QUARTERLY PROGRESS REPORT
As of December 31, 2016

Date: January 25, 2017 Dates Covered by this Report: October 1 – December 31, 2016

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

Fund Source	Amount Awarded	Amount Invoiced as of December 31, 2016	Total Amount Remaining
CDFW GGRF Grant Funds	$1,055,827	$ 271,156	$784,671
Cost Share	$1,306,048	$1,437,299*	<$131,251>
Agreement Totals	$2,361,875	$1,708,455	$653,420

* Includes in-kind staff time from USFWS (Refer to Attachment 1 for details.)

Invoice Submitted this Quarter: ☒ Yes ☐ No

PROGRAM/TECHNICAL REPORT

Activities Performed from October 1 to December 31, 2016:

- Curtin Maritime, the dredging contractor for the project (hired by Orange County Parks) issued their final report describing the sediment application process for the project (report provided under separate cover).

- Researchers continued their post-augmentation monitoring activities on the augmentation site and the control site (details of these monitoring efforts are provided below).

- USGS continued to monitor turbidity levels in the waters surrounding the augmentation site.

- USGS completed their "Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge: Elevation Change Assessment." This document summarizes the initial elevation of the augmentation site, the final elevations after the sediment application processes, the elevation change achieved using a variety of methods, and an estimate of the volume of sediment applied to the site (report provided under separate cover).

- Several presentations addressing various aspects of the project were made during this quarter, as addressed below under public outreach.

- During this period, we also completed our annual report for the State fiscal year that ended June 30, 2016.

- Refuge staff conducted monthly site visits to document site conditions.

Overview of Documented Site Conditions

The following observations were by Refuge Manager Kirk Gilligan and Refuge Biologist Rick Nye. These and other photos and videos of the site have been archived in the project files and are available upon request.

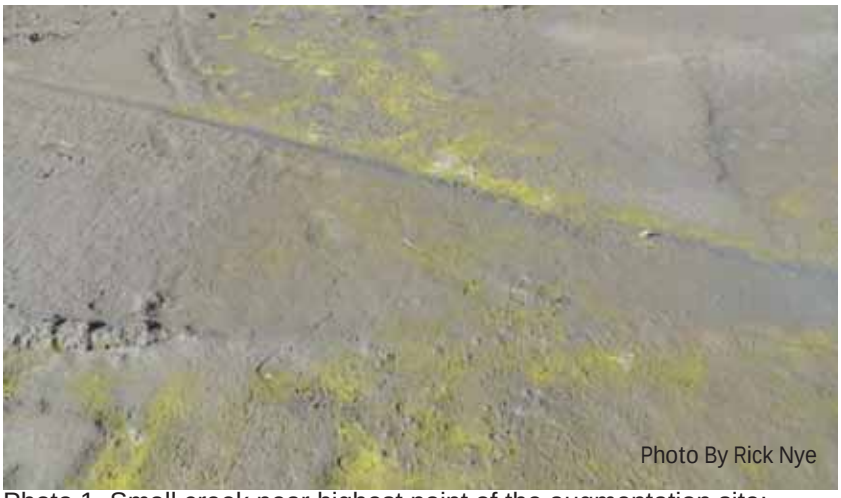

Photo 1. Small creek near highest point of the augmentation site; algae is also present on the site.

1. Overall site conditions

No standing water was observed on 08 November 2016, however, the soil appeared very moist. There were very few hard spots that did not give a little when walking on them. A very small creek appears to have formed which drains the highest point of the augmentation site and goes southeast to the edge of the site (Photo 1).

2. Sediment and Barriers

No significant reduction in hay bales was observed in early November. During September and October, only one hay bale was found at NASA Island where previously there had been at least a dozen. On 14 November 2016 during a spring tide event (+7.0ft/ 2.1m relative to MLLW) at least 8 hay bales were observed floating near the augmentation site.

Photo 2. Views of sediment in the buffer zone at the site's eastern corner; note the new *Batis maritima* growth in the area.

Most areas which have lost their hay bale barrier seem to have minimal loss of sediment. However, there are two areas where sediment has spread significanly into the buffer zone. First, the eastern corner to the southeast side appears much like it was 2 months ago, except it had some new *Batis maritima* growth (Photo 2). The second area with sediment spreading is on the northern end (Photo 3) and appears to be following a creek which existed pre-augmentation.

Photo 3. Northern end of the augmentation site showing sediment leaking past the hay bale barrier.

3. Plants

Areas where cordgrass (*Spartina foliosa*) has been growing since the end of the augmenation process appeared much as it did before with a couple exceptions noted below.

Cordgrass at the southern tip of the augmentation site included at least a dozen new cordgrass sprouts, some of which can be seen in Photo 4.

New *B. maritima* growth was observed (Photo 2) on the east side just south of the 3 height test plots where sediment has moved right to the edge of the buffer zone.

Photo 4. New shoots of cordgrass growing near the project site's southern boundary.

Pickleweed (*Salicornia*) growth near the western corner increased by 3 individual plants.

Eelgrass (*Zostera marina*) in the eastern channel, where the site was frequently accessed during construction, had been reported as having lost 4,931m^2 of eelgrass. While surveying this area by boat, at least one or two blades of eelgrass no more than 8 feet apart from each other were observed, and in some cases there were patches of up to 1m^2 of eelgrass.

Algae was visible in many areas, some of it was dried out while in other areas it was still wet (Photo 1).

4. Animals
During staff site visits, many birds have been observed on the site, including more than 400 least and western sandpipers, along with several long-billed curlews, killdeer, and willets. The results of monthly avian surveys are reported in Table 1 below.

5. Conditions at the Higher High Tides
The images below were taken on December 13, 2016 at high tide. Specifically, they were taken at 8:24 AM when the tide was estimated to be 7.2ft (2.2m) relative to MLLW. The images are looking northeast across the widest part of the site. Going left to right through the middle of the image are some hay bales marking the western side of the site; beyond that you can see some hay bales with egrets and herons on them marking the 3 test plots.

Photos 5 and 6. Long distance and closure view of the augmentation site during a 7.2ft high tide.

Project Coordination

- Team conference calls were held on October 7 and December 2, 2016.
- Researchers and monitors provided summaries of activities completed during the quarter and when available, provided relevant interim results.

- To minimize disturbance on the project site, all researchers continue to follow the following impact minimization measures while working out on the site:

  1) Minimize as much as possible the amount of foot traffic necessary on site (i.e. number of persons on site, number of visits, amount of time on site);
  2) Use Mudders or some other type of "snowshoe" device while walking on the site;
  3) Follow the same path to your sample locations each time (one very disturbed pathway is better than a broad area of disturbance), trying to follow the alignment of the pole grid system as general walking paths until close to a sample point; and,
  4) Use the area around the perimeter of the site to walk on as much as possible.

Project Outreach/Information Dissemination

- Refuge Manager Kirk Gilligan and Refuge Biologist Richard Nye participated in the Summer Webinar Series, Ecological Function of Coastal Salt Marshes in Response to Sea Level Rise conducted by the U.S. Army Corps of Engineers. These presentations were conducted on July 27, 2016 (Ecological Function of Coastal Salt Marshes in Response to Sea Level Rise - Part 1); August 18, 2016 (Ecological Function of Coastal Salt Marshes in Response to Sea Level Rise - Part 2); and September 20, 2016 (Ecological Function of Coastal Salt Marshes in Response to Sea Level Rise - Part 3). Videos of the three webinars are now available on the Corps Civil Works Environment Gateway at: https://cw-environment.erdc.dren.mil/exchange.cfm?option=ArchiveSchedule&CoP=Env.

- Kirk Gilligan presented the project at the Natural Areas Conference held at UC Davis on October 18, 2016.

- Evyan Sloane, California Coastal Conservancy and Karen Thorne, USGS, presented various aspects of the project during poster sessions held at the Restore America's Estuaries 2016 Summit, which occurred December 10 – 15, 2016, in New Orleans. The posters that were presented are provided as Attachments 2 and 3 to this report.

- A student of Dr. Keller presented the GHG flux work conducted on the site through November 2016 in poster format at a student research event at Chapman University. The poster is provided as Attachment 4.

- The project webpage provides information about the progress of the project. Go to: http://www.fws.gov/refuge/seal_beach/what_we_do/resource_management/Sediment_Pilot_Project.html

Status of Ongoing Research

UCLA (SEDIMENT CORING): Researchers at UCLA under the direction of Dr. Glen MacDonald have been completing their lab work and are currently finalizing their report on pre-augmentation net sediment accretion rates and average carbon accumulation rate (CAR) at Seal Beach NWR.

UCLA (CHANGES IN MARSH PLAIN POST-AUGMENTATION): Under the direction of Dr. Richard Ambrose, researchers have sampled creeks and feldspar plots in the control site (4 creek crossings and 15 feldspar plots); labeled the PVC pipes for the creek crossings at the control site; and sampled sediment accretion, feldspar plots, bulk density plots, and creek crossings on the augmentation site (73 sediment stakes, 23 feldspar/bulk density plots, and 8 creek crossings).

They have collected and are analyzing creek crossing elevation data and sediment accretion data (feldspar plots) for the control site; collected sediment accretion data by measuring sediment stakes and feldspar plots on the augmentation site; collected bulk density samples at both sites for lab analysis (including percent organic carbon and sediment grain size); and collected and are analyzing creek elevation data from the augmentation site.

A few problems have been encountered, including problems with relocating feldspar plots on the control site. The researchers were only able to relocate one of the feldspar plots that were placed in ponds within the control site. In addition, the Russian corer that must be used in the augmentation site due to the amount of sand present in the applied sediment has a larger diameter than the corer the Researchers had expected to use. As a result, it is necessary to ensure that sampling does not occur in the same places within the feldspar/bulk density plots over time. To avoid resampling in the same location within the feldspar plots, the researchers have started marking the sample locations on a diagram for each plot. For many of the plots you can see the markings from the last sample, but this is not always the case.

The use of a canoe to access the field sites is working well and allows the researchers to take advantage of the full tide. Conditions for sampling were great when accessing the augmentation site during +3.5ft MLLW up to +4.5ft MLLW tides. For the control site, access is best during +2.5ft MLLW down to +0.5ft MLLW. Site conditions are great for the lower tides, but +2.5ft MLLW seems a little too high.

CSU LONG BEACH (PLANT AND INVERTEBRATE STUDIES): Dr. Christine Whitcraft and her students have completed their fall sampling (2nd post-restoration time point) and monitoring of plant and invertebrate community parameters. They also conducted a colonization study to help determine if the observed changes in the invertebrate community were due to grain size or elevation differences between the augmentation and control sites.

In the laboratory, invertebrate sorting was ongoing throughout this period. All spring (1st post-augmentation spring) invertebrate samples (top 2 cm) have been sorted, and the process of identifying the invertebrates to species is underway.

Spring samples indicated that the invertebrate community at the sampling sites on the Seal Beal NWR is largely made up of oligochaetes, specifically Tubificidae and Enchytraeidae. Insect and insect larvae, mainly Dolichopodidae and Ceratopogonidae, amphipods and polychaetes are also found at all sites. Pond-dominated habitats tend to have the lowest overall abundance of invertebrates, except for one of the ponds in the augmentation site that has an unusually large

number of oligochaetes. Species richness is the highest in *Batis*-dominated habitats and lowest in pond-dominated habitats. Following augmentation, invertebrate abundances decreased significantly in the augmentation site. Invertebrates were found at 9 out of 24 sites with Ephydridae (type of fly) larvae having the highest representation.

Samples taken 6 months after augmentation in fall 2016 show an increase in the abundance of invertebrates with 18 out of 21 sites having invertebrates present (3 samples still need to be sorted). Although samples are still dominated by Ephydridae larvae, there is an increased representation of oligochaetes and polychaetes.

All belowground biomass cores are completely processed and the data will be analyzed during the next quarter.

Plants (including both *Spartina foliosa* and *Sarcocornia pacifica*) have returned to the site although none were found in our sampling plots. In order to deal with this, we sampled any plants that were found on the augmentation sites regardless of whether they fell within our regular sampling plots.

CHAPMAN UNIVERSITY (GAS FLUX): Dr. Jason Keller and his research team made 3 trips to the sites during this quarter (3 October, 2016; 6 November 2016; and 5 December, 2016). On each sampling trip, they collected gas samples from both the control and augmentation sites and analyzed those samples for carbon dioxide, methane, and nitrous oxide at Chapman University. Also collected during each sampling event was surface porewater, which was analyzed for chemical properties. After refining their sampling technique slightly, they were able to collect porewater from both the augmentation and control sites. The challenge was collecting porewater from the sediment at the augmentation site due to the high sand content.

In response to a question raised by Susan Southard, Soil Scientist from the USDA, Natural Resources Conservation Service regarding the potential for acidification of the augmentation site, Dr. Keller and his research team agreed to conduct pH measurements in standing water on the site, as well as in collected porewater while out on the site collecting gas samples.

Carol Roberts, Division Chief of Environmental Contaminants in the Carlsbad Fish and Wildlife Office, reviewed the results of the sediment characterization conducted for the dredge sites and the augmentation site, noting that sulfide concentrations measured in the composite samples taken from the two proposed dredge sites were lower in both cases than the reference sample taken from the Refuge. Concentrations of water soluble sulfides from all sites were less than 0.017 mg/kg dry, and total sulfides measured in the dredge sites ranged from 900 – 1800 mg/kg dry, while in the Refuge sample the result was 3000 mg/kg dry.

On November 6, 2016, samples were taken of standing water (ponded water) on the site. The average pH of the 11 samples taken throughout the morning was 8.5. Porewater collected from a depth of 10 cm below the sediment surface has an average pH of 6.9 (using 14 samples collected across the different vegetation communities). This porewater value is comparable to an average pH of 6.6 which was measured on samples from the control site collected from 10

cm depth on November 7, 2016 (using 14 samples collected across different vegetation communities).

The results of the fieldwork conducted during this quarter indicate that there does not appear to be acidification of the augmentation site; pH levels were generally comparable between the control and augmentation site. In addition, significant CH_4 fluxes were minimal, but there was a positive flux measured from a *Spartina* and pond community on the augmentation site. Low CH_4 fluxes are common from salt marsh soils.

One *Spartina* community on the augmentation site had a positive N_2O flux. Low N_2O fluxes are common in salt marsh soils without nitrogen pollution. CO_2 fluxes were generally lower from the control site pre-augmentation (possibly due to lower air temperatures during sampling) and were lowest from ponded communities. After the addition of sediment, the augmentation site had very low CO_2 fluxes compared to pre-augmentation and the control site.

USGS (SEDIMENT FLUX PATTERNS AND SETS): Staff from USGS continued to maintain YSI and ADCP monitoring equipment in the tidal channels located adjacent to the augmentation site during this quarter, as well as to gather data related to the elevation changes at the control site and the augmentation site as measured by the surface elevation tables (SETs). A complete discussion of these activities and the results are provided in the USGS report, dated January 4, 2017 (Attachment 5).

The results of monitoring this quarter are summarized below:

- In the deep channel site (Figure 1), mean suspended sediment concentration (SSC) and sediment flux calculations were similar between construction and non-construction periods, showing net export of sediment out of Seal Beach NWR, and mean SSC below 10mg/L.
- In the eelgrass site, mean SSC was elevated above 15 mg/L during particular construction activities, such as silt fence installation, spraying sediment with 12 inch pipe, dredging, and demobilization. Mean post construction SSC is similar to baseline levels observed in the deep channel, but is almost 4 times greater than mean pre construction SSC at the eelgrass site.

Figure1. Site Map with YSI and ADCP Monitoring Equipment

- High SSC near the eelgrass site adjacent to the augmentation site may have come from sediment leaving creeks at the augmentation site. High SSC only occurred adjacent to the application site. Increased SSC was localized and depended on construction activity, in particular demobilization of the equipment and spraying with a 12 inch pipe.

Control Surface Elevation Tables (SETs) have had gains and losses of elevation since installation, but have a mean cumulative increase of 3.07 mm from the date of installation. Augmentation SETs had a mean increase in elevation of 216 mm (8.5 in) with sediment application, but had a decrease in elevation of 63.16 mm (2.49 in) post sediment application. Approximately three months after the augmentation was completed, surface elevation tables were measured on June 28th, 2016, which showed that SET elevation at the Sediment Application Area averaged a decrease of -46.6 mm (-1.83 in). However, when measured again in October the average elevation decreased -16.6 mm (0.65 in). This elevation loss is presumably from soil compaction and the rate of loss has decreased as the site has become more stable over time.

Also during this quarter, USGS produced a final report entitled "Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge: Elevation Change Assessment". This document summarizes the initial elevation of the augmentation site, the final elevations after the sediment application processes, and the elevation change achieved using a variety of methods. The volume of sediment applied was also calculated. This document is provided under separate cover.

RESULTS OF BIRDS SURVEYS FOR THIS QUARTER: Bird use on the site varied, but was somewhat higher than the previous quarter. Between October and December 2016, the highest number of birds was observed during high tide counts, with only two individuals (both western gulls) observed during a low tide count.

Table 1 - Monthly Survey Results of Avian Usage at the Sediment Augmentation Site (October – December 2016)

Species	Oct. 14 low tide	Oct. 18 high tide	Nov. 14 high tide	Nov. 29 low tide	Dec. 13 high tide	Dec. 26 low tide
Great blue heron			1		1	
Great egret		1	1		1	
American Wigeon			1			
Red-breasted Merganzer			1			
Coot			2		18	
Black-bellied Plover		34	2			
Willet		1	1			
Long-billed curlew					12	
Killdeer			2			
Calidris sp.		45	190		125	
Western gull	2					
Ring-billed gull			1			
Total Birds Counted	**2**	**81**	**202**	**0**	**157**	**0**

Percentage of Task Completed as of December 31, 2016:

Task 1 – Project Management and Administration	40%
Task 2 – Sediment Augmentation	100%
Task 3 – Project Monitoring (overall)	39.3**%**
1) Carbon Storage/Sequestration Benefits	85%
2) Percent Total Plant Coverage	20%
3) Pacific Cordgrass Analysis	20%
4) Site Elevations	20%
5) Sediment Analysis (compaction, movement, bulk density)	30%
6) Turbidity Levels	50%
7) Eelgrass	50%
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)	40%
1) Oral/Poster Presentations	45%
2) Workshops and/or Webinars	30%
Overall Project	**63.9%**

Deliverables Completed for Each Task:

Task 1 – Project Management and Administration

1) Quarterly Progress Report	5 to date
2) Monthly Invoices	14 to date
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 site monitoring completed/core data processing underway
2) Percent Total Plant Coverage	pre-augmentation work completed/post augmentation work underway
3) Pacific Cordgrass Analysis	pre-augmentation work completed

4) Site Elevations	pre-augmentation RTK survey and initial post-augmentation photogrammetry work completed
5) Sediment Analysis	initial core samples retrieved/data processing underway; more coring to occur
6) Turbidity Levels	monitoring ongoing; prel. data available
7) Eelgrass	pre-augmentation and initial post-augmentation work completed

Task 4 – Engineering Design/Environmental Documentation

1) Engineering Plans for Augmentation Site	100% engineering plans completed
2) Environmental Documentation* *for USFWS and Coastal Conservancy	CEQA/NEPA documents final; ND recorded

Task 5 – Public Participation/Presentations

1) Oral/Poster Presentations	Presentations ongoing
2) Workshops and/or Webinars	Participated in U.S. Army Corps webinar; Lessons learned/first-year post augmentation webinar summer 2017

Problems/Delays Proposed Resolution:

No delays have been identified for post-augmentation monitoring. We continue to monitor eelgrass recovery, which is occurring, adjacent to the site and will conduct another survey, two years post augmentation.

Project Benefits and Results:

It is too early in the project to address project benefits and results, but we have learned quite a bit about the sediment augmentation process. Our “lessons learned” document will benefit those land managers contemplating the initiation of this process elsewhere on the Pacific Coast. The data being collected to better understand carbon sequestration rates at this site will also benefit other land managers along the southern California coast.

Summarize Benefits to Disadvantaged Communities (if applicable):

Not applicable to this project.

List of Proposed Activities and Tasks for the Next Quarter:

Task 1 – Project Management and Administration
Coordination of pre-project monitoring reports, which will be provided by all research teams in Spring 2017; preparation of a “lessons learned” document for the sediment augmentation process will be completed, assist researchers with site access; prepare invoices and the next quarterly report; and all other responsibilities needed to successfully complete the project will be addressed.

Task 2 – Sediment Augmentation
This task is now complete, although we will be working on the "lessons learned" documentation for the next few months.

Task 3 – Project Monitoring
USFWS staff will continue to work with the researchers to ensure that no impacts to listed or sensitive species occur during post-augmentation monitoring. Monthly shorebird surveys will continue and Refuge-wide monitoring of light-footed Ridgway's rail will begin again in February.

Dr. MacDonald and his team at UCLA will complete their core sample analyses and provide a final report.

Over the next quarter, Dr. Ambrose and his team at UCLA will analyze bulk density, grain size, and carbon content (loss on ignition [LOI]) for newly collected samples, as well as conduct data entry and analysis. The next round of field sampling (i.e., bulk density, sediment height, feldspar cores, tidal creek cross-sections) is scheduled for 12 months after the completion of sediment augmentation (April 2017).

Dr. Whitcraft and her team will continue invertebrate sorting in the laboratory on both the contract samples and the additional colonization experiment. In addition, they will survey the site 1 - 2 times in order to determine how plants are recovering and if there are enough for additional photosynthetic measurements. With all below ground biomass cores are sorted, the team will conduct data analysis on those data and discuss the results with UCLA (as well as the rest of the research team).

Dr. Keller and his team will develop a method for the analysis of porewater ions (e.g., chloride, sulfate) using a Dionex ion chromatograph. This instrument did not function over the entire quarter, but repair of the instrument should be schedule by early February 2017. The team will continue to measure greenhouse gas fluxes from the sites as more of the marsh begins to grow back following augmentation. Seasonal patterns in fluxes and their relationship to porewater chemistry will also be explored as the dataset expands.

USGS will continue collecting data from the YSIs and SETs.

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

Task 5 – Public Participation/Presentations
The projects lead researchers are working on a session focused on sediment augmentation that will be presented at the fall 2017 Coastal and Estuarine Research Federation meeting. The Refuge webpage will continue to be updated, and we will participate in conferences and webinars as opportunities arise. Once the "lessons learned" documentation is completed and we have some initial post-augmentation monitoring results, we will begin preparations for our first workshop or webinar.

Description of Amendments and Modifications to Grant:

No amendments or modifications were made this quarterly. We previously 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.The additional eelgrass elevation survey work is described in the final report, dated September 30, 2016, provided as Attachment 6.

Attachments

1. Itemized Cost Share Items and Activities
2. Poster (Evyan Sloane, CA Coastal Conservancy) Restore America's Estuaries 2016 Summit
3. Poster (Karen Thorne, USGS) Restore America's Estuaries 2016 Summit
4. Poster (Kyvan Elep, Chapman University) Student Research Event, Chapman University
5. USGS Quarterly Data Report (June 15, 2016)
6. Results of Bathymetry Survey and Potential Eelgrass Habitat Analysis at the Site of Potential Eelgrass Impacts at Seal Beach National Wildlife Refuge, Seal Beach, California (MTS 2016)

Document Provided Under Separate Cover (Compact Disc)

1. Seal Beach National Wildlife Refuge Sediment Augmentation Project (Curtin Maritime 2016)
2. Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge: Elevation Change Assessment (USGS 2017)

Attachment 1
Itemized Cost Share Items and Activities

Cost Share (October 1, 2016 to December 31, 2016)		
Activity or Item[1]	Funding Source	Expenditure
Total Cost Share from June 1, 2015 to September 30, 2016		
Pre and Post-augmentation monitoring[1]	California State Coastal Conservancy	$170,776
Purchase boat to access site	USFWS CRI Grant	$2,425
RTK elevation survey	US Army Corps of Engineers	$50,252
USFWS staff time[2]	USFWS CRI Grant	$137,592
Sediment augmentation[3]	Orange County Parks	$670,500
Sediment augmentation	USFWS CRI Grant	$350,000
	Subtotal	$1,381,545
October 1 – October 31, 2016		
Post-augmentation monitoring	California State Coastal Conservancy	$21,843
USFWS staff time[2]	USFWS CRI Grant	$1,822
	Subtotal	$23,665
November 1 – November 30, 2016		
Post-augmentation monitoring	California State Coastal Conservancy	$15,397
USFWS staff time[2]	USFWS CRI Grant	$5,589
	Subtotal	$20,986
December 1 – December 31, 2016		
Post-augmentation monitoring	California State Coastal Conservancy	$7,939
USFWS staff time[2]	USFWS CRI Grant and Station Funds	$3,164
	Subtotal	$11,103
	Total Cost Share to Date	**$1,437,299**

[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.

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THIN-LAYER SEDIMENT AUGMENTATION FOR SEA-LEVEL RISE ADAPTATION

Authors: Evyan Borgnis Sloane, Kirk Gilligan, Vicki Touchstone, Rick Nye, Karen Thorne, Rich Ambrose, Glen MacDonald, Christine Whitcraft, Jason Keller, and Mayda Winter.

Website: http://www.fws.gov/refuge/seal_beach/what_we_do/resource_management/Sediment_Pilot_Project.html

INTRODUCTION

Coastal wetlands around the world are threatened by sea-level rise (SLR). While current research and modeling demonstrates that many, but not all, wetlands in California are keeping pace with SLR via sediment accretion, this resiliency is expected to only resist SLR projections for 2030 and likely 2050.

The **Seal Beach National Wildlife Refuge** (Refuge) is at great risk of submergence as it experiences low rates of sediment accretion, as well as subterranean subsidence. Considering the current rate of SLR in southern California (2.1 mm/yr; NRC 2012) combined with the subsidence rates at the Refuge, the project site is experiencing a **relative SLR of 6.23 mm/yr**—a rate **three times higher** than that of similar southern California marshes not experiencing subsidence.

THIN-LAYER SEDIMENT AUGMENTATION

This project is testing the usefulness of adding a thin-layer of clean, dredge material to the marsh plain surface of the subsiding Refuge. The dredge material was free of contaminants and of similar characteristics to native sediment within the wetland, albeit slightly sandier than expected. The dredge material was added to the marsh using a rainbow spray method to reach a thickness of approximately 10 inches. An adjacent Orange County Parks' dredging project provided clean sediment for the site. Sedimentation augmentation began in January 2016 and ended in April 2016.

Permits & CEQA complete

Pre-construction monitoring

Reporting

2016 — 2017 — 2018 — 2019 — 2020

Sediment spray!

Seasonal Monitoring & Adaptation

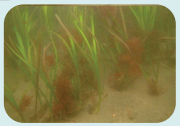
Workshops

Apply to other projects

The low elevations of the Refuge has resulted in stunted *Spartina foliosa* providing little habitat for the endangered Light-footed Ridgway's Rail.

MONITORING PROGRAM

1. Suspended sediment in channels
2. Precise elevations with RTK
3. Eelgrass productivity
4. Subsidence/uplift with Surface Elevation Tables
5. Accretion/erosion with feldspar markers
6. Vegetation and benthic invertebrates community & function
7. Creek morphology
8. Carbon sequestration
9. Greenhouse gas flux
10. Bird counts

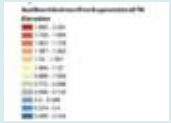


LESSONS LEARNED

- Increase focus on grain size analysis & avoid composite sampling in initial sediment analysis
- Cost of dredging and placement of material ~$1.5M
- Nozzle shape modification to reduce marsh impact
- Better estimation of marsh compaction
- Sediment pole method inadequate for thickness measurements

April 2016 Elevations

- 10' buffer around site
- Test plots
- Variable thicknesses (10" average)

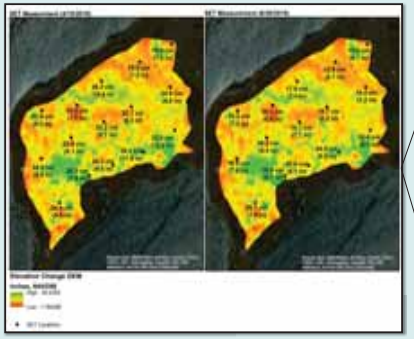


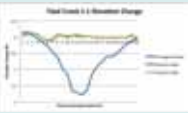
Sediment Characteristics

- Refuge reference samples were 49 - 62% silt & clay
- Averaged source samples indicated 40% silt & clay was available
- Augmentation site ended up with 16% silt & clay and 84% sand

PRELIMINARY RESULTS

- Initial elevation increase of ~10"
- Loss of elevation after 2 months due to compaction





- Evidence of tidal creeks reforming

Further info: evyan.sloane@scc.ca.gov

Monitoring thin-layer sediment application for sea-level rise adaptation in a southern California tidal marsh

Karen Thorne[1*] ▪ Chase Freeman[1] ▪ Jordan Rosencranz[1] ▪ Neil Ganju[2] ▪ Glenn Guntenspergen[3]

[1]Western Ecological Research Center, U.S. Geological Society [2]Woods Hole Coastal and Marine Science Center, USGS [3]Patuxent Wildlife Research Center, USGS

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Introduction

Seal Beach National Wildlife Refuge, CA is a coastal refuge with the primary mission to provide habitat for endangered and migratory wildlife (Figure 1). This important tidal marsh habitat is at risk of submergence from sea-level rise due to low accretion rates and regional subsidence.

A coordinated pilot project began in 2015 between managers and researchers to test the beneficial reuse of dredge material as thin-layer application to the marsh surface to build the surface elevation as a sea-level rise adaptation tool.

Study site

Figure 1. Study site map showing location of instruments, Surface Elevation Tables (SETs), as well as control and augmentation site boundaries at Seal Beach National Wildlife Refuge, CA

Research Questions

1) Did applied sediment stay on the marsh surface or leave the system?
2) How did suspended sediment concentrations (SSC) and sediment fluxes change during and after augmentation?
3) How much vertical elevation was achieved from sediment application?

Construction Activities

Erosion Control	Dredging	Spraying

Methods

We monitored SSC and sediment flux in adjacent channels and the elevation change of the application area and a control site using Surface Elevation Tables (SETs; Figure 2 and Figure 3). Construction application of the sediment ended in April 2016 and post-construction monitoring is ongoing.

SSC and Sediment Flux Monitoring

YSI	ADCP	Water Sampling

Figure 2. Continuous sediment flux and SSC monitoring) included YSI and ADCP deployment for two years with downloads every 6 weeks.

Methods

Elevation Monitoring – using Surface Elevation Tables (SETs)

Figure 3. The same SET during pre and post augmentation. Readings are being done every 3 months.

Results

SSC and Sediment Flux

During augmentation construction activities, SSC was high in the adjacent eelgrass bed compared to those observed in a deep site away from the application areas (Figure 4). Sediment does not appear to be leaving the wetland complex since flux measurements show very small export amounts (Figure 4 & Table 1).

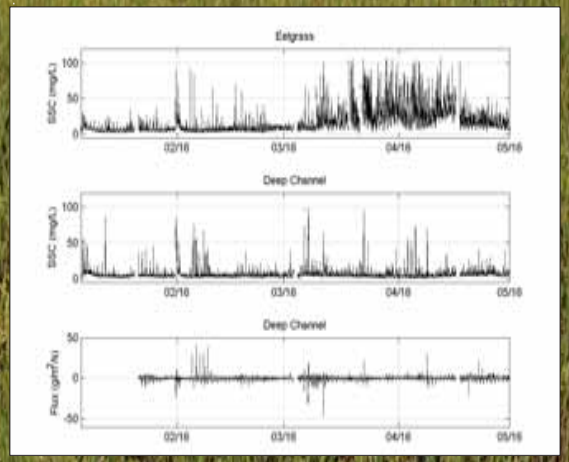


Figure 4. Time series of SSC and sediment fluxes during augmentation construction. Deep channel SSC was similar to non construction times.

Time

Activity	Eel SSC (mg/L; mean±se)	Deep SSC (mg/L; mean±se)	Deep Flux (g/m²/s; mean±se)
Hay Bale Install	11±0.13	6±0.08	-0.25±0.04
Silt Fence Install	21±2.11	6±0.45	-0.05±0.18
Spray Dredge 8in	9±0.12	6±0.11	-0.26±0.04
Spray Dredge 12in	30±0.45	6±0.14	0.01±0.04
Dredge Clam Shell	18±.017	6±0.07	-0.12±0.03
Demobilization	35±1.69	5±0.59	0.24±0.12
Post Construction	13±0.08	7±0.05	0.30±0.03

Table 1. Instantaneous SSC and sediment fluxes averaged across date range of activities. Spraying dredged sediment (12in pipe) and demobilization of equipment resulted in the highest SSC adjacent to the application site.

Results

Elevation

Control SETs have had gains and loses of elevation since installation, but have a mean cumulative increase of +3.07 mm from the date of installation. Augmentation SETs had a mean increase in elevation of +216 mm with sediment application, but had a decrease in elevation of 63.16 mm post sediment application (April-October).

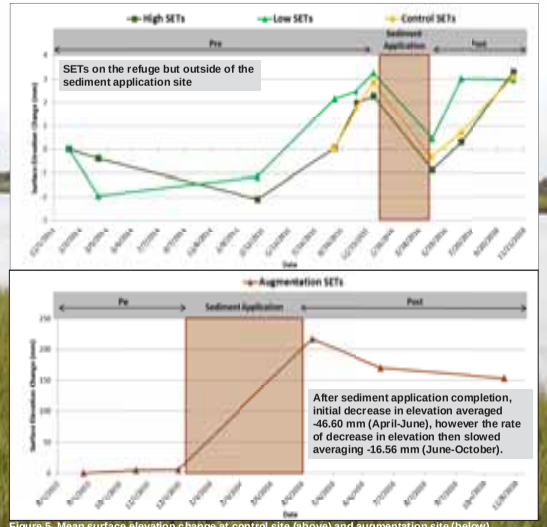


Figure 5. Mean surface elevation change at control site (above) and augmentation site (below) .

Conclusions

- High SSC near the Eelgrass site adjacent to the sediment application area may have come from sediment leaving creeks at the augmentation site. High SSC only occurred adjacent to the application site.
- Increased SSC was localized and depended on construction activity, in particular demobilization of the equipment and spraying with a 12 in. hose increased SSC.
- Using SET readings an initial surface elevation loss was observed after application, presumably from soil compaction.

Next Steps

- Continued monitoring of SSC and sediment flux measurement through summer 2017 (Figure 6)
- Quarterly SET monitoring for five years (Figure 6) with coring of feldspar co-located with SETs.

Figure 6. Creek formation is already occurring and a soil core taken at a SET on the augmentation site. The grey color is the applied sediment.

Acknowledgments & Partners

•PARTNERS & FUNDERS: We would like to thank and acknowledge the USFWS for their tremendous effort and leadership in this project (Kirk Gilligan, Rick Nye, Victoria Touchstone). In addition, Evyan Sloane, Mayda Winter, Rich Ambrose, & Christine Whitcraft for their help with a variety of project questions, contracting, and logistics.

•FIELD SUPPORT: A. Goodman, V. Corbett, K. Backe, & A. Sanchez

Greenhouse Gas Fluxes From A Salt Marsh Management Project

Kyvan Elep, G. E. Woerndle, C.A. Medvedeff, J.K. Keller
Chapman University, Schmid College of Science and Technology

INTRODUCTION

- Vegetated coastal wetland ecosystems – including salt marshes – sequester globally significant quantities of carbon (C) in their soils **(Figure 1)**. This soil carbon storage is the result of inefficient microbial decomposition under anaerobic (low O_2) conditions in salt marsh soils (**Figure 2**).

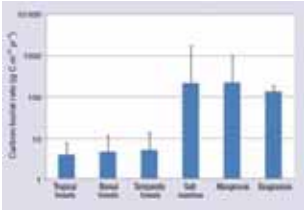


Figure 1. *Mean long-term rates of C sequestration (g C m^{-2} yr^{-1}) in soils in terrestrial forests and sediments in coastal vegetated ecosystems (Mcleod et al., 2011).*

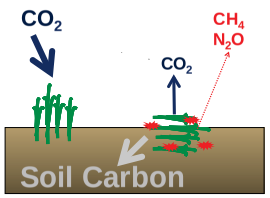


Figure 2. *Soil carbon sequestration and greenhouse gas production in salt marshes, simplified.*

- Due to their ability to sequester soil C, there is a growing interest in using salt marsh restoration and conservation efforts as climate change mitigation projects to help offset anthropogenic greenhouse gas emissions to the atmosphere.
- However, the same anaerobic conditions that lead to soil carbon storage can also result in the production of the potent greenhouse gases (GHG) methane (CH_4) and nitrous oxide (N_2O) by soil microbes **(Figure 2)**.
- CH_4 and N_2O have sustained global warming potentials of 45 and 270, respectively. This means that the release of these greenhouse gases can negate large amounts of soil carbon sequestration in the context of climate change mitigation projects.
- One salt marsh management technique under investigation as a possible mitigation effort is thin layer sediment augmentation. Seal Beach National Wildlife Refuge (SBNWR, Seal Beach, CA) is the first documented case of sediment augmentation on the West Coast (**Figure 3**).

Figure 3. *Seal Beach National Wildlife Refuge includes a variety of habitats with a large area of intertidal salt marsh (U.S. Fish and Wildlife Service). Thin layer sediment augmentation is being used at the site.*

RESEARCH QUESTION

The objective of this study is to investigate greenhouse gas (CH_4, CO_2, and N_2O) fluxes from a thin layer sediment augmentation project in a salt marsh at the Seal Beach National Wildlife Refuge.

THIN LAYER SEDIMENT AUGMENTATION AT SBNWR

- Seal Beach National Wildlife Refuge was chosen as a site for the experimental management technique of thin layer sediment augmentation to combat sea level rise and possibly lead to increased soil carbon sequestration.
- Sediment was dredged from the bottom of the Seal Beach Harbor. Using a powerful hose, the dredged sediment was spread over the salt marsh using a rainbow arching technique **(Figure 4)**.
- Ten inches of clean dredged material were spread over a 10 acre **Augmentation Site** at SBNWR **(Figure 5).** A second **Control Site** did not receive sediment augmentation and was used as a reference for post-augmentation comparisons.

Figure 4. *Dredged sediment being spread over the area using a rainbow arching technique.*

Before After

Figure 5. *The Augmentation Site before and after the sediment augmentation process. Sediment augmentation took place between January – April of 2016*

GHG FLUX MEASUREMENTS

- Greenhouse gas fluxes were measured from the dominant plant communities within both the Augmentation Site and the Control Site before and after the augmentation.
- Dominant plant communities included:
  - Ponds: Inundated with water
  - *Batis maritima*: Dry and high in the marsh **(Figure 6)**
  - *Spartina foliosa*: Wet and grassy **(Figure 7)**

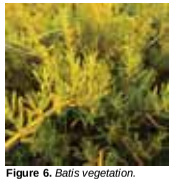


Figure 6. *Batis vegetation.*

Figure 7. *Spartina vegetation.*

Figure 8. *In field gas chamber.*

- We used static chambers **(Figure 8)** to measure the flux of greenhouse gases from the marsh surface over a ~2-hour sampling 2 months prior to the addition of sediment to the Augmentation Site and 4, 6, and 7 months after.
- Chamber samples were stored in Exetainers and were analyzed for CH_4, CO_2, and N_2O production using gas chromatography. Significant fluxes were defined as the linear (r^2>0.90) accumulation of a GHG over time.

ACKNOWLEDGEMENTS

- We thank Kirk Gillian and Rick Nye at the SBNWR for assistance with site access and sampling. Funding for this project was provided by the Southwest Interpretive Association under a cooperative agreement from the US Fish and Wildlife Service.

GREENHOUSE GAS FLUXES

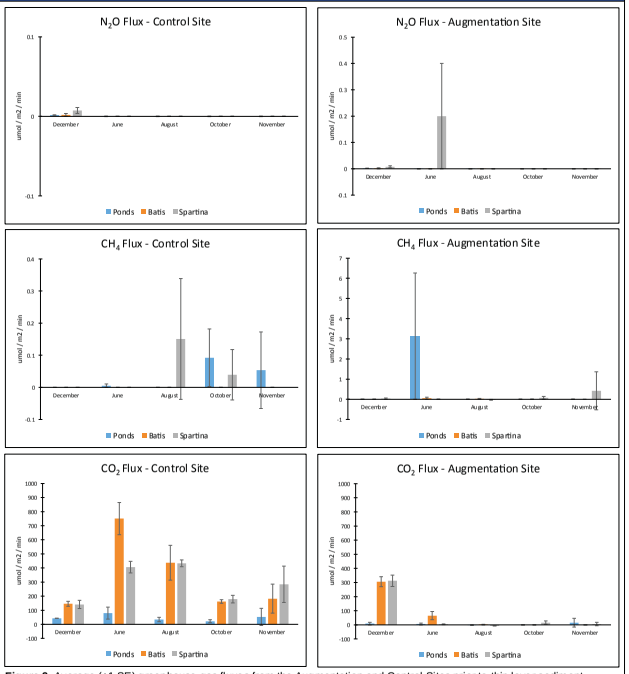


Figure 9. Average (±1 SE) greenhouse gas fluxes from the Augmentation and Control Sites prior to thin layer sediment augmentation at SBNWR.

GHG PRODUCTION – DISCUSSION

- Significant CH_4 fluxes were minimal, but there was a positive flux measured from a *Spartina* and pond community at the Augmentation Site. Low CH_4 fluxes are common from salt marsh soils.
- One *Spartina* community at the Augmentation Site had a positive N_2O flux. Low N_2O fluxes are common in salt marsh soils without nitrogen pollution.
- CO_2 fluxes were generally lower from the Control Site pre-augmentation (possibly due to lower air temperatures during sampling) and were lowest from ponded communities. After addition of sediment, the augmentation had very low CO_2 fluxes compared to pre-augmentation and the control site.

CONCLUSIONS AND FUTURE RESEARCH

- CH_4 and N_2O fluxes were minimal, suggesting that this site may be a good candidate for climate change mitigation through thin layer sediment augmentation.
- Future work will be continuing to measure greenhouse gas fluxes from the sites as more of the marsh begins to grow back. Seasonal patterns in fluxes and their relationship to porewater chemistry is also beginning to be explored.

References Cited: Mcleod et al. (2011) Frontiers in Ecology and the Environment doi:10.1890/110004…

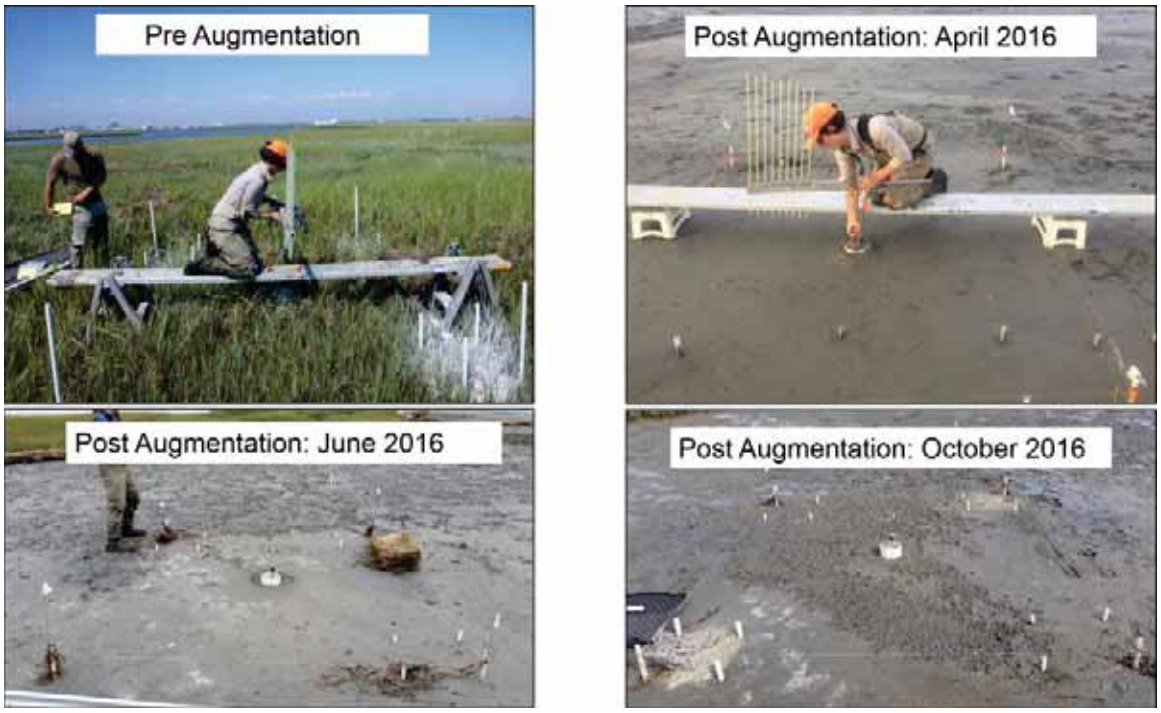
Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge: Sediment flux patterns and SETs

January 4, 2017

Principle Contact: Dr. Karen M. Thorne[1], 916-502-2996, kthorne@usgs.gov

Team: Dr. Neil K. Ganju[2], Chase Freeman[1], Karen Backe[1], and Jordan A. Rosencranz[1,3]

[1]USGS, Western Ecological Research Center, 505 Azuar Dr. Vallejo, CA, 94592
[2] USGS, Coastal and Marine Geology, 384 Woods Hole Road, Woods Hole, MA 02543-1598
[3]UCLA, Institute of the Environment and Sustainability, Los Angeles, CA 90095



The same SET during pre and post augmentation.

Summary

- In the deep channel site, mean suspended sediment concentration (SSC) and sediment flux calculations were similar between construction and non-construction periods, showing net export of sediment out of Seal Beach National Wildlife Refuge (NWR), and mean SSC below 10mg/L (Figure 1 and Table 1).
- In the eelgrass site, mean SSC was elevated above 15 mg/L during particular construction activities, such as silt fence installation, spraying sediment with 12 inch pipe, dredging, and demobilization (Table 1). Mean post construction SSC is similar to baseline levels observed in the deep channel, but is almost 4 times greater than mean pre construction SSC at the eelgrass site.
  - High SSC near the Eelgrass site adjacent to the sediment application area may have come from sediment leaving creeks at the augmentation site. High SSC only occurred adjacent to the application site. Increased SSC was localized and depended on construction activity, in particular demobilization of the equipment and spraying with a 12 in. pipe.
  - Surface Elevation Tables (SETs) continue to show elevation loss, although rapid surface elevation loss has now slowed presumably from soil compaction or settling.

Sediment Fluxes and Turbidity

During augmentation construction activities, SSC was high in the adjacent eelgrass bed compared to those observed in a deep site away from the application areas (Figure 1). Sediment does not appear to be leaving the wetland complex since flux measurements show very small export amounts. Localized impacts were observed near the Eelgrass site, where sedimentation was even observed on the top of the ysi sensor post construction. Deep channel SSC was similar to non-construction times, while Eelgrass SSC was high during particular construction activities such as demobilization and spraying dredged sediment with a 12inch diameter pipe (Table 1).

Elevation and Accretion – Surface Elevation Tables (SETs)

Control SETs have had gains and losses of elevation since installation, but have a mean cumulative increase of 3.07 mm from the date of installation (Figure 2, and Figure 3). Augmentation SETs had a mean increase in elevation of 216 mm (8.5 in) with sediment application, but had a decrease in elevation of 63.16 mm (2.49 in) post sediment application (April-October, Figure 2, and Figure 4). Approximately three months after the augmentation was completed, surface elevation tables were measured on June 28th, 2016, which showed that SET elevation at the Sediment Application Area averaged a decrease of -46.6 mm (-1.83 in). However, when measured again in October the average elevation decreased -16.6 mm (0.65 in). This elevation loss is presumably from soil compaction and the rate of loss has decreased as the site has become more stable over time.

Table 1. Instantaneous SSC and sediment fluxes averaged across date range of construction activities. Spraying dredged sediment (12in pipe) and demobilization of equipment resulted in the highest SSC adjacent to the application site.

Time

Activity	Eel SSC (mg/L; mean±se)	Deep SSC (mg/L; mean±se)	Deep Flux ($g/m^2/s$; mean±se)
Pre Construction	3±0.02	6±0.04	-0.34±0.02
Hay Bale Install	11±0.13	6±0.08	-0.25±0.04
Silt Fence Install	21±2.11	6±0.45	-0.05±0.18
Spray Dredge 8in	9±0.12	6±0.11	-0.26±0.04
Spray Dredge 12in	30±0.45	6±0.14	0.01±0.04
Dredge Clam Shell	18±.017	6±0.07	-0.12±0.03
Demobilization	35±1.69	5±0.59	0.24±0.12
Post Construction	11±0.06	6±0.08	0.17±0.02

*negative flux values indicate export

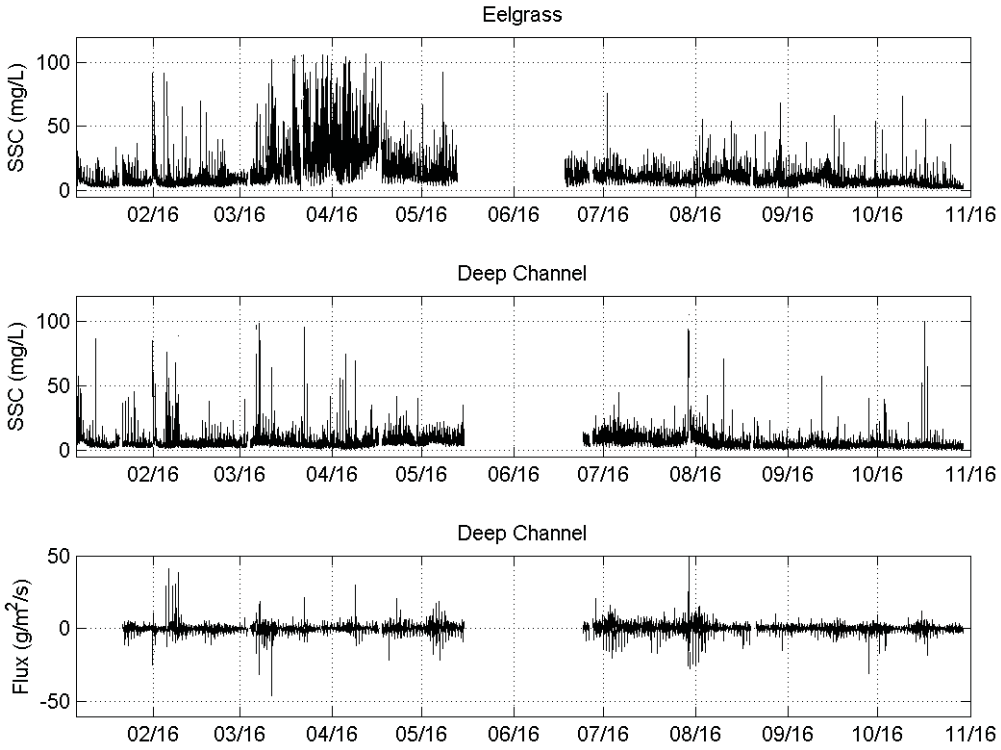


Figure 1. Time series of SSC and sediment fluxes during and after augmentation construction activities.

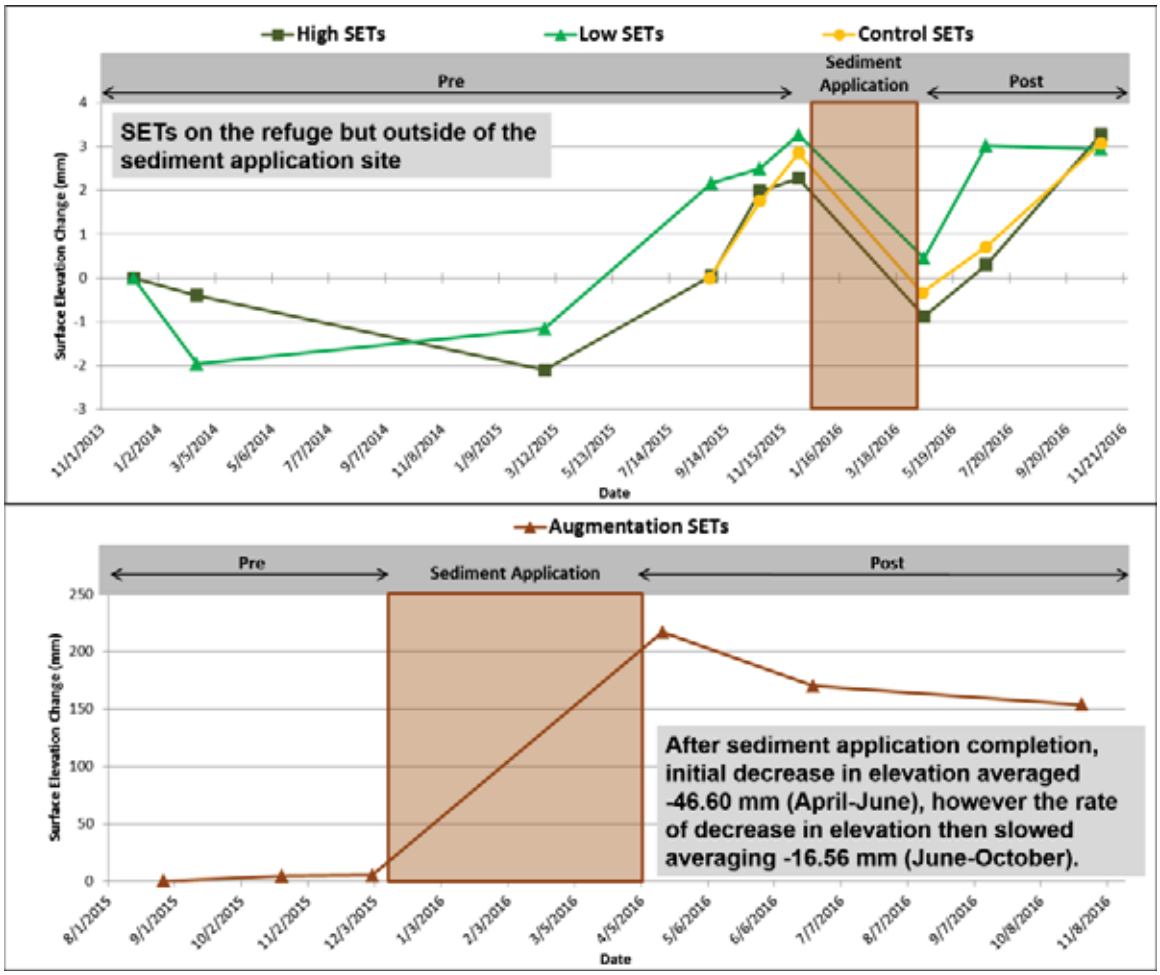


Figure 2. Mean surface elevation change at control site (above) and augmentation site (below).

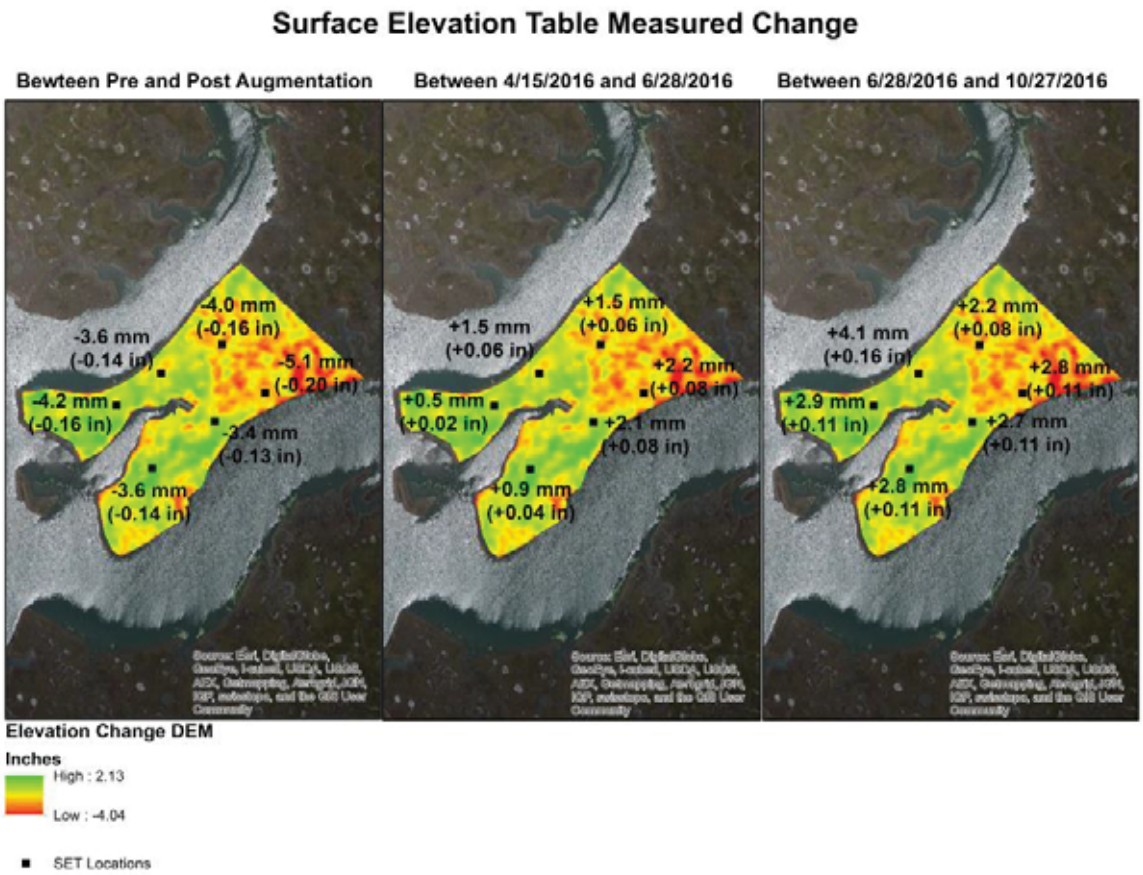


Figure 3. Mean surface elevation change at control site SETs between measurement time periods.

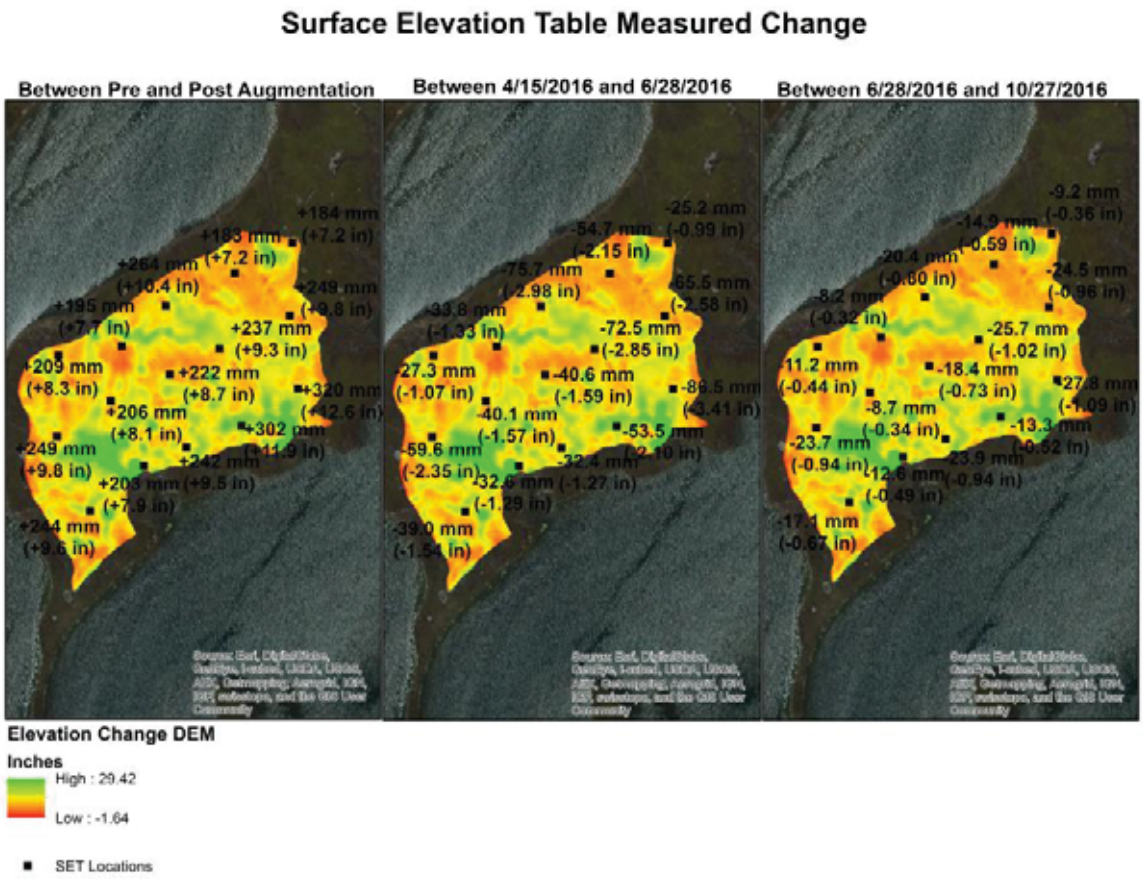


Figure 4. Mean surface elevation change at augmentation site SETs between measurement time periods.

Kirk Gilligan
Refuge Manager
Seal Beach National Wildlife Refuge
P.O. Box 815
800 Seal Beach Blvd., Bldg. 226
Seal Beach, CA 90740

September 30, 2016

Re: Results of Bathymetry Survey and Potential Eelgrass Habitat Analysis at the Site of Potential Eelgrass Impacts at Seal Beach National Wildlife Refuge, Seal Beach, California

Dear Kirk:

Thank you for contacting MTS regarding the need for additional survey services at the Seal Beach National Wildlife Refuge (SBNWR) in Seal Beach, CA. As you are aware, based on the pre- and post-construction eelgrass surveys performed for the Sediment Augmentation Pilot Project (Project), MTS determined that there were likely Project related impacts to eelgrass. In the post-construction survey report, MTS determined that up to 4,931 square meters of eelgrass had been impacted within a localized area near the Project's sediment placement area (MTS 2016). This area is referred to the "impact area" in this letter. That designation does not mean that all eelgrass within the impact area was impacted. This designation simply refers to the overall area within which there were potential eelgrass impacts.

After consultation with the National Marine Fisheries Service (NMFS), it was determined that the Project could monitor the site for two years to see if eelgrass returned to the impact area. This determination was based on the idea that the goal of the Project is to improve the marsh habitat value in the face of rising sea levels. Under that goal, some loss of eelgrass might be allowed given that the site may recover and that the site will have greater habitat value for threatened and endangered species following recovery from the sediment placement.

This letter presents the results of a focused bathymetric survey and subsequent analysis of the site to support eelgrass following the Project disturbance. The original goal of the survey was to collect bathymetric data in the impact area and compare the elevations within that area to data previously collected by the United States Geological Survey (USGS). Unfortunately, the USGS data were not of sufficient resolution within the impact area to make reasonable comparisons. This is not the fault of the USGS data as they were not collected with the goal of performing such an analysis in a relatively small portion of the SBNWR. However, MTS was able to use the bathymetry data and eelgrass data collected outside of the impact area to model eelgrass

distribution with depth. This model was then applied to the area within the impact area to predict how much eelgrass the impact area could support in the future. The methods and results of this effort are presented below.

MTS performed a single-beam sonar survey of the impact area and the waters around the Project area (Figure 1 and Figure 2) on July 1, 2016. The survey was performed with a 210 kHz, survey-grade echosounder. Soundings were confirmed in the field with a bar check prior to starting the survey. Data were collected by navigating a series of tracklines across the survey area.

Following the survey, depth sounding data were inspected in HYPACK™ hydrographic software for Windows™. Erroneous spikes and areas where the bottom could not be resolved were removed from the data. The soundings were corrected for tidal change during the survey using data from NOAA tidal station 9410660 (Los Angeles). The corrected trackline data were then processed in the triangulated irregular network (TIN) model generator in HYPACK. The triangulated irregular network (TIN) model allowed for spaces between tracklines to be filled by using an algorithm that connects the most suitable points into a series of non-overlapping triangles. The resulting data were exported to a 1-meter grid over the surveyed area. Depths were expressed in feet relative to NAVD 88.

The depth data were combined with the previously collected eelgrass data to determine the proportionate distribution of eelgrass within each of the depth classes present within the survey area. The area outside of the impact area was used to define proportionate cover of eelgrass by depth. The proportionate cover for each of the depth categories was then applied to the area within the impact area to determine how much eelgrass the impact area could be expected to support as eelgrass recovers in the impacted area.

The results of the bathymetric survey are shown in Figure 1 and Figure 2. Depths within the survey area ranged from +3.8 to -11.4-ft NAVD 88. Combining the depth data outside of the impact area with the corresponding eelgrass data show that eelgrass cover was greatest for the -1 and -2-ft depth classes (Table 1). Table 1 provides the actual percent cover by eelgrass within each depth class for the May 2016 eelgrass data. Table 2 provides the expected eelgrass recovery within the impact area. The expected recovery uses the predicted percent cover from the model to calculate predicted cover throughout the impact area and then subtracts any eelgrass that was present within the impact area following construction. Figure 3 provides a visual representation of expected eelgrass recovery by percent cover within the impact area.

The results of the analysis indicate that the impact area should support approximately 8,353 square meters of eelgrass based on the model. There were 8,909 square meters of eelgrass within the impact area prior to the Project construction. Given that there are currently 3,950 square meters of eelgrass within the impact area (not all eelgrass within the "impact area" was actually impacted), it is anticipated that an additional 4,403 square meters of eelgrass can be supported within the impact area. This is close to but lower than the 4,931 square meters identified as potentially impacted within the post-construction survey report. This result assumes that elevations will not change over time. It is possible that sediment will move, causing slight changes in elevation that may change how much eelgrass the impact area may ultimately support.

Given the model results and current bathymetry within the impact area, it is reasonable to expect that eelgrass will recover within much of the impact area over the next few years. However, the model results predict that there will be 528 fewer square meters following recovery relative to what may have been impacted. It is impossible to know for certain how accurate this estimate is given that eelgrass growth varies across space and time. It is possible that eelgrass within the impact area may outperform eelgrass in the surrounding area. The model already shows that within the -3-ft depth class that the impact area already supports more eelgrass than it should relative to the model. It is also possible that actual recovery will outperform the model because the model simply applies the expected percent cover to areas within each depth class irrespective of whether those areas were known to support eelgrass before the Project. In other words, areas that actually supported and then lost eelgrass may have a greater likelihood of supporting eelgrass in the future due to factors beyond depth. Depth was chosen for the model because it is easy to classify and has the greatest effect on light availability. In turn, light availability is a significant factor in determining whether or not a given location can support eelgrass.

The overall loss of eelgrass habitat predicted by the model may be explained in part by shallow areas becoming shallower due to Project sediment that was released into nearby intertidal and shallow sub-tidal areas. For instance, converting a grid cell from the +1-ft NAVD depth class to the +2-ft depth class would result in a lost potential of 47.2% for that grid cell to support eelgrass. However, the lack of high resolution pre-Project bathymetry within the impact area makes it impossible to know for certain how the depth distribution may have changed in specific areas. As mentioned above, future sediment movement may change the recolonization

of eelgrass. If deposited sediments in very shallow areas erode, those areas will outperform the model.

Ultimately, the Project goals involve improving the SBNWR salt marsh habitat value for sensitive species. While some eelgrass habitat may have been lost, there will likely be increases in cordgrass habitat. Additionally, given that the Project seeks to improve habitat value in the face of sea level rise, areas made shallower by the Project will ultimately support eelgrass as sea level rises.

It has been a pleasure working on the Project with you and your team. If you have any questions about this document or the data herein please do not hesitate to contact me at 760.331.7897 or robert@consultmts.com. In addition to the attached figures and tables, we have provided the digital depth model as an xyz data set in electronic format.

Sincerely,

Robert Mooney, Ph.D.
VP / Principal Consultant

References:

[MTS] Marine Taxonomic Services. 2015. Seal Beach National Wildlife Refuge Sediment Augmentation Post-Construction Eelgrass Survey. Letter Report. Prepared for Southwest Wetlands Interpretive Association, May 16, 2016.

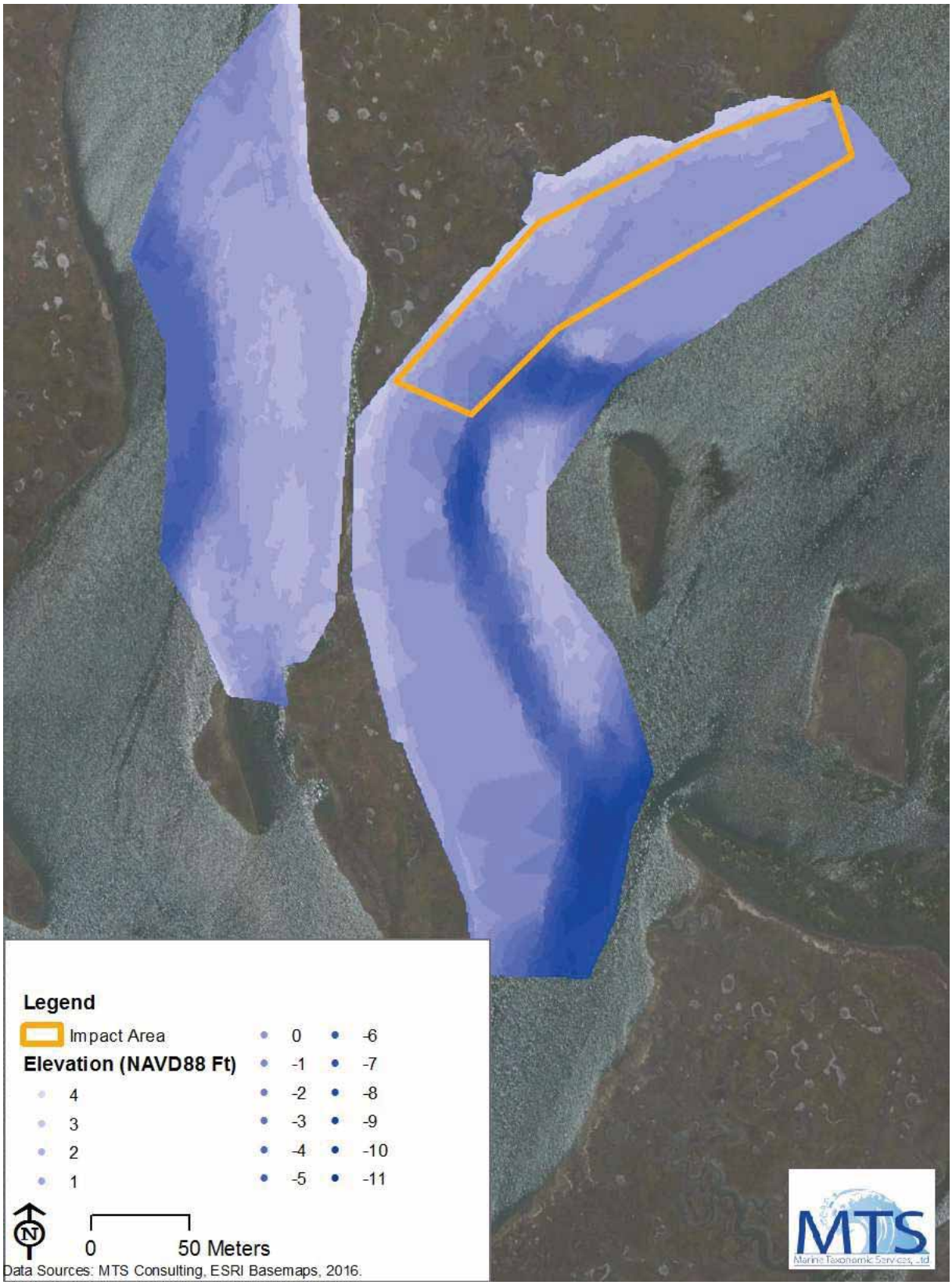


Figure 1. The above figure provides a color shaded representation of the seafloor elevation within the surveyed area at Seal Beach National Wildlife Refuge.

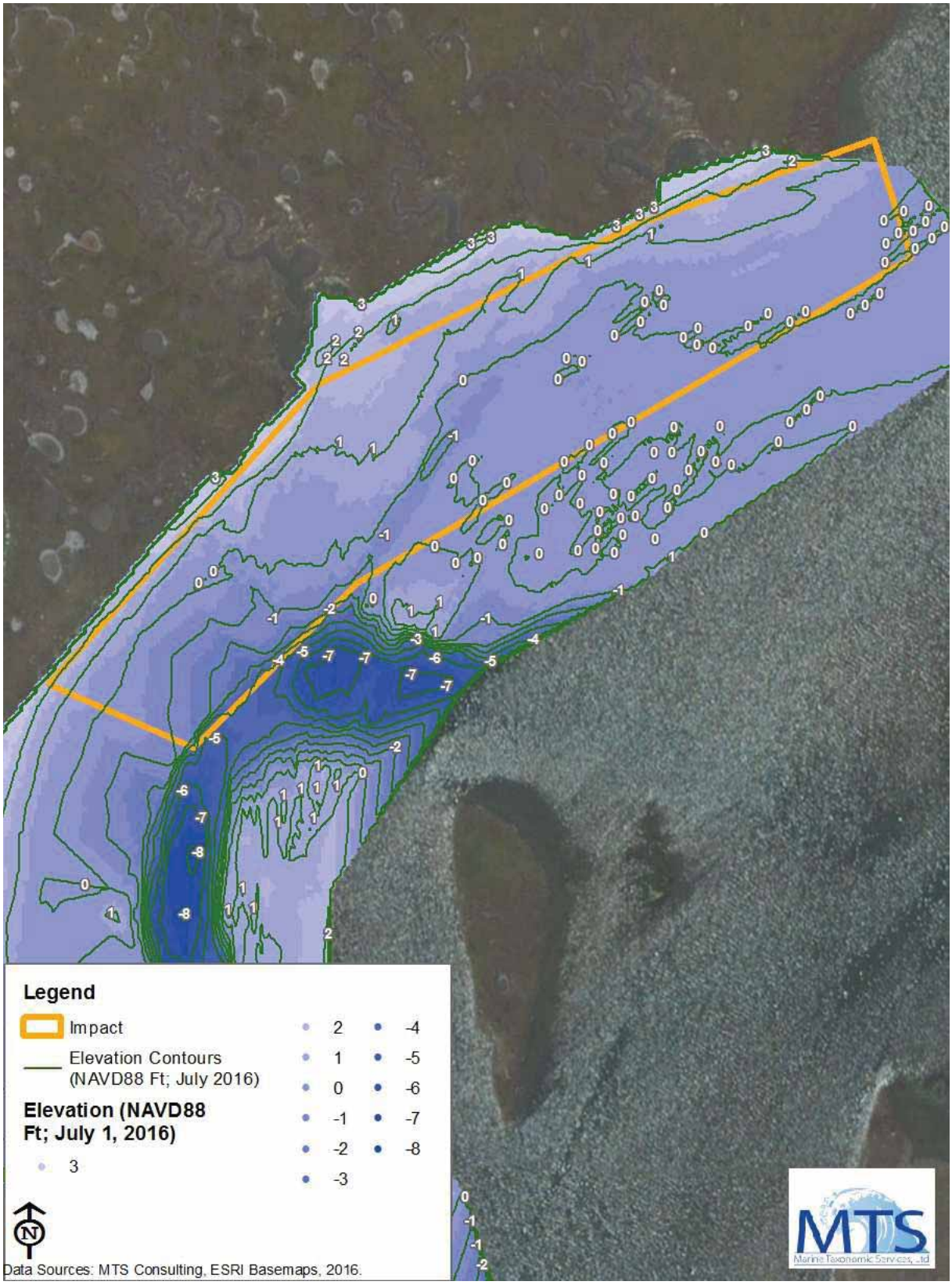


Figure 2. The above figure provides a color shaded representation of the seafloor elevation and depth contours within the impact area at Seal Beach National Wildlife Refuge.

Table 1. Eelgrass presence and absence for each grid cell mapped for eelgrass (May 2016) and depth (July 2016) within the surveyed area (excluding the impact area).

Depth Class	Eelgrass Present May 2016 (sq m)	Eelgrass Absent May 2016 (sq m)	Total Depth Class (sq m)	Eelgrass Cover
-11		278	278	0.00%
-10		551	551	0.00%
-9		1,667	1,667	0.00%
-8		1,411	1,411	0.00%
-7	4	1,262	1,266	0.32%
-6	139	1,873	2,012	6.91%
-5	785	3,486	4,271	18.38%
-4	1,215	1,559	2,774	43.80%
-3	1,433	666	2,099	68.27%
-2	3,702	698	4,400	84.14%
-1	15,063	1,008	16,071	93.73%
0	11,834	4,719	16,553	71.49%
1	6,500	6,589	13,089	49.66%
2	123	4,938	5,061	2.43%
3	10	740	750	1.33%
4		20	20	0.00%
Totals	40,808	31,465	72,273	

Table 2. The below table provides eelgrass presence and absence, predicted cover from the model and expected eelgrass recovery within the impacted area. Expected eelgrass recovery is based on the predicted cover from the relative distribution of eelgrass with depth outside of the impact area as applied to the depth classes within the impacted area and then corrected for eelgrass currently present within the impact area.

Depth Class	Eelgrass Present May 2016 (sq m)	Eelgrass Absent May 2016 (sq m)	Total Depth Class (sq m)	Post-Impact Cover	Predicted Cover	Predicted Cover (sq m)	Expected Eelgrass Recovery (sq m)
-5		26	26	0.00%	18.38%	5	5
-4	14	66	80	17.50%	43.80%	35	21
-3	156	34	190	82.11%	68.27%	130	-26
-2	415	279	694	59.80%	84.14%	584	169
-1	2,550	1,483	4,033	63.23%	93.73%	3,780	1,230
0	806	3,440	4,246	18.98%	71.49%	3,036	2,230
1	8	1,563	1,571	0.51%	49.66%	780	772
2	1	154	155	0.65%	2.43%	4	3
3		2	2	0.00%	1.33%	0	0
Totals	3,950	7,047	10,997			8,353	4,403

Figure 3. The above figure shows modeled results of predicted eelgrass cover in the impact area based on the current depth distribution and the percent cover of eelgrass by depth categories across the surveyed area.