ANNUAL REPORT
October 1, 2018 – September 30, 2019

Date: October 31, 2019
Agreement No.: P1496011 00
Grant Term: March 1, 2020
Project Title: Initiation of Thin-Layer Sediment Augmentation on the Pacific Coast
Grantee: U.S. Fish and Wildlife Service, San Diego NWRC

FISCAL REPORT

<table>
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<tr>
<th>Fund Source</th>
<th>Amount Awarded</th>
<th>Amount Invoiced for Services through September 30, 2019†</th>
<th>Total Amount Remaining</th>
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† Includes Invoice 35-2019
* See itemized cost share expenditures presented in Attachment 1.
‡ Cost Share agreements have already been achieved and are therefore not included in this total.

PROGRAM/TECHNICAL REPORT

Project Overview

The Seal Beach National Wildlife Refuge (Refuge or NWR) Thin-Layer Sediment Augmentation Project is the first project of this kind to be implemented on the Pacific Coast. The primary goal of the project is to test the benefits of this technique as a sea-level rise adaptation strategy for ensuring the long-term availability of coastal salt marsh habitat for carbon sequestration, as well as for the conservation of listed and sensitive species that are dependent on coastal salt marsh habitat for their existence. Design and implementation of the project and its associated research components represents a collaborative effort involving public agencies, educational/research institutions, and volunteers. The project team includes the U.S. Fish and Wildlife Service (Service), Naval Weapons Station Seal Beach, U.S. Army Corps of Engineers (ACOE) Engineer Research and Development Center, U.S. Geological Survey (USGS) Western Ecological Research Center, California Department of Fish and Wildlife, California State Coastal Conservancy (SCC), County of Orange Parks, researchers from the University of California, Los Angeles (UCLA), California State University, Long Beach (CSULB), and Chapman University, and volunteers from the Friends of the Seal Beach NWR.
The pre- and multiple year post-augmentation monitoring plan is essential to the project goals of successfully raising the elevation of the marsh plain to support Pacific cordgrass (Spartina foliosa) and associated salt marsh species, and providing a thin-layer sediment augmentation guidance document that describes this “proof-of-concept” project. The guidance will include a description of the procedures and techniques employed to achieve sediment depths and minimize movement of sediment offsite (including the effectiveness of all tested procedures and lessons learned) during the augmentation process. The project’s pre and post augmentation monitoring program will provide data related to the biological and physical responses of the site to augmentation, including the reestablishment of Pacific cordgrass needed to support nesting and foraging habitat for the light-footed Ridgway’s rail and to facilitate carbon sequestration. Project results, which will be disseminated to interested parties, will assist in the design and implementation of future thin-layer sediment augmentation projects along the California coast implemented to protect salt marsh habitat from the effects of sea level rise.

Summary of Activities Performed from October 1, 2019 to September 30, 2018

Overview
This is the fourth annual report for the thin-layer sediment augmentation project. The project team has now completed three full years of post-augmentation monitoring. The first annual report addressed pre-project site monitoring at the control site and 10-acre augmentation site; thin-layer sediment placement over approximately 7.9 acres of the 10-acre site (Figure 1); and initiate post-augmentation monitoring of physical and biological conditions at the control and project site. Subsequent annual reports addressed post-augmentation monitoring efforts and results. Post augmentation monitoring began in earnest in June 2016 and will continue with funding from this grant through December 2019. With additional funding available from the SCC, periodic monitoring of the site will continue through 2022.

Monitoring and Analysis Activities and Observations

Plants and Invertebrates. Fall sampling of plants and invertebrates was conducted in October 2018 and spring sampling was conducted in April 2019 at both the augmentation site and control site by CSULB. In April 2018, Pacific cordgrass was present in only one of the monitoring plots, although it was also present in several other locations on the site where the elevations were slightly lower, including along the edges of site. During fall sampling (October 2018), the research team noted a slight increase in the percent cover of Pacific cordgrass throughout the site, with Pacific cordgrass present in several monitoring plots (Figure 2). Annual pickleweed (Salicornia biglovii) continued to be the dominant plant on the site (Figure 3). In November 2018, saltwort (Batis maritima), which previously was observed primarily along edge of the buffer area, was now found growing in various locations within the augmentation site (Figure 4). Hundreds of annual pickleweed seedlings were also observed throughout the site, many growing at the base of last year’s plants. During spring sampling in April 2019, CSULB observed the continued recovery of the low salt marsh plant community. Species included annual pickleweed (Figure 5), saltwort, Pacific cordgrass, and pickleweed (Sarcocornia pacifica) (Figure 6). Annual pickleweed continued to be present in the highest numbers.
Figure 1. Site Elevations Following Sediment Augmentation
Figure 2. Sediment augmentation site in October 2018. Photo: CSULB

Figure 3. Annual pickleweed occurs in various densities throughout the site. Photo: CSULB
Figure 4. Saltwort growing in an area near the center of the site. Photo: USFWS

Figure 5. Annual pickleweed growing in areas where sand from emptied sandbags was deposited on the site. Photo: USFWS

Figure 6. View of the site looking south. The majority of the plants in this photo are annual pickleweed with some occurrences of saltwort and Pacific cordgrass in the area. Photo: USFWS
The overall establishment of Pacific cordgrass was still limited as of June 2019, with only a slight increase since the last growing season.

Although not necessarily related, Refuge staff noted that Pacific cordgrass presence elsewhere in the marsh reached a point where its decline was noticeable. For example, several areas within the Refuge where the cordgrass had previously been thick enough to provide shelter and was therefore considered an ideal location for placement of a rail nesting platform were found to be dominated by pickleweed in 2019. The reason for this transformation from cordgrass to pickleweed remains unknown.

During a site visit on August 20, 2019, the Refuge Manager noted the continued growth of annual pickleweed throughout the site. Saltwort was also prevalent in many locations. Where Pacific cordgrass was growing, it appeared denser and taller than during previous site visits. This may relate to the increased rainfall experienced at the site during the 2018/2019 rainy season, as well as rain events that occurred in the spring and early summer of 2019.

Photosynthesis Surveys. Photosynthesis surveys were conducted at both the augmentation site and the control site by CSULB in October 2018 and April 2019, and will be conducted again in October 2019. The results of this work will be included in the October to December 2019 quarterly report. All leaf area measurements from *Spartina* leaves are being analyzed on the LiCor Leaf Area Meter.

Laboratory Processing of Invertebrates. In December 2018, CSULB completed sorting invertebrates from cores taken in spring 2018, and by March 2019, Dr. Whitcraft and her students completed sorting and identification of invertebrates for the top 2 cm of sediment for all samples collected including fall 2018. Invertebrate vouchers were processed for identification to lowest taxonomic level. Also between January and March 2019, the team continued to sort the bottom 4 cm samples for all prior time points.

Invertebrate sorting and identification for top 2 cm samples was completed in September 2019 for all samples collected including spring 2019 samples and invertebrate vouchers were processed for identification to lowest taxonomic level. Sorting the bottom 4 cm samples for all prior time points is ongoing.
Results from October 2018 indicated that abundance, species richness, and diversity of infaunal invertebrates have increased since immediately after augmentation was completed and 1-year post-augmentation. Prior to augmentation, the community composition of invertebrates was dominated by oligochaetes and polychaetes. Following augmentation, the community composition shifted to insects and insect larvae.

Preliminary analysis of invertebrate data from fall 2018 (as compared to fall 2015, pre-augmentation) indicates that abundances, species richness, and diversity have increased but have not yet recovered to pre-augmentation levels (Figures 8, 9, and 10). The augmentation site still had a higher proportion of insects (specifically Ephydridae flies) than the control site. Since then, CSULB has observed a continued increase in the presence of oligochaetes on the augmentation site. Analysis of samples taken in spring 2019 continue to indicate that insect larvae remain abundant, and species richness is still lower in the augmentation site than in the control site.

**PERMANOVA**

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<td>Year</td>
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</tr>
<tr>
<td>Treatment</td>
<td>0.001</td>
</tr>
<tr>
<td>Year x Treatment</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Figure 8. Abundance of infaunal invertebrates in the control and augmentation sites in fall 2015 (pre-augmentation) and fall 2018 (post-augmentation). Letters indicate significant differences at the 0.5 level.
Figure 9. Species richness of infaunal invertebrates in the control and augmentation sites in fall 2015 (pre-augmentation) and fall 2018 (post-augmentation). Letters indicate significant differences at the 0.5 level.
Figure 10. Diversity of infaunal invertebrates in the control and augmentation sites in fall 2015 (pre-augmentation) and fall 2018 (post-augmentation). Letters indicate significant differences at the 0.5 level.

Porewater, Grain Size, and Nutrient Analysis. In late 2018, CSULB and Chapman University initiated a project with funding from the California State Coastal Conservancy to analyze the nutrient content in pre- and post-augmentation sediments, porewater, and salt marsh plants from the site. This analysis will consider among other things, the differences in the nutrient content of the pre-augmentation sediments, as well as the differences in grain size present on the sediment applied during augmentation. Sediment samples were collected in fall 2018 from three areas of the site augmentation site that supported different species mixes prior to augmentation (i.e., a Pacific cordgrass dominated site, a saltwort dominated site, a “ponded” site). The sediment samples were analyzed for grain size and nutrient content. The grain size analysis indicated that sediment on the augmentation site remains very sandy, with significantly less clay and silt than is found on the control site (Figure 11). Monitoring is ongoing.
In fall 2018, CSULB purchased the necessary supplies for analyzing nutrients present in the sediments and engaged Jason Keller, Chapman University, to conduct C:N analysis of sediment samples. Porewater nutrient samples were gathered by researchers from Chapman University and are being run for nutrients in collaboration with the CSULB Geology Department. A method has been developed to run the samples with de-oxygenated water.

**Marsh Elevations.** USGS collected measurements at the Surface Elevation Tables (SETs) and feldspar plots at both the augmentation site and the control site on February 7, 2019, April 24, 2019, and August 28, 2019. Figure 12 shows one of the SET locations during data collection.
The most recent elevation SET pin measurements taken on August 28, 2019 showed that the augmentation site experienced a gradual decrease in elevation of -4.57 mm averaged across all fifteen SETs since April 24, 2019, while the control site showed a zero-net change across its six SETs. The original SETs (n=4), located elsewhere on the Refuge, also showed a small increase of 0.60 mm (Figure 13).

The control SETs have had gains and losses of elevation since installation but have a mean cumulative increase of 4.58 mm from the date of installation. The augmentation SETs have had a mean increase in elevation of 216 mm with sediment application, but have had a decrease in elevation of -99.33 mm post sediment application (April 2016-August 2019) and therefore a mean cumulative increase in elevation of 117.33 mm.

Between April 24, 2019 and August 28, 2019, the feldspar readings showed an increase in sediment above the feldspar layer of 9.59 mm. However, overall post monitoring has showed little overall change in depth of the feldspar layer with a small decrease of -23.62 mm averaged across all 15 SETs. This finding shows that the majority of elevation decreases shown in the elevation pin measurements are most likely due to the original marsh surface compacting below the feldspar marker horizon, while the rest could be due to the compaction or loss of the applied sediment.

Final analysis and conclusions will be presented by USGS in a final report that is expected to be available in early 2020.
Photogrammetry Flights. A second photogrammetry flight was conducted on Aug 22, 2018 with funds provided by the U.S. Army Corps of Engineers, Engineer Research and Development Center (ACOE ERDC). In August 2019, approval was provided to use some remaining grant funds to analyze the elevation data from the second flight and compare the data from the first and second photogrammetric surveys. USGS will use ArcGIS (ESRI 2011. ArcGIS Desktop: Release 10.5 Redlands, CA: Environmental Systems Research Institute) for all spatial analysis and product generation and update their previously prepared report, Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge: Elevation Change Assessment (Thorne and Freeman 2017), to include the most recent imagery analysis.

Sediment Accretion. UCLA researchers, working under the direction of Dr. Richard Ambrose, have been documenting sediment thickness at multiple locations distributed across the augmentation site. The two types of sampling stations consist of consolidated stations including feldspar plots, sediment stakes and bulk density sampling locations, and sediment stake stations. The researchers are also studying of the redevelopment of tidal creek within the augmentation site. Re-sampling of the augmented marsh plain to identify evidence of tidal creek development was conducted in winter/spring 2019. The researchers also began exploring with working with Navy the possibility of using a UAV to collect images of the entire site rather than using a hand-held camera/pole set up to take images near specific tidal creeks. Approval for UAV flights has not yet been granted, so GPS data is collected along with individual images of tidal creek formation using a hand-held camera/pole set up, as shown in Figure 14.

In April 2019, UCLA completed the 36-month field sampling for the project. Data collected at the control site included measuring creek cross-section elevations at four creek crossings and measurements of sediment accretion at 15 feldspar plots. On the augmentation site, sediment accretion data was collected by measuring sediment stakes and feldspar (deep and shallow) plots, involving 73 sediment stakes and 23 feldspar/bulk density plots. Bulk density samples were also collected for lab analysis, and creek cross-section elevation data was collected at eight creek crossings on the augmentation site.

Figure 14. UCLA researchers using a hand-held camera/pole to take images of developing tidal creeks.
Laboratory work on the acquired samples from the feldspar/bulk density plots was also conducted to determine bulk density and percent organic carbon. Grain size analysis was also conducted. Graphs were updated to include data from most recent sampling effort and data organization and management on the UCLA online server (BOX) was also accomplished.

In July 2019, UCLA once again collected images and GPS data for tidal creeks in the control site and the augmentation site. Photographs were taken of one tidal creek area using low-altitude photography and then RTK GPS was used to map the same tidal creek area for comparison with modeled creeks. That data was processed and a digital mosaic was formed using the photographs. The tidal creek networks were then modeled using DEM and DSM created from the photographs. The data was used to compare modeled creeks to field mapped creek locations.

Avian Use. Starting in October 2018, the timing for when avian surveys are conducted on the project site was changed to better capture bird use on the site when the tides are more favorable for foraging and loafing. Prior to this change, surveys were occurring when the site was completely submerged or totally exposed. The new timing for these surveys will continue throughout the remainder of the monitoring program and the surveys will be conducted by refuge staff. The timing and results of the avian surveys is presented in Table 1. Note that due to inclement weather conditions, the federal government shutdown, and staff time constraints, no surveys were conducted the first quarter of 2019.

Light-footed Ridgway’s Rail. Rail monitoring on the project site is conducted as part of a refuge-wide rail monitoring survey. Annual monitoring reports are prepared following the end of each rail nesting season. A high tide count is conducted in fall and a night call survey is conducted just prior to the start of the breeding season. Nesting data is obtained through monthly visits to the nesting rafts.

During the 2018 nesting season, 88 rafts were deployed at the Seal Beach NWR. Rafts and other nesting areas were visited every 3 – 4 weeks during the breeding season (March 26 – July 20). Surveys were conducted by two observers, who accumulated 131 field-hours over six rounds of raft checks. Direct evidence of breeding activity on the Refuge included the observation of 27 clutches of eggs laid on 26 rafts and 15 marsh hatches with subsequent brood nests built on 17 rafts. There were an additional 22 brood nests built on 22 rafts in 2018. Overall nesting success on rafts was 98 percent1. The 2018 call count was conducted on 9 March by nine observers when 21 pairs, 2 males, and 1 female were heard. A total of 60 pairs of rails were reported at the Seal Beach NWR in 2016 and 2017. This was based on combine call count and raft nesting data for those years. In 2018, the total count of 43 pairs was down 28 percent from the past two years and is the lowest count since 2013.

Reductions in total pair counts between 2017 and 2018 were also observed at other rail nesting sites, with an overall reduction of 300 fewer breeding pairs, a 31 percent decrease from 2017 data.

### Table 1. Avian Monitoring Results for October 2018 – September 2019

<table>
<thead>
<tr>
<th>Date</th>
<th>26 Oct 2018</th>
<th>30 Nov 2018</th>
<th>13 Dec 2018</th>
<th>No surveys were conducted Jan - March 2019 due to inclement weather and staffing constraints</th>
<th>17 Apr 2019†</th>
<th>10 May 2019†</th>
<th>6 Jun 2019</th>
<th>9 Jul 2019‡</th>
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<th>15 Sept 2019</th>
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<td>Time</td>
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<td>9:30 AM</td>
<td></td>
<td>10:15 AM</td>
<td>6:15 PM</td>
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<td>Tides</td>
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<td>1.12m (3.7 ft), rising</td>
<td>1.12m (3.7 ft), rising</td>
<td></td>
<td>1.33 m (4.4 ft), falling</td>
<td>0.98m (3.2 ft), falling</td>
<td>0.78m (2.6 ft), rising</td>
<td>1.51m (4.9 ft), rising</td>
<td>1.18m (3.9 ft), rising</td>
<td>1.53m (5.0 ft), peak</td>
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<tr>
<td>Long-billed curlew</td>
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<td></td>
<td></td>
<td>2019 due to inclement weather and staffing constraints</td>
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<tr>
<td>Black bellied plover</td>
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<td>Osprey</td>
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<tr>
<td>Semi-palmated plover</td>
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<tr>
<td>Least/western sandpiper</td>
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<td>Other sandpipers (Calidris sp.)</td>
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† Surveys were conducted in April and May, but no birds were observed. Shorebird numbers are low at this time of the year throughout the Refuge.
‡ The tides were high during the July survey, as a result no birds were observed on the site.
During the 2018 nesting season, rail nesting and other activities were noted on 61 of the 88 available rafts. Although most of the estimated 43 pairs in the Refuge nested and brooded on rafts, at least 18 clutches probably hatched in the marsh (Zembal et al. 2018).

On August 20, 2019, the Refuge Manager conducted a site visit to check the light-footed Ridgway’s rails nesting platforms. The three nesting platforms located south of the augmentation site on the peninsula had no evidence of being used by light-footed Ridgway’s rails during the 2019 breeding season.

The population of rails on the Seal Beach NWR mirrors that of the entire sub-species in that it has decreased significantly. The cordgrass in the area where these three platforms are located was also noted to be very sparse relative to other areas where rails were found to be breeding in 2019. Throughout the entire marsh, the rail population only used eight nesting platforms for egg nests. Two of these platforms, one of which is platform #115, were used twice. Platform #115 was relocated from the augmentation area to an area of the marsh opposite the channel on the west side of the augmentation site prior to the start of the augmentation project.

Final monitoring results for the 2019 light-footed Ridgway’s rail nesting season are expected to be available in the first quarter of 2020. No rails were observed on the augmentation site between October 2019 and September 2020.

**Project Management**
Research team conference calls were conducted by Rick Nye, Refuge Manager, on October 5, 2018, March 29, 2019, and June 26, 2019.

On November 30, 2018, Rick replaced the batteries and microSD cards in the time-lapse cameras, which are still taking five images per day. A few month later, Rick replaced the close-up time-lapse camera using the same model as before. The old camera was starting to show some wear due to the accumulation of moisture inside the case. Despite its condition, he was able to download the pictures from the previous period. Some of the images were taken as 5-second videos instead of photographs.

On December 13, 2018, Elizabeth Murray and Christine Vanzomeren, U.S. Army Corps of Engineers, Engineer Research and Development Center (ACOE ERDC), were escorted to the site by a Refuge volunteer with boat operator training so they could shoot footage of the site for videos they are preparing about the project site and about the field identification of iron sulfides (FeS) in restoration sites.

**Project Outreach/Information Dissemination**
A webpage (https://www.fws.gov/refuge/seal_beach/what_we_do/ resource_management/ Sediment_Pilot_Project.html) for the project is maintained on the Seal Beach NWR website. Information about the sediment augmentation project is posted and progress on the project is updated periodically. Quarterly reports prepared for CDFW are also posted, and photos and links to time lapse photography are provided. The page also acknowledges our funding partners.
On December 9, 2018, the Seal Beach NWR hosted a field trip for about 20 participants of the Restore America’s Estuaries 9th National Summit on Coastal and Estuarine Restoration and Management, held in Long Beach, CA. Kim Garvey, Coastal Engineer for Moffatt & Nichol, who working with Orange County Parks assisted the project team in the design and implementation of the augmentation project, provided the group with an overview of the sediment augmentation process that was conducted on the Refuge. The Seal Beach thin-layer sediment augmentation project was also included in the discussion at several of the Summit’s breakout sessions in which project team members were contributing speakers.

The ACOE ERDC produced a technical note that provides a summary of marsh assessment, design, implementation, and monitoring at three salt marsh restoration projects, including the Seal Beach NWR site, undertaken to address the effects of relative sea level rise (RSLR). In addition, Christine Vanzomeren, ACOE ERDC, produced two videos recorded during her visit to the project site in December. The videos should soon be available for viewing online.

Elizabeth Murray, ACOE ERDC, presented a discussion on thin-layer placement, including information about the Seal Beach NWR project, at the Society of Wetland Scientists, held in Baltimore, Maryland on May 28 - 31, 2019. The Long Beach Post ran an article on April 22, 2019 about the project entitled “Nature can soften impact of rising seas – if we let it.”

Dr. Thorne and her team at USGS prepared an article entitled: Thin-layer sediment addition to an existing salt marsh to combat sea-level rise and improve endangered species habitat in California, USA. This article was published in Ecological Engineering in June 2019.

In September 2018, CSULB submitted a draft paper, Short-Term Impact of Sediment Augmentation on Plants and Invertebrates in a Southern California Salt Marsh, related to the augmentation project to Wetland Ecology and Management. It was accepted pending major revisions, which were submitted in January 2019. The article has not yet been published.

On July 3, 2019, Rick Nye, Refuge Manager, and Andy Yuen, Project Leader for the San Diego National Wildlife Refuge Complex, had the opportunity to discuss the project with U.S. Congressmen Harley Rouda (CA-48), Chair of the Oversight and Reform Subcommittee on Environment, and Alan Lowenthal (CA-47) during their visit to the Refuge (Figure 15).

On September 18, 2019, Rick also discussed the project with Lauren Barich from Representative Rouda’s local office. She was provided with a copy of the case study for the sediment augmentation project.
On October 3, 2019, Rick met briefly with California State Senator Thomas Umberg (State Senate District 34) during his tour of the Naval Weapons Station Seal Beach (NWSSB). Senator Umberg asked about projects being implemented on NWSSB to address sea level rise, which provided the opportunity for Rick to discuss the sediment augmentation project and acknowledge the project funders.

**Status of Ongoing Research**

**UCLA (Sediment Coring).** UCLA researchers under the direction of Dr. Glen MacDonald completed their analysis and prepared the final results of their assessment of pre-augmentation net sediment accretion rates, carbon stock, carbon accumulation rates, and historic sea-level rise on the Seal Beach NWR from historic sediment core data. The final report (Brown et al. 2018) was provided with the last annual report for the project.

**Chapman University (Greenhouse Gas Flux).** Sampling to measure seasonal emissions of CO₂, CH₄, and N₂O and associated abiotic parameters (i.e., water level, porewater salinity, sulfate and nitrate) in the three dominant plant communities at Seal Beach NWR, including the project site pre- and post-augmentation, has been completed. We are awaiting Dr. Keller’s final report.

**UCLA (Changes in Marsh Plain Post-Augmentation).** Under the direction of Dr. Richard Ambrose, sediment thickness continues to be sampled at multiple locations distributed across the project area. Two types of sampling stations have been established on the marsh plain: consolidated stations including feldspar plots, sediment stakes and bulk density sampling locations, and sediment stake stations. This research team also continues to monitor and assess newly forming tidal creeks on the site. This data will provide insight into how tidal creeks form or reestablish following augmentation.

To improve data collection related to tidal creek development, Dr. Ambrose has also been preparing an application to the Navy to obtain permission to use a drone to collect digital elevation data. This will enable better characterization of tidal creek development.

**CSU Long Beach (Plant and Invertebrate Studies).** Dr. Christine Whitcraft and her students continue to monitor plant and invertebrate diversity, abundance, and distribution, as well as associated abiotic parameters (e.g., temperature, porewater salinity, redox), of the control and augmentation sites both pre- and post-augmentation. Plant community sampling locations are co-located with the invertebrate sampling locations, and these locations were selected in collaboration with USGS and UCLA so that the sampling locations overlap with placement of sediment monitoring stakes.

Dr. Whitcraft is coordinating with Dr. Keller to conduct C:N analysis on sediment samples and porewater samples for the purpose of analyzing the nutrient content of the augmentation sediments. This work is being funded by the California State Coastal Conservancy. These researchers are also assessing the ability of plants and sediment to store carbon by collecting data on the photosynthetic rate of plants, C:N ratios of plants, plant traits (e.g. leaf area), and isotope ratios in sediment. Initial results indicate that the cordgrass present in the augmentation site and control site is photosynthesizing at comparable rates. Site sampling will occur again in spring 2020.
In March 2019, Dr. Whitcraft submitted a pre-proposal (Accelerating Recovery at Seal Beach National Wildlife Refuge Salt Marsh Following Sediment Augmentation Using Experimental Planting) for Proposition 84 USC Sea Grant funding. Unfortunately, the proposal was not accepted. The project team is continuing to explore opportunities for funding a research project to examine the benefits of planting Pacific cordgrass as a component of thin-layer augmentation projects.

USGS (Sediment Flux Patterns and Sets). Between winter 2014 through the end of August 2017, USGS maintained two YSI EXO2 multi-parameter sondes (ysi) to monitor turbidity and a Nortek aquadopp current profiler (ADCP) to monitor inundation and flow velocities within tidal channels located in proximity to the augmentation site. A final report has been issued.

In August 2019, USGS completed their data collection from 21 deep rod surface elevation tables (SETS) (15 SETs in the sediment augmentation area and 6 SETs in the control area) installed in August 2015. The data has been used to assess changes in elevation, including accretion and shallow subsidence, before, during, and immediately after sediment application at the sediment augmentation site. A final report will be available in early 2020. We are exploring additional funding sources to support the continuation of this work by USGS.

Bird Surveys and Light-Footed Ridgway’s Rail Monitoring. Bird surveys were initially conducted twice monthly, during a high tide and a low tide, however, due to the timing of the surveys, observations were occurring when the site was either completely submerged or totally exposed. As a result, no birds were being recorded on the site during these surveys. To provide better bird data, last quarter, the Refuge Manager initiated site-specific surveys for the augmentation site. These surveys, to be conducted during moderate falling and/or rising tides, will continue throughout the remainder of the monitoring program.

Rail monitoring is conducted as part of a refuge-wide rail monitoring survey. Annual monitoring reports are prepared following the end of the rail nesting season. A high tide count is conducted in fall and a night call survey is conducted just prior to the start of the breeding season. Nesting data is obtained through monthly visits to the nesting rafts. Data for the 2018 nesting season is expected to be available before the next quarterly report. A night call survey was conducted in March 2019.

Eelgrass Surveys. As part of our effort to understand the overall physical and ecological responses of the marsh ecosystem, which includes adjacent eelgrass habitat, the project included requirements for pre- and post-augmentation eelgrass surveys. To date four surveys have been conducted: pre-augmentation, immediately following augmentation, and one and two years post-augmentation. Survey results have been provided to CDFW, NOAA Fisheries, and ACOE.
Percentage of Task
Task 1 – Project Management and Administration 80%

Task 2 – Sediment Augmentation 100%

Task 3 – Project Monitoring (overall) 91%

1) Carbon Storage/Sequestration Benefits 100%
2) Plant and Invertebrate Monitoring 80%
3) Pacific Cordgrass Analysis 80%
4) Site Elevations 90%
5) Sediment Analysis (compaction, movement, bulk density) 95%
6) Turbidity Levels 100%
7) Bird monitoring 80%
8) Eelgrass 100%

Task 4 – Engineering Design/Environmental Documentation (overall) 100%

1) Engineering Plans for Sediment Augmentation Site 100%
2) Environmental Documentation* 100%
   *CEQA/NEPA has been completed by SCC/USFWS

Task 5 – Public Participation/Presentations (overall) 70%

1) Oral/Poster Presentations 90%
2) Workshops and/or Webinars 50%

Overall Project 92%

Deliverables Completed for Each Task

Task 1 – Project Management and Administration

1) Quarterly Progress Report 17 reports
2) Monthly Invoices 34 monthly invoices
3) Subcontractor Selection Orange County Parks & SWIA selected
4) Data Management preliminary data for monitoring locations
5) Acknowledgement of Credit ongoing

Task 2 – Sediment Augmentation

1) Sediment Application completed
2) Adaptive Management on going
3) Reporting Results/Lessons Learned in process

Task 3 – Project Monitoring

1) Carbon Storage/Sequestration Benefits pre-augmentation monitoring completed; long core data processing complete; post-augmentation monitoring underway; long core data final report in preparation.
2) Plant and Invertebrate Monitoring  pre-augmentation work completed; post-augmentation work underway.

3) Pacific Cordgrass Analysis  pre-augmentation work completed; post-augmentation monitoring underway.

4) Site Elevations  pre-augmentation RTK survey; post-augmentation photogrammetry; SET data downloads completed; monitoring of USGS feldspar plots completed.

5) Sediment Analysis  initial core samples retrieved; data processing completed; grain size analysis of new sediment nearing completion.

6) Turbidity Levels  monitoring completed in August 2017; final report completed.

7) Bird Monitoring  pre-augmentation work completed; post-augmentation work ongoing.

8) Eelgrass  pre-augmentation, post-augmentation and year one and year two post-augmentation surveys completed.

Task 4 – Engineering Design/Environmental Documentation

1) Engineering Plans for Augmentation Site  100% engineering plans completed

2) Environmental Documentation*  CEQA/NEPA documents final; ND recorded

*for USFWS and Coastal Conservancy

Task 5 – Public Participation/Presentations

1) Oral/Poster Presentations  Presentations ongoing

2) Workshops and/or Webinars  Participated in USACOE webinar; primarily results presentation planned for early 2020

Problems/Delays Proposed Resolution

Sediment Augmentation. All of these outcomes will be addressed in a forthcoming lesson learned document, which is underway.

Changes in Eelgrass Distribution. The post-augmentation and one year post-augmentation surveys indicated a declining trend in the areal extent and density of eelgrass in the project study area, while the reference site showed an increase in areal extent and density one-year post augmentation. There is no definitive evidence at this point that the augmentation process is solely responsible for this decline as eelgrass losses were experienced throughout the range of this species. During the one year post augmentation survey, a specific area known to be impacted during the augmentation construction phase was showing signs of recovery. At two years post-augmentation, the affected area is now showing strong eelgrass recovery. It has 7,646 m² of eelgrass coverage, which is 86% of the eelgrass coverage it had in that area during the pre-augmentation survey.
Although the eelgrass survey conducted in May 2018 showed improvement in eelgrass coverage throughout the 263,168 m² survey area, the current coverage (36.6%) does not yet match pre-project conditions (42.1%). There are various factors that could be affecting coverage, including both project and non-project conditions. Since eelgrass loss is occurring in other wetlands along the California coast, continuing with our series of annual surveys may benefit those who are trying to understand changes in eelgrass distribution elsewhere.

Nutrient Analysis in the Augmented Site. The team has acquired funding from the California State Coastal Conservancy to complete a sediment nutrient study. The results of an analysis of nutrient content in pre- and post-augmentation sediments and in salt marsh plants from the site will inform other land managers of the relative importance of sediment grain size and nutrient content in sediments to be considered for use in thin-layer sediment application projects. The study will analyze material from stored sediment cores and plant tissue taken from the site prior to augmentation, along with sediment and plant samples present on the site today. This study will allow the project team to determine the extent of differences in nutrient content between the native marsh sediment and the new sediment that has been added to the site. It may also provide a better understanding of the relationship between nutrient content and current plant growth on the site.

Tidal Creek Formation. The project team continues to study the importance of tidal creek development in the reestablishment of native plants and invertebrates on the augmentation site. Initial notching did not result in increases in the rate of tidal creek formation, but it also did not result in increases in the loss of sediment from the site. Therefore, all hay bale dams have been removed. Evaluation of tidal creek formation will continue.

Reestablishment of Cordgrass. Pacific cordgrass is present on the site in low numbers and has been observed in a few monitoring plots. Reestablishment, however, is slower than anticipated. The project team continues to evaluate this issue.

**Project Benefits and Results**

Thin-Layer Sediment Augmentation. We continue to assess project benefits and results and have already learned quite a bit about the sediment augmentation process. The lessons learned document will include suggested changes to the process to benefit future projects. We have already address some of this information at various workshops and seminars. Ongoing analysis of the effects of higher sand content in the sediment used for augmentation will provide important information for future projects, particularly because sediment with a higher sand content may be more readily available for use in thin-layer projects. Early data from the site suggests that some salt marsh vegetation, including cordgrass, can be supported at elevations higher than are currently present within the Refuge. This is important information that can be used to design future thin-layer projects. This and other information will continue to be recorded and disseminated to all interested parties.
Greenhouse Gas Assessment. The results of radiocarbon (14C) dating of long cores taken from the Seal Beach NWR by UCLA researchers indicate an average long-term accretion rate at the Refuge of 1.55 ± 0.16 mm yr⁻¹, which is typical for accretion rates obtained from 14C. In addition, radiocesium (137Cs) and radiolead (210Pb) dating results from three control site and four augmentation site cores had an average 137Cs- and 210Pb-measured accretion for all cores of 3.2 ± .21 mm yr⁻¹, with average 137Cs-measurements showing slightly higher accretion rates (3.2 ± .28 mm yr⁻¹) compared to 210Pb-measurements (3.1 ± .33 mm yr⁻¹) (Figure 15). Variation in accretion rates between control and augmentation for all methods was consistently < 0.5 mm yr⁻¹, and only significant using 210Pb methods.

Using the chronological control obtained from 14C, 137Cs, and 210Pb results, a CAR based on carbon estimates made from loss-on-ignition (LOI)² provided an average carbon sequestration for salt marsh habitat at the Seal Beach NWR control site and augmentation site to 100 cm depth of 117 g C m⁻² yr⁻¹, consistent with rates of carbon sequestration around California³ of ~100 g C m⁻² yr⁻¹ and global⁴ averages of approximately 220 g C m⁻² yr⁻¹.

The estimated carbon sequestration benefit from the USFWS Seal Beach NWR thin-layer sediment augmentation project is presented in Table 2.

<table>
<thead>
<tr>
<th>Grantee (Abbrev. Title)</th>
<th>Project Acreage</th>
<th>Project Life as defined in proposal</th>
<th>Carbon Sequestered as Reported in the Application</th>
<th>Conversion Process to Arrive at Reported GHG sequestration value</th>
<th>Value to Report on Project Report (MT CO2-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Fish and Wildlife Service Seal Beach NWR Sediment Augmentation</td>
<td>10 acres</td>
<td>n/a</td>
<td>Carbon storage estimate of 250 Mg C ha⁻¹ of tidal marsh (i.e., 917.5 Mg CO2 ha⁻¹) represents avoided emissions - associated with halting loss of tidal marsh at the SBNWR</td>
<td>250 MT C ha⁻¹ * 3.67 = 917.5 MT CO2 ha⁻¹</td>
<td>917.5 MT CO2 ha⁻¹ * (1 ha/2.471 ac) = 371.3 MT CO2 ac⁻¹</td>
</tr>
</tbody>
</table>

Summarize Benefits to Disadvantaged Communities (not applicable)
List of Proposed Activities and Tasks for October 2019 - December 2019

Task 1 – Project Management and Administration
Refuge staff will continue to coordinate individually and through conference calls with researchers and other team members. Invoices and quarterly reports will be prepared. A “lessons learned” document will be completed. The research team will begin compilation of their data and monitoring results and conclusion as final reports will be due in February 2020.

Task 2 – Sediment Augmentation
This task is now complete.

Task 3 – Project Monitoring
a) Post-augmentation monitoring will continue and expand as the augmentation site continues to revegetate.

b) USFWS staff will continue to work with the researchers to ensure that no impacts to listed or sensitive species occur during post-augmentation monitoring.

c) Monthly bird surveys and annual monitoring of the light-footed Ridgway’s rail will continue.

d) Dr. Ambrose and his team at UCLA will continue to analyze core samples from feldspar plots to measure the thickness of sediment over the feldspar. Laboratory analyses of bulk density, grain size, and carbon content (LOI) will also be conducted on core samples taken from the site. Tidal creek formation will continue to be studied.

e) Dr. Whitcraft and her staff will continue to conduct post-augmentation sampling and analysis related to plant and invertebrate diversity and abundance, plant photosynthesis, and biomass.

f) Dr. Keller from Chapman University will complete his final report.

g) Time-lapse videos will be updated and posted to the Refuge website.

Task 4 – Engineering Design/Environmental Documentation
This task has been completed.

Task 5 – Public Participation/Presentations
We will continue to update the project webpage and participate in conferences and webinars as opportunities arise. The “lessons learned” document will be completed and a workshop will be held in late February 2020 to discuss these lessons learned with land managers and other interested parties.
Description of Amendments and Modifications to Grant

We have amended the USGS contract to include conducting data analysis for the most recent photogrammetry flight that was funded by ACOE ERDC. The use of grant funds to continue analysis of changing site elevations was approved by CDFW on August 28, 2019.

We made a minor modification to the existing grant by redirecting $4,950 of unallocated research funds to additional eelgrass survey work. The reallocation of funds was approved by CDFW on June 10, 2016.

Attachment
1. Cost Share Expenditures Table
# Attachment 1
## Itemized Cost Share Accounting

### Cost Share (June 1, 2015 to September 30, 2019)

<table>
<thead>
<tr>
<th>Activity or Item</th>
<th>Funding Source</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Cost Share from June 1, 2015 to September 30, 2016</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre and Post-augmentation monitoring</td>
<td>California State Coastal Conservancy (revised 6/2018 to exclude funding provided prior to 6/2015; changing expenditure from $177,070 to $173,120)</td>
<td>$173,120</td>
</tr>
<tr>
<td>Purchase boat to access site</td>
<td>USFWS CRI Grant</td>
<td>$2,425</td>
</tr>
<tr>
<td>RTK elevation survey</td>
<td>US Army Corps of Engineers</td>
<td>$50,252</td>
</tr>
<tr>
<td>USFWS staff time</td>
<td>USFWS CRI Grant</td>
<td>$137,592</td>
</tr>
<tr>
<td>Sediment augmentation</td>
<td>Orange County Parks</td>
<td>$670,500</td>
</tr>
<tr>
<td>Sediment augmentation</td>
<td>USFWS CRI Grant</td>
<td>$350,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>$1,383,916</strong></td>
</tr>
<tr>
<td><strong>Total Cost Share from October 1, 2016 to September 30, 2017</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-augmentation monitoring</td>
<td>California State Coastal Conservancy</td>
<td>$231,753</td>
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<tr>
<td>USFWS staff time</td>
<td>USFWS CRI Grant</td>
<td>$22,714</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>$254,466</strong></td>
</tr>
<tr>
<td><strong>Total Cost Share From October 1, 2017 to September 30, 2018</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-augmentation monitoring</td>
<td>California State Coastal Conservancy</td>
<td>$58,384</td>
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<tr>
<td>USFWS staff time</td>
<td>USFWS Station Funds</td>
<td>$1,294</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>$59,680</strong></td>
</tr>
<tr>
<td><strong>Total Cost Share from October 1, 2018 to September 30, 2019</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-augmentation monitoring</td>
<td>California State Coastal Conservancy</td>
<td>$55,713</td>
</tr>
<tr>
<td>USFWS staff time</td>
<td>USFWS Station Funds</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td><strong>$55,713</strong></td>
</tr>
<tr>
<td><strong>Total Cost Share to Date</strong></td>
<td></td>
<td><strong>$1,753,775</strong></td>
</tr>
</tbody>
</table>

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1. Costs associated with bird surveys and light-footed Ridgway's rail monitoring are not included.
2. This does not include staff time accounted for on monthly invoices.
3. The bids for sediment augmentation came is much higher than estimated by the project engineer, therefore, some of the cost for sediment augmentation was covered by the Orange County Parks.
4. As of September 30, 2017, all USFWS CRI Grant funds have been expended and the grant is closed.
5. All Coastal Conservancy costs were revised in March, 2018 to reflect the full amount expended rather than the showing the cost less the 10% held by the Conservancy during each billing (this will avoid confusion in the future).