store carbon in their plant matter, roots, and soils and are recognized for their role in carbon sequestration and carbon storage (http://thebluecarboninitiative.org, accessed on 12/05/14, Brevik and Homburg 2004, Chmura et al. 2003). Unlike other carbon-dense ecosystems, tidal wetlands sequester carbon at dramatically large rates due to high primary productivity, continuous sediment burial, and low organic matter decomposition (Chmura et al. 2003). According to Coverdale et al. 2014 "if preserved, salt marshes are a sustainable solution to curtailing increasing atmospheric carbon."

In addition to serving as a carbon sink, tidal salt marshes also provide other ecosystem services, including feeding, breeding, and nursery grounds for numerous fish and wildlife species, including a number of listed and sensitive species; recreational opportunities such as fishing and bird watching; and protection from coastal storms and extreme weather events (http://www.habitat.noaa.gov/coastalbluecarbon.html, accessed on 12/05/14, Emmett-Mattox and Crooks 2014). When lost or degraded, the natural and economic ecosystem services provided by these wetlands are eliminated or diminished. Further, the carbon sequestration capacity of the tidal wetland is not only lost, but the stored carbon is released, contributing to increases in the level of greenhouse gases (GHG) in the atmosphere (Pendleton et al. 2012). The National Oceanic and Atmospheric Administration (NOAA), supporters of the Blue Carbon Initiative, and others have identified the need to protect and restore coastal ecosystems to ensure their continued ecosystem service value.

Sea-level rise projections for California, as calculated by the National Research Council (2012), vary from north to south, with coastal San Francisco expected to experience a 14.4 $\pm$ 5.0 cm rise in sea level between 2000 and 2030 and a 28.0 $\pm$ 9.2 cm rise by 2050. For Los Angeles, a 14.7 $\pm$ 5.0 centimeters (cm) rise is expected by 2030 and a 28.4 $\pm$ 9.0 cm rise by 2050.

To survive projected increases in sea level over the next 30 to 40 years, the surface elevations of the marsh plain must increase with rising sea levels (Chmura et al. 2003). While current research and modeling demonstrates that many wetlands in California are keeping pace with sea-level rise via sediment accretion, this resiliency is expected to only resist sea-level rise projections through 2030, with some areas keeping pace through 2050 (Takekawa et al. 2013a). Maintaining coastal wetlands along the California coast will require: 1) high sediment supply; 2) uplift and/or no subsidence; and/or 3) undeveloped, topographically suitable inland areas where salt marsh habitat can migrate inland as sea levels rise. The SBNWR lacks all three components, and several other southern California salt marshes lack one or more of these components, particularly open areas available for inland migration. As a result, sea-level rise adaptation strategies must be developed for our coastal wetlands now if we are to ensure long-term protection of the ecosystem services they provide. Emmett-Mattox and Crooks (2014) identify raising soil surfaces with dredge material as one of the types of restoration activities that can provide net GHG benefits.

Background. Most of what remains of the historical Anaheim Bay marsh complex is protected within the SBNWR (USFWS 2012) (Figures 1 and 2). The areas within the Refuge support habitats historically found along the southern California coast, with much of the site falling under the estuarine intertidal or estuarine subtidal habitat classification per the National Wetlands Inventory (USFWS 2010). About 750 acres (ac) (304 hectares [ha]) within the Refuge are subject to regular, unobstructed tidal influence, supporting 565 ac of coastal salt marsh vegetation, 65 ac of intertidal mudflats, and 120 ac of tidal channels and open water.

The coastal salt marsh habitat protected within the SBNWR was once part of a much larger salt marsh complex that encompassed 4,600 acres (CDFG and USFWS 1976). The majority of the historical marsh has been filled to accommodate development and in other places dredged to create marinas and boat navigation channels. Based on the results of studies conducted in the 1950s, the maximum thickness of the lagoonal-alluvial deposits within this salt marsh is estimated to be 35 to 50 feet deep (Poland and Piper 1956).

Studies conducted at the SBNRW in 2012 by USGS (Takekawa et al. 2013a) concluded that the long-term sustainability of the SBNWR's tidal salt marsh ecosystem faces threats from regional and local subsidence, limited sediment availability, and sea-level rise. The effects of these threats on the Refuge's low marsh habitat quality were observed as early as the 1980s, when Massey et al. (1984) concluded, "the dearth of suitable nesting habitat in the coastal marshes of southern California [due to the absence of cordgrass of a suitable height] is a severely limiting factor to the growth of the Light-footed Clapper [now Ridgway's] Rail population." To address the current lack of natural nesting habitat for the rail on

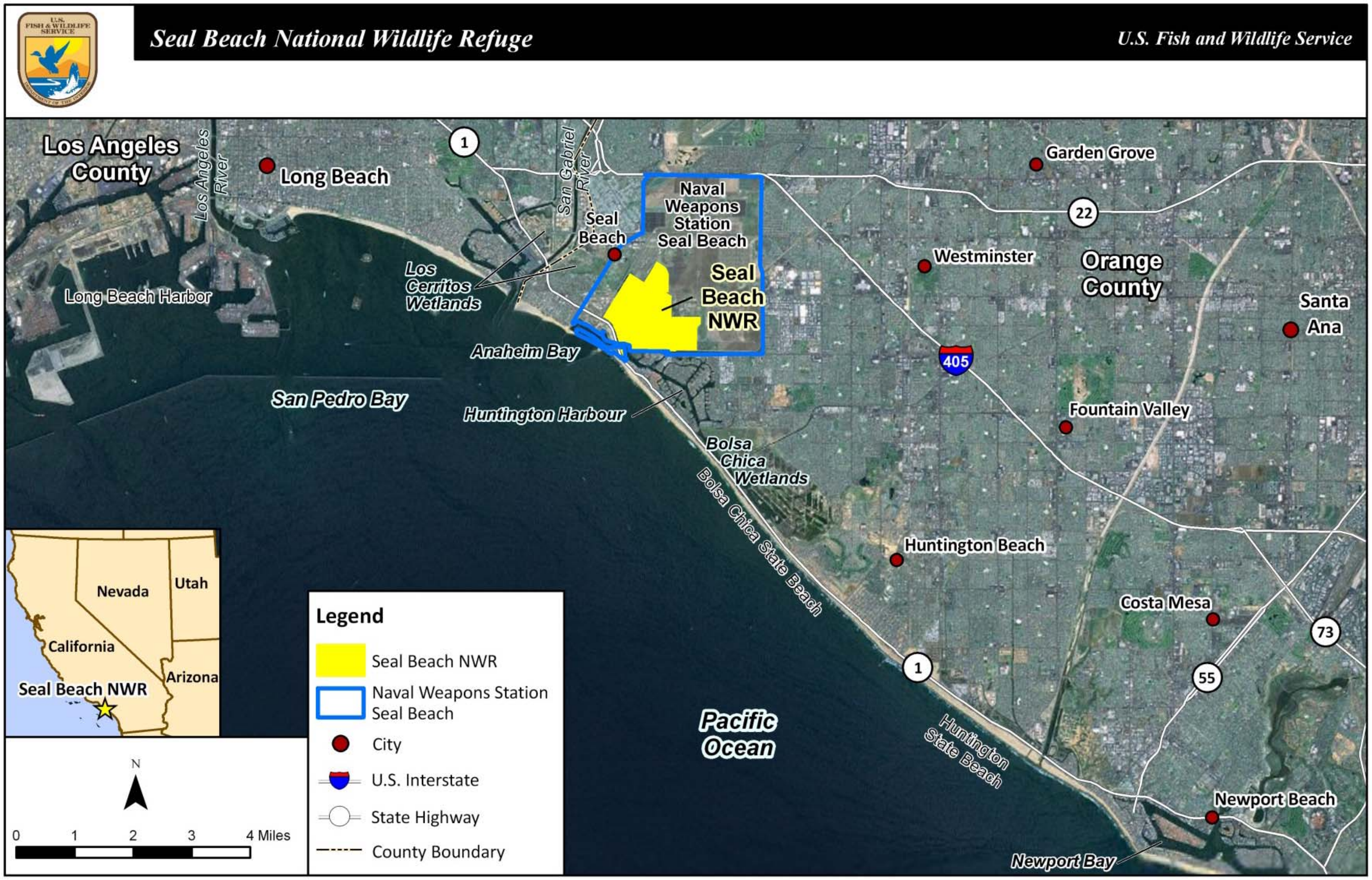


Figure 1. Vicinity Map

Figure 2. Pilot project location within the Seal Beach National Wildlife Refuge.

the SBNWR, about 90 artificial nesting platforms are maintained to provide safe, dry nesting sites for the rails. These platforms also provide year round sources of cover for rails during the higher high tides when most, if not all, salt marsh vegetation is submerged.


Artificial rail nesting platform at SBNWR

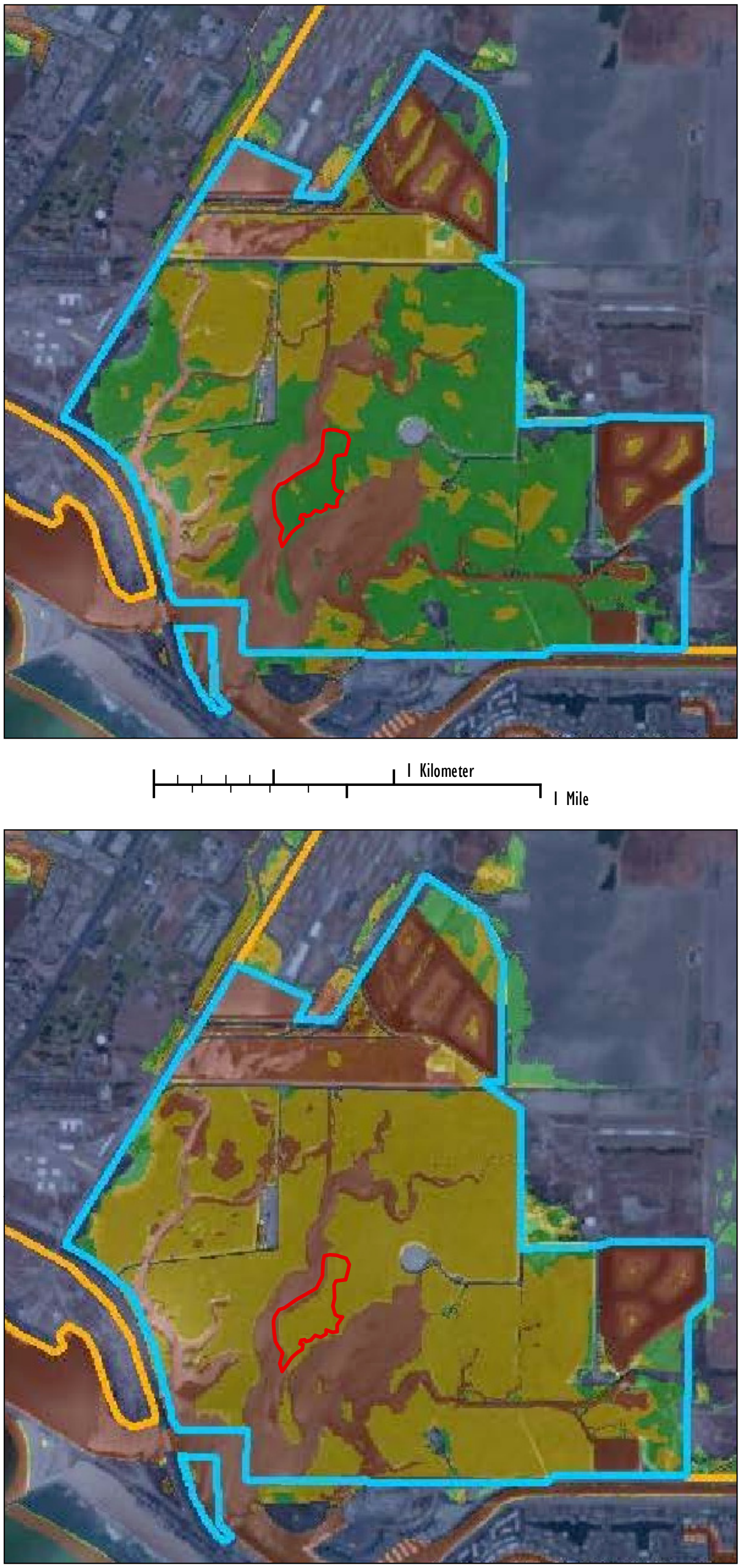
Although cordgrass on the SBNWR is abundant within low marsh habitat, tall dense stands are rare and the percent cover is lower. The average height of the cordgrass within the project site when surveyed in October 2011 was 43.2 cm (Katherine Powelson, USGS, pers. comm.), while the average height of the cordgrass throughout the SBNWR during a study conducted in 1979 was 57 cm, with stem heights ranging from 43 to 76 cm (Massey et al. 1984). According to Zedler (1993), "reference data from natural marshes that are used by light-footed [Ridgway's] rails indicate that the standard for 'suitable habitat' should be a density of at least 100 stems/m^2 with at least 90 stems/m^2 greater than 60 cm, of which at least 30 stems/m^2 are greater than 90 cm in height."

The low elevations of the marsh plain within the SBNWR, a result of subsidence (Takekawa et al. 2013a), cause cordgrass in this marsh to be totally immersed by only moderately high tides. Prolonged immersion has been shown to impact cordgrass by reducing the availability of oxygen to the cordgrass roots and sunlight to the stems (Massey et al. 1984). Based on the low quality of the cordgrass at this site, it is likely that carbon sequestration is also less than optimal within the marsh. As sea levels rise, the conditions at Anaheim Bay will be replicated in other marshes along coastal southern California and likely in other locations to the north.

To understand how sea-level rise and subsidence are affecting tidal inundation at the SBNWR, studies funded by the USFWS Region 8 Inventory and Monitoring (I&M) Program and the California Landscape Conservation Cooperative (CA LCC) were conducted for the SBNWR by USGS. These studies included downscaling climate change models to local conditions (Takekawa et al. 2013b) at several southern California marshes, including SBNWR, and evaluating the current rate of subterranean subsidence at SBNWR (Takekawa et al. 2013a). Predicted changes in elevation at SBNWR from 2010 to 2050 under mid sea-level rise projections (NRC 2012) are illustrated in Figure 3. Based on the field data, USGS concluded that when taking into consideration the effect of land subsidence, the current relative rate of sea-level rise at SBNWR is 6.23mm/yr, a rate that is three times higher than that of similar southern California marshes not experiencing subsidence (Takekawa et al. 2013a). Sea level rise projections indicate that other southern California marshes will not reach these conditions until 2036, providing a unique opportunity to develop and assess climate adaptation strategies at SBNWR first.

Since migration of salt marsh to surrounding areas is not always feasible given the extent of development surrounding California's coastal wetlands, raising marsh plain elevations through thin-layer sediment augmentation may be the only tool available to sustain and improve coastal salt marsh habitat quality and the benefits it provides both as a carbon sink and as habitat supporting a wide range of fish and wildlife species, including listed species, that are dependent upon this habitat for forage, refuge, and breeding. The concept of thin-layer sediment augmentation originated with the recognition that marshes are adapted to respond to the natural process of sediment deposition.

<u>Conceptual Model</u>. This pilot project is considered a component of a larger iterative process involving the development and refinement of a sea-level rise adaptation strategy for conserving tidal salt marsh habitat and the many ecosystem services it provides, including carbon sequestration and carbon storage.



Seal Beach NWR
2010
Digital Elevation Model

Data Sources:
RTK GPS (less than 2 cm) - within Refuge
SCC/NOAA LiDAR (9 cm) - outside Refuge

- Project Area
- Below MTL
- MTL - MHW
- MHW -MHHW
- Above MHHW
- Seal Beach NWR
- Naval Weapons Station

Seal Beach NWR
Mid Sea-Level Rise Projection
2050
+0.28 m SLR
Digital Elevation Model[1,2]

Data Sources:
RTK GPS (less than 3 cm) - within Refuge
SCC/NOAA LiDAR (9 cm) - outside Refuge

[1]Projected sea-level rise (NRC 2012).
[2]Does not include effects of subsidence, infrastructure, sediment accretion, or storms.

Maps derived from maps by USGS. Project boundary from Moffat & Nichol. All other data from USGS. Underlying imagery credits: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

Figure 3. Sea-level rise comparison.

The intent of this project is to ensure efficient management decisions involving data collection and monitoring to assess on-the-ground results and to inform future iterations of this adaptation strategy (Figure 4). The project will also generate much needed data regarding the rate of carbon sequestration occurring in southern California wetlands.

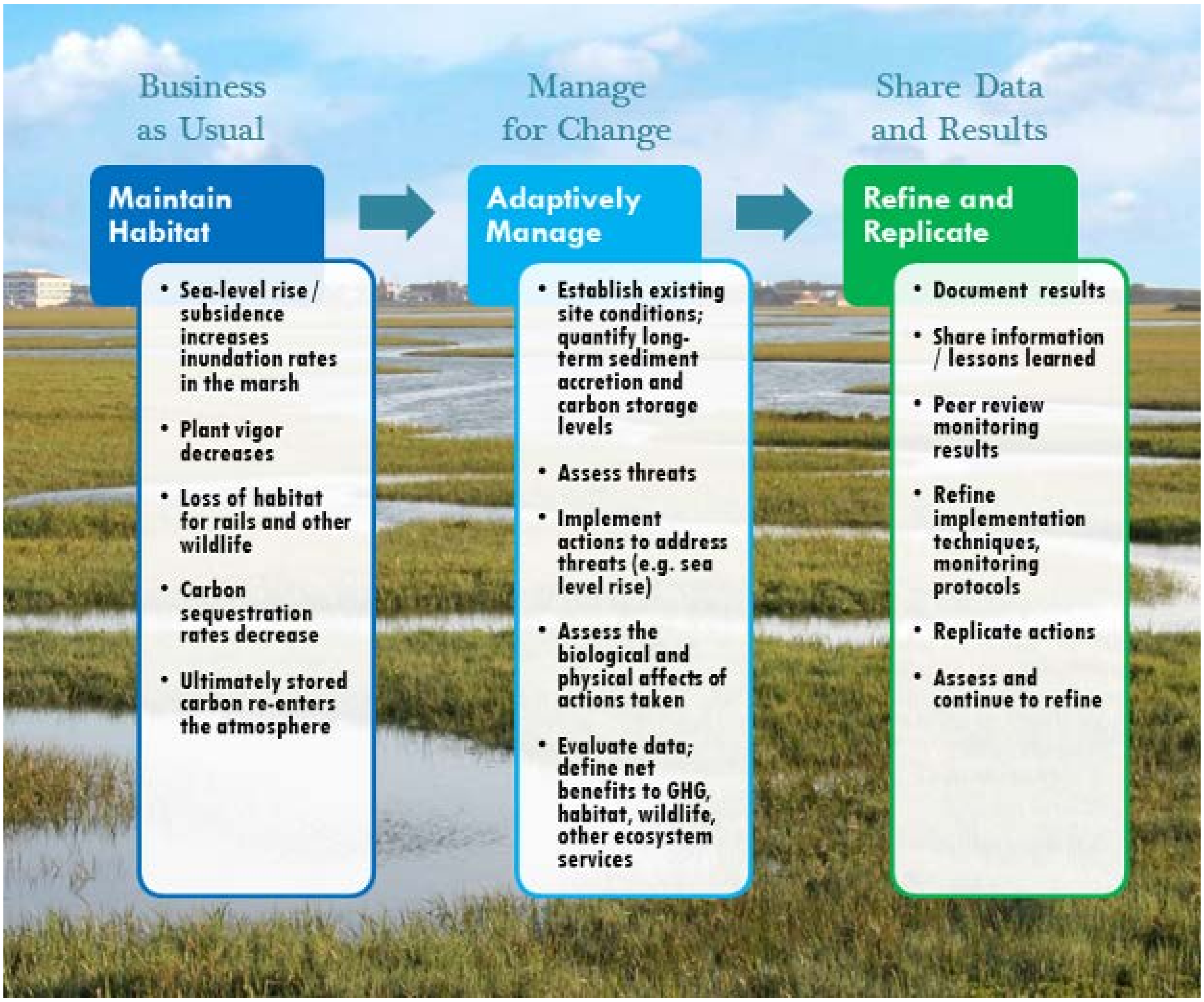


Figure 4. Conceptual Model

Although sediment augmentation has not been tested in California, the placement of fill material on existing marsh plain to address subsidence and sea-level rise has been successfully implemented along the Gulf and East Coast (Ray 2007, Slocum et al. 2005, Ford et al. 1999). There is also evidence that Pacific cordgrass is capable of growing up through a thin-layer of sediment. Ward et al. 2003 describes the establishment of Pacific cordgrass in Tijuana Estuary following sedimentation from winter storms, and post-construction monitoring for a restoration site in South San Diego Bay (Nordby Biological Consulting and TRNERR 2014) noted above ground plant coverage from cordgrass rhizomes after two years. Preliminary small-scale sediment application experiments at SBNWR showed that cordgrass and pickleweed were able to successfully grow through a layer of dredge material 12 inches deep within 36 weeks. This indicates a very high likelihood for success.

Implementation of this sediment augmentation project is expected to produce increases in carbon sequestration within the site and increased habitat value for the endangered light-footed Ridgway’s rail, migratory birds, and invertebrates, as well as provide the guidance necessary to refine and replicate this sediment augmentation process at other marshes along the California coast, thereby approaching the maximum potential gains for this landscape (coastal salt marsh habitat). This is based on the current site conditions, which include less than optimal above and below ground vegetation (primarily Pacific cordgrass) which results in reduced carbon sequestration and loss of nesting habitat and cover for the endangered light-footed Ridgway's rail. By increasing the elevation of the marsh plain, salt marsh plants will spend less time submerged under the tides. Hubbard (1969) noted that at lower elevations within British marshes, *Spartina anglica* had reduced stem heights and stem diameters, which is consistent with observations of the *Spartina foliosa* present within the SBNWR (Massey et al. 1984). Following an increase in marsh plain elevation, vegetative growth is expected to improve in terms of stem height, stem density, and below-ground root growth. Currently, cordgrass stems heights on the site, and throughout much of the SBNWR are 28% lower than the optimum height described by Zedler (1993). Below-ground root growth is also assumed to be diminished due to current elevations at the site. Improving cordgrass vigor, including increased stem height, stem density, and below-ground root growth is expected to result in a net increase in carbon sequestration and improved carbon storage.

The existing conditions at the SBNWR provide a unique opportunity to proactively develop this sea-level rise strategy. Through this pilot project, we can test and refine methods for quantifying GHG benefits from enhancing habitat quality and addressing the adverse effects of sea-level rise. Beaumont et al. (2014) identify the "continuing need for methodology development regarding the calculation of carbon sequestration rates, carbon stocks, and the valuation" of the ecosystem services provided by coastal systems. By demonstrating that the outcomes of implementing this adaptation strategy are consistent with our objectives, others will have the tools needed to implement and refine the techniques of the process, as necessary, elsewhere along the California coast before the quality of our coastal salt marshes is so compromised by tidal inundation that the habitat can no longer be recovered. As result, the net GHG benefits of this project will be expanded by ensuring that the carbon currently stored in the marsh plains along the California coast is maintained within the soils and not released back into the atmosphere.

<u>Linkages with Other Planning and Implementation Activities</u>. The concept of implementing thin-layer sediment augmentation on the SBNWR was first addressed in the Seal Beach NWR Comprehensive Conservation Plan (CCP) (USFWS 2012), and the current proposal is consistent with and would implement the CCP goals, as well as the CCP's objective and strategy for addressing climate change and sea-level rise.

The proposal would also address several actions described in the Light-footed Clapper Rail Recovery Plan (USFWS 1985) including: 1) determine the causes of the elevational differences between Anaheim Bay and Upper Newport Bay and investigate the feasibility of implementing corrective actions, and 2) enhancing cordgrass vigor in Anaheim Bay.

The current proposal is also consist with the *National Fish, Wildlife and Plants Climate Adaptation Strategy* (National Fish, Wildlife, and Plants Climate Adaptation Partnership 2012), which advocates for taking steps to address the effects of climate change, including sea-level rise, to help conserve ecosystems and make them more resilient. Additionally, consistent with the recommendations in *Safeguarding California: Reducing Climate Risk, an Update to the 2009 California Climate Adaptation Strategy* (California Natural Resources Agency 2014), this pilot project proposes an adaptation strategy that relies on sound science to highlight risks and help provide solutions, involves State, Federal, and local agency partnerships, and is designed to promote collaborative and iterative processes for crafting and refining climate risk management strategies.

Following the steps in the climate-smart conservation cycle (Stein et al. 2014), Refuge staff assessed climate impacts, identified key vulnerabilities, identified adaptation options, and chose to further explore the potential for raising the elevation of the existing marsh plain to improve cordgrass vigor and coverage. A Vulnerability Assessment and Climate Adaptation Planning Project for the Refuge is currently in process with project oversight and funding provided by the USFWS Region 8 I&M Program.

The assessment identifies the Refuge's rail population as a high priority resource of concern and rail reproductive success as a key ecological attribute.

Contact with the U.S. Army Corps of Engineers (Corps) identified successful implementation of the sediment augmentation process along the East and Gulf Coasts, but no similar projects were identified in California. As we continued to discuss the potential for implementing this strategy on the Pacific Coast, we discover considerable interest throughout California in identifying an adaptation strategy for preserving coastal salt marsh habitat, particularly in locations experiencing marsh degradation / subsidence (i.e., Elkhorn Slough, Humboldt Bay), as well as in areas with no room for inland migration (i.e., most south California marshes) and/or depleting sediment supplies (i.e., San Francisco Bay-Delta). Studies funded by the CA LCC to evaluate the effects of sea level rise on California's coastal habitats provide guidance for how and when this conservation strategy might be implemented in a particular area and in our case provide justification for why the SBNWR is the ideal location for testing this approach.

A successful outcome at the SBNWR will encourage the beneficial use of dredge material (a recommendation of the National Dredge Team and the Dredged Material Management Action Agenda for the Next Decade [USEPA 2003]) and open the door for land managers to implement thin-layer sediment augmentation. Through this strategy, it may be possible to keep pace with sea-level rise, conserve our salt marsh dependent species, and protect an important source of carbon sequestration and long-term carbon storage.

3. ***Detailed project description, including all tasks to be performed:***

Project Partners. Initially, this project involved a unique partnership between the County of Orange Parks Department (OC Parks), USFWS - Seal Beach NWR, and Naval Weapons Station Seal Beach (NWSSB). But it has since grown to include OC Parks, California State Coastal Conservancy (Conservancy), USFWS, NWSSB, USGS, Southwest Wetlands Interpretive Association (SWIA), researchers from UCLA and CSU Long Beach, and participates from the Huntington Beach Wetlands Conservancy. We continue to seek funding to ensure that all pertinent details associated with this pilot project, from sediment application techniques to biological, physical, and carbon sequestration/storage responses, are monitored, documented, and disseminated to other entities interested in implementing this sea-level rise adaptation strategy elsewhere along the California coast.

Project Summary. The SBNWR and its partners propose to implement a pilot project involving the application of a thin-layer of clean sediment over 10 acres of degraded cordgrass habitat on the Refuge to improve habitat quality and the ecosystem services associated with healthy coastal salt marsh vegetation. As a pilot project, the sediment application process will be monitored to identify and document suitable application techniques. Pre- and post-application monitoring will be conducted to evaluate the overall effectiveness of this process as a sea-level rise adaptation strategy.

Sediment Application. Approximately 10,000 to 13,500 cubic yards of clean dredge material will be applied at a fairly uniform depth over 10 acres of degraded low salt marsh habitat within a 16-acre site on the Seal Beach NWR (refer to Figure 2). Sediment application is scheduled to occur between November 2015 and February 15, 2016. Most of the 16-acre area within the Refuge is owned by the U.S. Navy, with a small area held by the California State Lands Commission and leased to the USFWS for management as a National Wildlife Refuge.

Dredge material will be provided by OC Parks from their Sunset/Huntington Harbour Maintenance Dredging Project, located in a portion of Anaheim Bay situated to the southwest of the Refuge. Based on the results of sediment characterization studies (Kinnetic Laboratories, Inc. and Moffatt & Nichol 2014) funded by OC Parks and the evaluation of the results of these studies by contaminants experts at the Carlsbad Fish and Wildlife Office and Naval Weapons Station Seal Beach, the material to be used will come from the Main Channel West portion of the dredging operation. OC Parks and their civil engineering contractor, Moffatt & Nichol, will oversee both the dredging operation and the sediment application process on the Refuge.

Dredge material would be transported and applied to the project site by a qualified contractor hired by OC Parks. Transport of the material from dredge site will be via a small containment barge or as slurry through a pipeline placed on the bed of bay and channel, or floated on the water surface from the maintenance dredge site to the project site. Under either option, the slurry will be applied to 10 acres of the 16-acre site as a fairly uniform thin layer of sediment, approximately 8 to 10 inches (20.32 to 25.4 centimeters [cm]) deep. Various application methods (e.g., rainbow sprayer, open pipe, end-of-pipe baffle impingement) will be tested at the beginning of the project to determine which are best suited for ensuring uniform coverage and confining sediment application to the predetermined application site. The entire process, which could take from four to six weeks to complete, will be adaptively managed to meet project design criteria, including achieving the desired depth of sediment within the confines of the 10-acre application site and minimizing the potential for introduction of sediment into the tidal channels that abut the site. The remaining six acres of the 16-acre site will provide a vegetated buffer around the augmentation site in an effort to minimize the movement of sediment off the site and into the adjacent tidal channels.

An on-site monitor will be present during sediment application to ensure that sediment is not moving off the site. Sediment movement and turbidity levels will be monitored throughout the process. The monitor will have the authority to direct the contractor to adapt the application technique to avoid offsite impacts, as well as to require the implementation of additional measures, such as the instillation of a silt curtain or other appropriate barrier, should these measures be deemed necessary to minimize the effects of the project on adjacent habitats. The process, including the effectiveness and efficiency of the application methods and sediment containment practices, will be documented and recommendations will be developed to ensure that future projects can benefit from the lessons learn during project implementation.

Conservation measures have been incorporated into the scope of the project, as outlined in the Final Mitigated Negative Declaration / Finding of No Significant Impact prepared for this project in accordance with both CEQA and NEPA by the Conservancy and USFWS, to ensure that no significant adverse effects to the environment, including listed and sensitive species, will occur as a result of this project. The processing of all required permits, Essential Fish Habitat review, and compliance with the Endangered Species Act are currently underway.

Project Methods – Monitoring. Pre- and post-application monitoring is an essential component of the proposed action, as monitoring results will inform the USFWS, State agencies, and other land managers of the effectiveness of thin-layer sediment augmentation in achieving the project objectives. Some of the key questions to be addressed through this monitoring program include: Will the application of sediment improve cordgrass vigor and if so, what is the time frame post-application for this to occur; how quickly will rails and other birds return to the site for roosting and foraging; will cordgrass stature and density be adequate to support rail nesting; how will other plants and invertebrates respond to thin-layer sediment augmentation, and does this response vary by species; and what are the net GHG benefits of this action; do they improve over time? Additional questions to be addressed include how much sediment will remain on the site during application, after two years; what effect does sediment application have on turbidity levels in adjacent waters; how effective is the vegetated buffer at reducing sediment runoff; what is the on-site sediment compaction rate, what is the depth of sediment following compaction; and following compaction, how has the topography of the site changed, are tidal channels forming?

Monitoring will be performed by wetland scientists and qualified avian monitors, as described below. The effectiveness and ecological response of the Refuge's coastal salt marsh habitat to thin-layer sediment augmentation will be quantified using data generated during pre- and post-construction monitoring. Monitoring will address:

- Percent total plant cover and percent cover contributed by each species present on the site will be measured prior to and following sediment application;
- For Pacific cordgrass, percent coverage, terminal stem height, stem density, and below ground root density will be measured prior to and for five years following sediment application;
- Site elevations will be measures before and periodically after sediment augmentation, the formation of tidal channels within the site will be observed and documented;
- Sediment compaction rates, sediment movement, total organic carbon, grain size, and bulk density over time;
- Turbidity levels will be monitored in adjacent tidal channels before, after, and during sediment augmentation; and
- Changes, if any, in eelgrass presence and coverage in adjacent tidal channels.

Monitoring reports will be prepared annually, and a workshop or webinar will be held following year two of our post-construction monitoring effort, with another workshop or webinar to be scheduled following completion of the final monitoring report.

All monitoring contracts, with the exception of avian monitoring, will be administered by SWIA using funding from the Conservancy for a portion of the research tasks and all of SWIA's administrative costs, as well as funding from the Wetlands Restoration for GHG Reduction Grant Program for the remainder of the research tasks. Monitoring efforts will involve researchers and staff from USFWS, USGS, UCLA, CSU Long Beach, Huntington Beach Wetlands Conservancy (which receives annually funding from the U.S. Navy for rail surveys),and volunteer avian monitors for general avian surveys.

<u>Project Personnel and Tasks to be Completed</u>.

- USFWS - Kirk Gilligan, Refuge Manager for the Seal Beach NWR, will manage all aspects of the project, including overseeing the sediment augmentation process; assisting in site monitoring before, during, and after sediment augmentation; and coordinating pre- and post-construction monitoring efforts by other project partners. Two additional staff members from the San Diego NWRC staff, as well as trained avian monitor volunteers, will assist Kirk in permit processing (*an EA/FONSI has already been completed for this project*), project coordination, rail high tide and call count surveys, preparation of annual and final monitoring reports, procedures manual development, and public outreach.

  Kirk Gilligan has been the Refuge Manager at the SBNWR since 2006. He has primary responsibility for managing and monitoring the Refuge's population of light-footed clapper rails, for coordinating research and monitoring programs on the Refuge, and has successfully managed several habitat enhancement projects. Other Refuge staff will include a Natural Resource Specialist, with extensive experience in permitting, report preparation, and public outreach, and a Biologist from the SDNWRC with experience in monitoring and project management.

- Carlsbad Fish and Wildlife Office Coastal Program - Carolyn Lieberman, Coastal Program Coordinator, will provide guidance on issues related to project design, monitoring, and public outreach. She will also participate in the review and analysis of monitoring results and public outreach.

  Carolyn Lieberman is the Coastal Program Coordinator at the Carlsbad Fish and Wildlife Office. She has assisted partners in restoring coastal wetlands for six years. As the chair of the Southern California Wetlands Recovery Project Wetland Managers Group, Carolyn can provide guidance on issues related to project design, monitoring, and public outreach.

- USFWS Region 8 Inventory and Monitoring (I&M) Program **-** Giselle Block, Inventory and Monitoring Specialist will assist in the review of monitoring protocols and annual reports, storage of final products on ServCat, and incorporation of relevant information from the project into their climate adaptation planning.

Giselle Block, Inventory and Monitoring Specialist, who recently completed a contract with USGS and UCLA to analyze subsidence rates and conduct sea level rise modeling for the SBNWR and is currently working with USGS, USFWS, and the U.S. Navy on a vulnerability assessment for SBNWR, will provide the project team with important insight about the project site and the values of the resources it supports.

- CA LCC – Annual and final monitoring reports will be posted on the CA LCC's Climate Commons site and staff will assist in conducting webinars to disseminate project data, methods, and results.

- U.S. Navy (Naval Weapons Station Seal Beach) – Navy staff will provide engineering and biological expertise.

- California State Coastal Conservancy – Conservancy staff, who have extensive experience in the planning and implementation of coastal wetland projects throughout California, will assist in the review and analysis of monitoring results. The Conservancy Board has agreed to provide $550,000 ($525,000 will represent a match for this proposal) to assist in implementing pre- and post-sediment augmentation monitoring and public outreach for this project.

- Southwest Wetlands Interpretative Association (SWIA) – SWIA will manage monitoring contracts funded through the Conservancy and other sources, including any CDFW funds awarded to the project. SWIA has extensive experience implementing grants and administering funds from public agencies for monitoring and research projects, including the five-year monitoring program for the South San Diego Bay salt ponds restoration project and research projects implemented on the Tijuana River National Estuarine Research Reserve.

- Orange County Parks Department (OC Parks) – OC Parks will be responsible for providing dredge material for the project, as well as engineering oversight. Susan Brodeur, a registered civil engineer, is OC Parks' project manager (see qualifications under Section 6). A portion of the funds requested in this grant application would be provided to OC Parks to cover some of the costs associated with implementing sediment augmentation on the project site, as well as for monitoring of the augmentation process to ensure that sediment is uniformly applied and retained on-site. OC Parks has not yet initiated the bid process associated with hiring a construction contractor to implement the dredging project.

- Researchers (UCLA and CSU Long Beach) - Dr. Richard Ambrose of UCLA and Dr. Christine Whitcraft of CSU Long Beach will assist in pre- and post-augmentation monitoring efforts for the project. Both Dr. Ambrose and Dr. Whitcraft have conducted research projects on the SBNWR in the past.

  Dr. Whitcraft has been an assistant professor in the Department of Biological Sciences at California State University, Long Beach since 2008, advising eight graduate students during that time. She is part of the monitoring team for the San Diego Bay salt ponds restoration project, responsible for invertebrate monitoring.

  Dr. Ambrose has been a professor in the Department of Environmental Health Sciences and Institute of the Environment and Sustainability at UCLA since 2000. His research addresses the restoration of degraded coastal habitats, especially wetlands, evaluating the effectiveness of wetland mitigation programs, and evaluating climate-change topics related to coastal wetlands, including projected changes in vegetation and carbon sequestration in coastal wetlands as a means for mitigation greenhouse gas emissions.

- USGS - Dr. Karen Thorne and other staff at USGS will assist in monitoring activities related to sediment flux . Dr. Thorne received her PhD from the Department of Geography (emphasis: Global Change) from the University of California, Davis in 2012. She has been involved various studies related to coastal habitats including evaluating site specific sea-level rise impacts of salt marshes in San Francisco Bay, Humboldt Bay, San Diego Estuary, and Anaheim Bay (18 sites); evaluating elevation, tidal datum, and plant community distributions at each marsh and developing sea-level rise models; and determining the risk from sea-level rise on salt marsh habitats and wildlife.

- Dr. Richard Zembal (Huntington Beach Wetlands Conservancy) – Dr. Zembal and his staff will conduct pre- and post-augmentation rail monitoring on the site and elsewhere on the SBNWR. Dr. Zembal has been conducting studies and surveys related to the light-footed Ridgway's rail for more than 35 years.

- Eelgrass Surveys – A bid process will be used to hire a qualified consultant to conduct pre- and post-construction eelgrass surveys at a control site and within the tidal channels that abut the project site.

4. ***Timeline:***

The CEQA/NEPA process for this project has already been completed and permitting processing is underway. Monitoring components have been defined and monitoring protocols are being developed. It is likely that vegetation and invertebrate studies to establish existing site conditions will be initiated in early 2015, as a result, not all of the funding being provided by the Conservancy is indicated as match for this proposal. Any work anticipated to be conducted prior to the award of this grant has been included as match. Sediment augmentation is expected to occur in November/December 2015, but in no case would it occur later than February 15, 2016.

Pre-augmentation collection of data (as described below under monitoring costs) to establish existing conditions would occur between July and November 2015, which the exception of invertebrate analysis, which would be conducted in January or February of 2015 (to be funded by the Conservancy and not reflected in the match for this grant).

In January 2016, following sediment augmentation, UCLA would begin monitoring sediment retention, and compaction. This work would be replicated in January 2017 – 2020. Evaluation of tidal formation would begin in January 2017.

Invertebrate analysis post-augmentation would begin in February/March 2016 and would be replicated in February 2017 – 2020. Vegetation monitoring post-augmentation would begin in September 2016 and would be replicated annually from 2017 – 2019. The fifth year of sampling would occur in February 2020.

USGS studies related to sediment flux would be initiated during sediment augmentation (2015) and would continue to be evaluated through 2019.

Analysis related to carbon sequestration and carbon storage would begin in October 2015 to establish existing conditions, with additional analysis conducted in fall 2018 and 2019.

Eelgrass surveys will be conducted 30 days prior to sediment augmentation and 30 days after sediment augmentation, as well as in October 2016 and 2017.

5. ***Deliverables:***

- GIS Data and Maps for the Project Site - GIS data (primarily in the form of shapefiles) will document monitoring locations, boundaries of the area affected by sediment augmentation, progress of vegetation reestablishment over time, and results of eelgrass monitoring. Maps and metadata will accompany the data

- Annual Monitoring Reports – One report describing site conditions prior to sediment application and five subsequent reports describing the results of annual monitoring conducted post-sediment application. Reports will include a description of the site-specific protocols implemented at the site, all raw data and an analysis of that data, recommendations, and lessons learned. Meta data will be provided for all spatial data provided. Reports will be posted on the CA LCC's Climate Commons site, distributed to interested agencies and land managers, and all final products will be stored by the USFWS on ServCat.

- Final Monitoring Report – Summary of five years of monitoring, final results including quantitative results of GHG reductions (reports to be posted on the CA LCC's Climate Commons site, distributed to interested agencies and land managers, and all final products will be stored by the USFWS on ServCat)

- Sediment Application Guidance Document – Document that describes the procedures and techniques employed to achieve uniform sediment depths and minimize movement of sediment offsite, including the effectiveness of the all tested procedures and lessons learned (Document will be posted on the CA LCC's Climate Commons site and distributed to interested agencies and land managers)

6. ***Expected quantitative results (project summary):***

As indicated in our conceptual model (see Figure 4), simply managing for the existing conditions at the SBNWR is not an option. Recent data collected by USGS at the major marshes along the southern California coast indicate that the elevation of the marsh plain at SBNWR is the lowest of any of the marshes included within the study. In fact, NGS benchmark surveys taken in 2013 indicated that subsidence is occurring a rate of -4.13 mm/yr (SE ± 1.21 mm/yr) (Takekawa et al. 2013a). The long-term sustainability of the 750 ac (304 ha) tidal salt marsh ecosystem conserved within the SBNWR faces threats from regional and local subsidence, the lack of sediment availability, and sea-level rise. The current rate of sea-level rise in southern California is 2.1 mm/yr (NRC 2012) and when combined with subsidence rates, SBNWR is experiencing a relative sea-level rise rate three times more (6.23 mm/yr) than that of similar southern California marshes not experiencing subsidence.


Conditions in the marsh during spring high tides

Compared to the NRC (2012) sea-level rise projection curve, USGS found that the current rate of relative sea-level rise at SBNWR with subsidence is now similar to the rate expected in 2036 for areas of southern California without subsidence. Figure 4 presents digital elevation models for SBNWR both in 2010 and under mid sea-level rise projections for 2050 (NRC 2012). The loss of a significant area of low salt marsh habitat appears enviable. When that occurs, carbon sequestration by salt marsh vegetation will cease and the standing pools of carbon within the sediment will be subject to erosion and ultimately release into the atmosphere or water column (Pendleton et al. 2012). Carbon loss per hectare of coastal salt marsh lost is not well understood, and little data is available for the carbon storage capacity of southern California salt marshes. Therefore, estimating the potential effects of salt marsh loss, as well as the benefits of salt marsh enhancement in these marshes without additional data provides results with have a high level of uncertainty. According to Pendleton et al. (2012), studies suggest conservative carbon storage estimates of about 250 Mg of carbon per hectare of tidal marsh or 917 Mg of potential CO_2 emissions. Vegetation biomass increases the near-surface estimates to global means of 259 Mg C ha^{-1} (949 Mg of potential CO_2 emissions) for tidal marshes. Based on these estimates, the loss of the tidal marsh at the SBNWR could result in the following CO_2 emissions:

250 Mg of carbon per 228.6 ha (total salt marsh habitat at SBNWR) = 57,150 Mg of carbon

or

917 Mg of potential CO_2 emissions x 228.6 ha = 209,626 Mg of potential CO_2 emissions

We have no data regarding the levels of carbon within the Refuge's emergent living biomass and because the estimated mean values range from 1 to 129 Mg C ha^{-1} (Pendleton et al. 2012), we have not included this in our calculation.

When considering GHG benefits from enhancing coastal salt marsh, it is not necessary to adjust the benefits to address methane (CH_4) as sediment sequestration rates exceed CH_4 emission rates in CO_2 equivalent units (Poffenbarger et al. 2011). Further, studies of gas fluxes in tidal wetlands suggest that nitrous oxide (N_2O) emissions are also negligible in this habitat (Smith et al. 1983, DeLaune et al. 1990).

Pendleton et al. 2012 notes the need for more research to better understand the amount of carbon stored by tidal marshes. Although there are several studies conducted for portions of San Francisco Bay wetlands and else (Beaumont et al. 2014, Callaway et al. 2012, Brevik and Homburg 2004), the data provided by these studies is not necessarily applicable to southern California marshes, which are much smaller in size, support different plant species, and generally are situated immediately adjacent to the coast rather than within the confines of a significant embayment. However, a limited sampling effort (n=2 at "middle" elevations) in the Refuge conducted by USGS suggests the Refuge may be storing carbon at a limited capacity due to low concentrations of organic matter (~11%) and high bulk densities (~0.9) in the soil (pers. comm. Karen Thorne, USGS). Additional data is required to make substantive decisions regarding the carbon storage capacity of restored or enhanced tidal wetlands in southern California. Through the studies to be conducted as a part of this pilot project, relevant data about the levels of long-term carbon storage within the sediments, as well as the effect of sediment augmentation on carbon sequestration rates in the low elevation areas of a salt marsh will be obtained. This much needed information will benefit future habitat restoration projects, as well as projects needed to protect the natural marsh habitats that existing along California's vulnerable coast.

7. ***Protocols:***

A critical component of this pilot project will be pre- and post-sediment augmentation monitoring. The results of this monitoring will enable us to assess project outcomes, evaluate whether objectives are being achieved, and help refine adaptive management decisions. An accurate evaluation of the responses of the tidal marsh ecosystem to thin-layer sediment application depends on systematic and consistent data collection as well as the development and application of proven and repeatable monitoring methods. The monitoring results from this pilot project will assist in advancing this sea-level rise adaptation strategy and through the communication of lessons learned and shared experiences, including details about monitoring methods and monitoring results, other agencies and land managers can implement this action at tidal salt marshes throughout California that are threatened by sea-level rise and/or subsidence.

Site specific monitoring protocols are currently being developed for the project. These protocols will take into consideration standard operating procedures (SOPs) that have been developed by the San Francisco Bay Area wetland regional monitoring program for tidal marsh, as well as SOPs developed by USGS for tidal marshes. Contracts for all researchers working on this project will specifically state that deliverables will include site-specific protocols that have been developed in cooperation with USFWS and other project partners, annual reports, and all raw data. In addition, any spatial data should have appropriate Meta data.

Monitoring Tasks to be Completed

1. **Monitoring the depth of augmented sediment over time following application (compact rate, movement off-site) and documentation of marsh plain elevations – pre and post-application (UCLA)**

   To measure the success of the following objective:
   Sediment Objective - Enhance 10 acres of subsiding tidal salt marsh habitat by applying 10,000 to 13,500 cubic yards [CY] of clean dredge material as a fairly uniform thin layer of sediment, about 8 to 10 inches (20.32 to 25.4 centimeters [cm]) deep, to achieve and maintain a minimum three-inch increase in the marsh plain elevation within the project site two year after sediment augmentation.

   Sediment Retention and Compaction Rate
   Preliminary monitoring proposal (currently being refined) includes evaluating compaction rates and sediment retention at 2, 6, 12, 24, 36, 48, and 60 months following application by cryo-coring within 0.25 m^2 subplots that were pre-treated with a feldspar marker horizon.

   Marsh Plain Elevations
   Preliminary monitoring proposal (currently being refined) includes using methods established by USGS during a recent elevation study conducted at SBNWR and supplementing existing elevation data recorded by USGS to document elevations and compaction at specific intervals within the project area both pre-application and annually for up to five years following post-application.

2. **Document pre- and post-application tidal creek status, including formation and/or reformation. Primary, secondary, and tertiary creek systems are thought to be a key component of light-footed Ridgway's rail foraging habitat (UCLA)**

   To measure the success of the following objective:
   Light-footed Ridgway's Rail and Migratory Birds Objective - Within one year of sediment augmentation, provide foraging opportunities for migratory birds and the light-footed Ridgway's rail.

   Preliminary monitoring proposal (currently being refined) includes documenting and mapping topography of primary, secondary, and tertiary tidal creeks within the project area pre-application and studying changes in these systems and the potential reformation of creek systems for five years following post-application.

3. **Sediment flux measurements augmented by channel water samples to determine turbidity and sediment movement off site and in adjacent tidal channels pre and post application (USGS)**

   To measure the success of the following regulatory measure:
   Water quality and turbidity as regulated by the Clean Water Act, Santa Ana Regional Water Quality Control Board and the National Marine Fisheries Service (NMFS) (Essential Fish Habitat).

   It is important to use integrative measures of sediment flux which will help assess sediment transport to and from the wetland site during the sediment augmentation effort. Sediment flux measurements in a wetland tidal channel constrain the sediment budget to the landward portion of the marsh complex and spatially integrate the mechanisms contributing to material gain or loss. These measurements are useful to gauge sediment transport off the marsh surface where sediment augmentation will occur. Sediment flux measurements will be made using a combination of autonomous optical and acoustic devices to measure suspended-sediment concentration and water flux respectively.

Preliminary monitoring proposal (currently being refined) includes deploying autonomous equipment at multiple channels over two years to continually measure turbidity and sediment flux in adjacent and adjoining channels and more specifically eelgrass beds within the vicinity of the project site. Locations of instruments will be agreed upon by Investigation team and Refuge staff. Sampling will be conducted prior to sediment application to establish sediment flux baselines at the spraying locations. Measurements will be done during spraying application and water samples will be taken to make periodic measurements to calibrate the sensors. Sensors will include two turbidity meters (YSIs 6920 optical turbidity probes) and acoustic Doppler current profilers (ADCP) mounted on the channel bed at key cross-sections that drain the majority of the wetland complex. Periodic cross-sectional measurements will constrain lateral and vertical variability within the channel and enable a more robust flux calculation (Ganju et al. 2005). Water level monitoring will be done every six minutes with Solinst loggers at four locations within the Refuge. Data will be synthesized into sediment flux budgets which will be used to assess the difference in flux and turbidity between baseline conditions and sediment augmentation spraying. This data will help answer the following questions: What is the sediment flux budget during a ‘normal’ winter and how did this differ during marsh augmentation? When did turbidity decrease after sediment spraying was completed? These questions will help us understand when sediment moving off the site decreased after application. This turbidity information will also help inform eelgrass monitoring. Monitoring will continue for up to five years (if it is determined that sediment is not moving off the project site two years after sediment augmentation, no further monitoring will be necessary).

4. **Eelgrass monitoring in adjacent tidal channels and a control site**

Measures success of the following regulatory measure:
Southern California Eelgrass Mitigation Policy as regulated by NMFS.

Eelgrass near the application site, as well as at an approved control site, will be systematically monitored using sonar and SCUBA surveys. The sonar survey will provide a means to create a spatially accurate eelgrass survey map and an estimate of eelgrass coverage. The SCUBA survey component will provide a means to ground truth the sonar data, provide a separate estimate of eelgrass cover with an estimate of sampling variation and will be the means by which eelgrass density is determined. Baseline conditions will be established pre-sediment application and compared to Merkel et al. 2013 surveys. Merkel et al. 2013 used interferometric sidescan sonar and dive surveys to assess baseline extent of subtidal eelgrass habitats. Following sediment application, these same areas will be monitored within 30 days after sediment application, as well as one year and two years after sediment augmentation during the growing season to assess any change in the extent and/or health of the eelgrass beds.

5. **Vegetation cover, biomass, and composition, and cordgrass terminal elevation, stem length, and stem density – pre and post-application (over time) (CSULB)**

To measure the success of the following objective:
Cordgrass Objective - Within two years of sediment application, achieve stem heights and stem densities of Pacific cordgrass equal to or greater than pre-project conditions, and within five years of sediment application achieve stem heights, stem densities, and below-ground root structures that exceed pre-project conditions and thereby result in a net increase in the carbon sequestration capacity within the site, as well as enhanced habitat quality to support the endangered light-footed Ridgway’s rail and other salt marsh-dependent species;

Plant Community and Cordgrass Descriptions

Preliminary monitoring proposal (currently being refined) includes estimating plant cover and biomass for each plant species within random generated plots using point contact methods that also measure layering within 0.25m^2 quadrats. Heights and stem density of the cordgrass will be recorded in the field to estimate total stem length, a proxy for biomass. Study will be conducted pre-application and for five years post-application.

6. Infaunal and epifaunal invertebrate distribution and abundance (pre and post-application) (CSULB)

To measure the success of the following objective:

Benthic Invertebrate Objective - Within two years of sediment augmentation, achieve a diversity and abundance of benthic invertebrates within the project sediments that are similar to the selected reference site.

Invertebrate Community

Preliminary monitoring proposal (currently being refined) includes obtaining cores in the areas where dredge material will be spread and in a reference control site to assess infaunal invertebrate community structure, measuring the diversity and abundance of macroinvertebrates. Cores will be taken pre-application and at time 0, 4 weeks, 6, 12, 24, 36, 48, and 60 months post-application with the exact schedule based on available funding. These cores will be subdivided in the field into 0-1, 1-2 cm and 2-6 cm depth sections and preserved (unsieved) in 8% buffered formalin with Rose Bengal dye. For macroinfaunal quantification, cores will be washed through 0.3 mm mesh. The animals that are retained will be sorted from the sediments using a dissecting microscope, identified to the lowest taxonomic level possible and stored in 70% ethanol as vouchers. In addition, epifauna (typically snails and crab burrows as a proxy for crabs) will be counted with 0.25 m^2 quadrats in both dredge and non-dredge areas. We will measure diversity for invertebrates (infauna, epifauna) at the species-level as indicated by the number of species and number of feeding groups present in each treatment, the number of species per unit area, dominance (J', Berger-Parker index), and H' (information index). Study will be conducted pre-application and for five years post-application.

7. Abundance and diversity of avian species (USFWS Volunteers)

To measure the success of the following objective:

Light-footed Ridgway's Rail and Migratory Birds Objective - Within one year of sediment augmentation, provide foraging opportunities for migratory birds and the light-footed Ridgway's rail.

Monthly high and low tide bird counts will continue for five years post-application. Two surveys a month will be conducted within one hour of the highest high tide and lowest low tide of the month during working hours (8:00 am through 5:00 pm). Observations will be made from roads within the Refuge. All avian species observed within the project area will be recorded. Surveys will be consistent with monthly Refuge-wide high and low tide bird counts conducted since 1996. These surveys will be conducted pre-application and for five years post-application for purposes of this grant.

8. Light-footed Ridgway's rail nesting, presence, and use of the site - pre and post-application (over time) (NWSSB and USFWS)

To measure the success of the following objective:

Light-footed Ridgway's Rail and Migratory Birds Objective - Within one year of sediment augmentation, provide foraging opportunities for migratory birds and the light-footed Ridgway's rail.

Annual spring call counts, fall high tide counts, and monthly breeding season reproductive success surveys will continue on all areas of the Refuge (including the project site) for five years post-application. Protocol will follow methods outlined in “Status and Distribution of the Light-footed Clapper Rail in CA 2014” (Zembal et al. 2014). These methods have been used to survey rail populations on the Refuge since 1980. These surveys will be conducted pre-application and for five years post-application for purposes of this grant.

9. Evaluation of the biological and physical monitoring results (including estimated carbon sequestration and carbon storage rates at the project site prior to and five years after sediment augmentation)

To measure the success of the following objective:
Within four years of sediment application, demonstrate that enhancing the vegetative cover within this tidal salt marsh site has produced net GHG benefits that can be duplicated in other tidal salt marsh habitat along the California coast that is threatened by sea-level rise and/or subsidence.

Abiotic parameter description (Pore water salinity, redox potential, and temperature within the application site and the adjacent unmodified marsh pre and post-application)
Preliminary monitoring proposal (currently being refined) includes measurements of pore water salinity, redox potential, and temperature within haphazardly placed plots (established within dredge and non-dredge zones) using a refractometer, digital redox meter, and a digital thermometer, respectively. Soil samples will be collected from the surface (1-2 cm) and in the root zone (10-15 cm) and will be analyzed in the laboratory for water content, soil salinity, grain size and percent organic matter. These properties often reflect flow regime and typically influence the diversity of flora and fauna. Small scale inundation metrics (e.g. via vial method) can be added if needed later in the study.

Physiological condition of plants
Preliminary monitoring proposal (currently being refined) includes randomly selecting 12 plants per area (within the application site and in a control site) for continual physiological monitoring at biweekly intervals prior to and for four years post-augmentation. On each of the measurement dates, leaf-level photosynthesis and conductance will be measured (using a Li-Cor LI-6400X portable photosynthesis system – owned by CSULB already) under light-saturating conditions (>900 lmol m) on a single, young but fully expanded leaf on each of these 12 plants. On each date, 12 additional, randomly chosen plants will be measured similarly, then harvested and preserved in formalin-acetic acid-alcohol mixture. These sections will be used to determine total leaf thickness, total chlorophyll, total leaf area (using LiCor), foliar % N, and percent C, H, and N. Plant mortality (number or percent dead) will be measured every month throughout the experiment.

Assessment of Carbon Stock and Carbon Sequestration Assessment
Preliminary monitoring proposal (currently being refined) includes obtaining six cores across the Refuge in late summer prior to sediment augmentation. The cores will be collected along two transects of three cores per transect; one within the augmentation site and another transect outside the site but within the Refuge’s low marsh habitat. The six cores will be collected per (Callaway et al. 2012) and sent to a lab for dating and analysis of organic matter and bulk density. Following augmentation, vegetation growth within the project site will be monitored, and once cordgrass stem terminal height and stem density exceed pre-application conditions, an additional six surface samples will be collected in late summer for analysis of organic matter and bulk density to document the change in carbon sequestration from pre-project conditions. Carbon sequestration rates will be calculated following Callaway et al. (2012).

8. ***Literature Cited:***

Beaumont, N. J., L. Jones, A. Garbutt, J. D. Hansom, and M. Toberman. 2014. The value of carbon sequestration and storage in coastal habitats. Estuarine, Coastal and Shelf Science 137:32-40.

Brevik, E. C. and J. A. Homburg. 2004. A 5000 year record of carbon sequestration from a coastal lagoon and wetland complex, Southern California, USA. Catena 57:221-232.

California Department of Fish and Game and U.S. Fish and Wildlife Service (CDFG and USFWS). 1976. The Natural Resources of Anaheim Bay.

California Natural Resources Agency. 2014. Safeguarding California: Reducing Climate Risk, An update to the 2009 California Climate Adaptation Strategy. July 2014.

Callaway, J. C., E. L. Borgnis, R. E. Turner, and C. S. Milan. 2012. Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands. Estuaries and Coasts 35:1163-1181.

Chmura, G. L., S. C. Anisfeld, D. R. Cahoon, and J. C. Lynch. 2003. Global carbon sequestration in tidal, saline, wetland soils. Global Biogeochemical Cycles 17(4):22-1-22.12. doi:10.1029/2002GB001917, 2003.

Cloverdale, T. C., C. P. Brisson, E. W. Young, S. F. Yin, J. P. Donnelly, and M. D. Bertness. 2014. Indirect Human Impacts Reverse Centuries of Carbon Sequestration and Salt Marsh Accretion. PLoS ONE 9(3):e93296. Doi:10.1371/journal.pone.0093296.

DeLaune, R. D., W. H. Patrick Jr., C. W. Lindau, and C. J. Smith. 1990. Nitrous oxide and methane emissions from Gulf Coast wetlands, In Soils and the Greenhouse Effect, edited by A. F. Bouwman, pp. 497-502. John Wiley, New York.

Emmett-Mattox, S. and S. Crooks. 2014. Implementing Coastal Blue Carbon Projects: Lessons Learned and Next Steps. National Wetlands Newsletter 36(1):5-8. Published by the Environmental Law Institute. January/February 2014.

Ford, M. A., D. R. Cahoon, and J. C. Lynch. 1999. Restoring marsh elevation in a rapidly subsiding salt marsh by thin-layer deposition of dredged material. Ecological Engineering 12:189-205.

Ganju, N. K., D. H. Schoellhamer, and B. A. Bergamaschi. 2005. Suspended sediment fluxes in a tidal wetland: Measurement, controlling factors, and error analysis. Estuaries 28:812–822, doi:10.1007/BF02696011.

Hansen, V. D. and J. A. Nestlerode. 2014. Carbon sequestration in wetland soils of the northern Gulf of Mexico coastal region. Wetlands Ecology and Management 22:289–303.

Hubbard, J. C. E. 1969. Light in relation to tidal immersion and the growth of *Spartina townsendii* (s.l.). Journal of Ecology 57:795-804.

Intergovernmental Panel on Climate Change (IPCC). 2013. Coastal Wetlands. In: 2013 Supplement to the 2006 IPCC guidelines for National Greenhouse Gas Inventories (eds. Alongi, D., Karim, A., Kennedy, H., Chen, G., Chmura, G., Crooks, S., et al.).

Kinnetic Laboratories, Inc. and Moffatt &Nichol. 2014. Sampling and Analyis Report, Dredge Material Evaluation Sunset/Huntington Harbour Maintenance Dredging and Waterline Installation Project. Prepared for: County of Orange, OC Community Resources/OC Parks and the City of Huntington Beach, Public Works Department. May 2014.

Li, Xiuzhen, Linjing Ren, Y. Liu, C. Craft, U. Mander, and S. Yang. 2014. The impact of the change in vegetation structure on the ecological functions of salt marshes: the example of the Yangtze estuary. Regional Environmental Change 14:623–632.

Massey, B. W., R. Zembal, and P. D. Jorgensen. 1984. Nesting Habitat of the Light-Footed Clapper Rail in Southern California. Journal of Field Ornithology, 55(1):67-80. Winter 1984.

Merkel & Associates, Inc. 2014. 2013 Anaheim Bay Benthic And Fish Community Assessments At Naval Weapons Station Seal Beach Final Report CONTRACT # N62473-10-D-0805. Prepared for: Department of the Navy Naval Facilities Engineering Command, Southwest and Naval Weapons Station Seal Beach, Environmental Department.

National Fish, Wildlife, and Plants Climate Adaptation Partnership. 2012. National Fish, Wildlife, & Plants Climate Adaptation Strategy. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, DC.

National Oceanic and Atmospheric Administration (NOAA). Coastal Blue Carbon webpage. (http://www.habitat.noaa.gov/coastalbluecarbon.html), accessed on 12/05/14.

National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies; National Research Council.

Nordby Biological Consulting and Tijuana River National Estuarine Research Reserve. 2014. South San Diego Bay Coastal Wetland Restoration and Enhancement Project Year 2 Postconstruction Monitoring Report. Unpubl. May 2014.

Pendleton, L., D. C. Donato, B. C. Murray, S. Crooks, W. A. Jenkins, S. Sifleet, C. Craft, J. W. Fourqurean, J. B. Kauffman, N. Marbà, P. Megonigal, E. Pidgeon, D. Herr, D. Gordon, and A. Baldera. 2012. Estimating Global "Blue Carbon" Emission from Conversion and Degradation of Vegetated Coastal Ecosystems. PLoS ONE 7(9): e43542. doi:10.1371/journal.pone.0043542

Poffenbarger, H. J., B. A. Needelman, and J. P. Megonigal. 2011. Methane emissions from tidal marshes. Wetlands 31:831-842.

Poland, J. F. and A. M. Piper, et al. 1956. Ground water geology of the coastal zone, Long Beach – Santa Ana area, California. USGW Water Supply Paper #1109 (referenced in CDFG and USFWS 1976).

Ray, Gary. 2007. Thin Layer Placement of Dredged Material on Coastal Wetlands: A Review of the Technical and Scientific Literature. U.S. Army Corps of Engineers. ERDC/EL TN-07-1. December 2007.

Slocum, M. G., I. Mendelssohn, and N. L. Kuhn. 2005. Effects of sediment slurry enrichment on salt marsh rehabilitation: Plant and soil responses over seven years. Estuaries 28:519-528.

Smith, C. J., R. D. DeLaune, and W. H. Patrick Jr. 1983. Nitrous oxide emission from Gulf Coast wetlands. Geochim. Cosmochim. Acta 47:1805-1814.

Stein, B. A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, D.C.

Takekawa, J. Y., K. M. Thorne, K. J. Buffington, C. M. Freeman, and G. Block. 2013a. Evaluation of subterranean subsidence at Seal Beach National Wildlife Refuge. Unpubl. Data Summary Report. U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 24pp.

Takekawa, J. Y., K. M.Thorne, K. J. Buffington, C. M. Freeman, and G. Block. 2013b. Downscaling climate change models to local site conditions: San Diego National Wildlife Refuge Complex. Unpubl. Data Summary Report. U.S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 88pp.

The Blue Carbon Initiative. Coastal Blue Carbon Methods for Assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows. (http://thebluecarboninitiative.org), accessed on 12/05/14.

U.S. Environmental Protection Agency (USEPA). 2003. Dredged Material Management Action Agenda for the Next Decade. Based on a workshop sponsored by the National Dredging Team, January 23 – 25, 2001 in Jackson, Florida. July 2003.

U.S. Fish and Wildlife Service (USFWS). 2010. Wetlands Mapper Documentation and Instructions Manual. U.S. Fish and Wildlife Service Division of Habitat and Resource Conservation Branch of Resource and Mapping Support National Standards and Support Team Madison, WI 53711-1061. August 2010.

U.S. Fish and Wildlife Service (USFWS). 2012. Seal Beach National Wildlife Refuge Final Comprehensive Conservation Plan.

Ward, K. M., J. C. Callaway, and J. B. Zedler. 2003. Episodic colonization of an intertidal mudflat by native cordgrass (*Spartina foliosa*) at Tijuana Estuary. Estuaries 26:116–130.

Zedler, J. B. 1993. Canopy Architecture of Natural and Planted Cordgrass Marshes: Selecting Habitat Evaluation Criteria. Ecological Applications 3(1):123-138.

Zembal, R., S. M. Hoffman, and J. Konecny. 2014. Status and Distribution of the Light-footed (Ridgway's) Clapper Rail in California, 2014. California Department of Fish and Wildlife, Wildlife Management, Nongame Wildlife Unit Report, 2014-05. Sacramento, CA.