Sonoma Creek Enhancement Project; Creating Functionality in a Centennial Marsh of Sonoma, California
Grant Agreement No. P1475008
Project Final Report
07/30/14-5/31/16

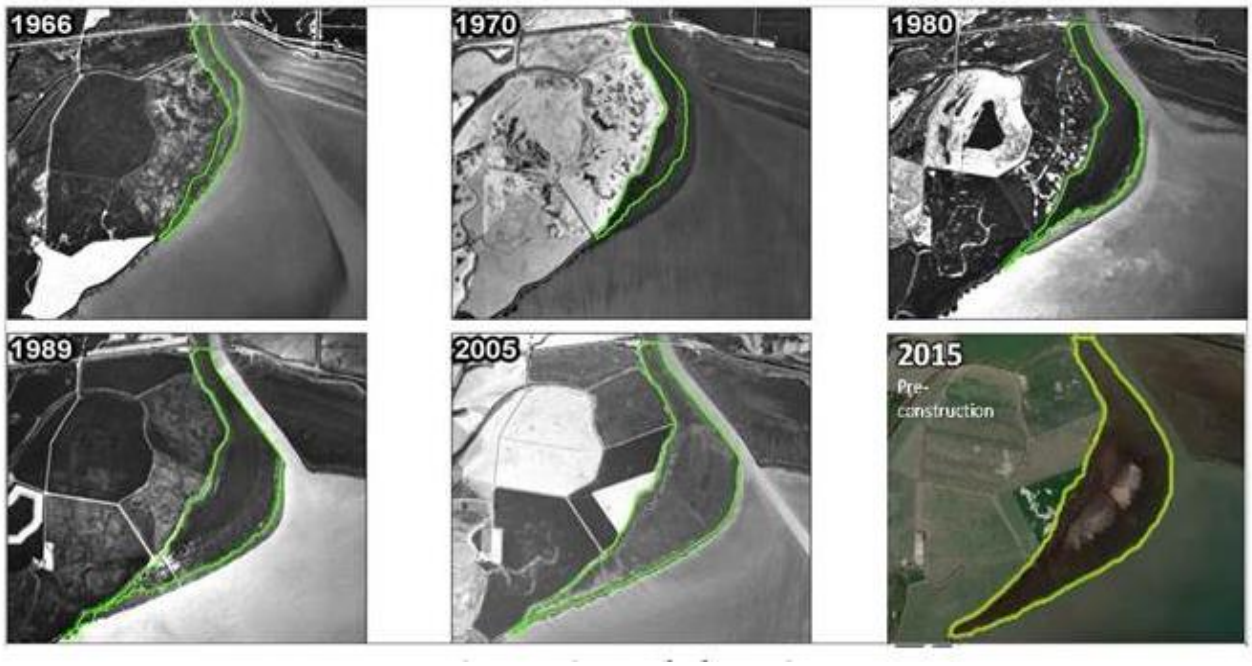

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Figure 1. Aerial image of 400-acre Sonoma Creek marsh with 260-acre inundated "dead zone."

SUMMARY OF PROJECT AND ACTIVITIES

The Sonoma Creek Enhancement Project (SCEP or Project) was originally designed in 2010 to enhance tidal fluctuation and habitat functionality to the Sonoma Creek marsh. This project would enhance the over 260 acre central basin (or "dead zone") of the 400 acre centennial, tidal fringe marsh at San Pablo Bay National Wildlife Refuge (SPBNWR). The goal of the project is to improve water quality by reducing the application of pesticides used to control mosquitoes in poorly functioning tidal marsh that ponds water and facilitates mosquito production. The Project will protect against flooding of adjacent private lands, help maintain water quality through natural marsh filtering processes and provide nursery and stopover feeding habitat for endangered as well as commercial fishes. In addition, the project will provide the Sonoma Creek marsh with improved resiliency to impending sea level rise and extreme storm events brought about as a result of climate change. Implementation of the project will provide opportunities for project partners to present hands-on environmental education to underprivileged children and students who would not otherwise experience natural history in the field setting.

The main features of this project include 1) a main channel that connects to Sonoma Creek 2) interior marsh mounds and a 3) transition ramp that both offer high tide refugee for marsh wildlife in extreme storm events, high tides, and sea level rise expected in Climate Change. This project now provides enhanced habitat for the following species of interest: Ridgway's Rail, California Black Rail, Salt Marsh Harvest Mouse, California Vole, Marsh Thrush and San Pablo's Bay Song Sparrow. As permits were acquired, two years of pre-construction monitoring of Sonoma Creek Marsh hydrology, endangered/threatened wildlife, song birds, shore/waterbirds, vegetation, and mosquito populations were completed. After undergoing five years of fund raising, planning, design and environmental compliance, the project went to construction on July 29th, 2015 and was completed on November 30th, 2015. This project has been cooperatively managed by the project manager Audubon California (Audubon), land manager San Pablo Bay National Wildlife Refuge (SPBNWR), and vector managers Marin Sonoma Mosquito and Vector Control District (MSMVCD). Project funders include the California Wildlife Conservation Board, the U.S. Fish and Wildlife Service's National Coastal Wetlands Conservation Grant Program, the U.S. Environmental Protection Agency, California's Department of Fish and Game's Environmental Enhancement Fund, California State Coastal Conservancy, the National Fish and Wildlife Foundation, SPBNWR, Audubon, MSMVCD and private donors (Table 1).

Table 1. **Complete Project Fund Sources and Budget**

Agency	Grant Total	Expended to Date	Remaining
U.S. Fish and Wildlife Service (Federal):	$1,000,000.00	$ 1,000,000.00	$ -
State of California (State):	$ 700,000.00	$ 668,546.23	$ 31,453.77
Local (SPBNWR):	$ 143,840.00	$ 10,000	$ 133,840.00
Local (Audubon CA & Donors):	$ 30,000.00	$ 25,000.00	$ 5,000.00
Local (MSMVCD):	$ 115,500.00	$ 88,000.00	$ 27,500.00
State Coastal Conservancy (State)	$ 210,000.00	$ 209,999.98	$ 0.02
National Fish and Wildlife Foundation (Federal)	$ 175,000.00	$ 175,000.00	$ 0.00
Environmental Enhancement Fund (State)	$ 100,000.00	$ 100,000.00	$ 0.00
Environmental Protection Agency (Federal)	$ 235,884.00	$ 235,884.00	$ -
		$ 2,512,430. 21	$ 197,793.79
Total Federal	$1,554,724.00	$ 1,420,884.00	$ 133,840.04
Total Match	$1,155,500.00	$ 1,091,546.21	$ 63,953.75
Total Project:	$2,710,224.00	$ 2,512,430.21	$ 197,793.79

Pre-Construction Monitoring Activities

Monitoring was not paid for by the EEF grant but the SCEP included 2 years of pre-construction and 20 years of post-construction surveying in Sonoma Creek marsh for shorebirds/waterbirds, songbirds, vegetation, threatened/endangered species (Ridgway's Rail, California Black Rail, Salt Marsh Harvest Mouse and Salt Marsh Birds Beak), hydrology, geomorphology, soil accretion and photo points.

Sonoma Creek Enhancement Project Team

Competitive bids were publically released when searching for project partners for both SCEP's construction and engineering roles. Bid packages were accepted, reviewed and the following contractors were chosen to join the project partners to complete this project (Figure 2).

<u>Project Partners</u>

- Audubon California (Audubon)
- San Pablo Bay National Wildlife Refuge (SPBNWR)
- Marin/Sonoma Mosquito-Vector Control District (MSMVCD)

Figure 2. SCEP primary project partners from Audubon CA, USFWS San Pablo Bay NWR, Hanford ARC and ESA.

<u>Contractors</u>

- Construction- Hanford Applied Restoration and Construction (Hanford A.R.C, or Hanford)
- Engineering- Environmental Science Associates (ESA)
- Monitoring Hydrology/Geomorphology- Wetlands and Water Resources Inc. for pre-construction, Gillenwater Consulting Inc. for post-construction.

Other Participants

- Levee owner- Vallejo Sanitation and Flood Control District
- Levee manager- local, private farmer

Construction/Earth Moving

Project Design

SCEP design plans were originally developed in 2010 by Water and Wetland Resources environmental consulting firm. Several hydrologic and hydraulic models were used to model conditions present at Sonoma Creek marsh, and the effect that the Central Channel would have on current site conditions.

The length of channel was originally designed to be built at 5,700ft long, however Audubon was only able to acquire sufficient funds to successfully excavate 4,560ft of channel (Figure 3).

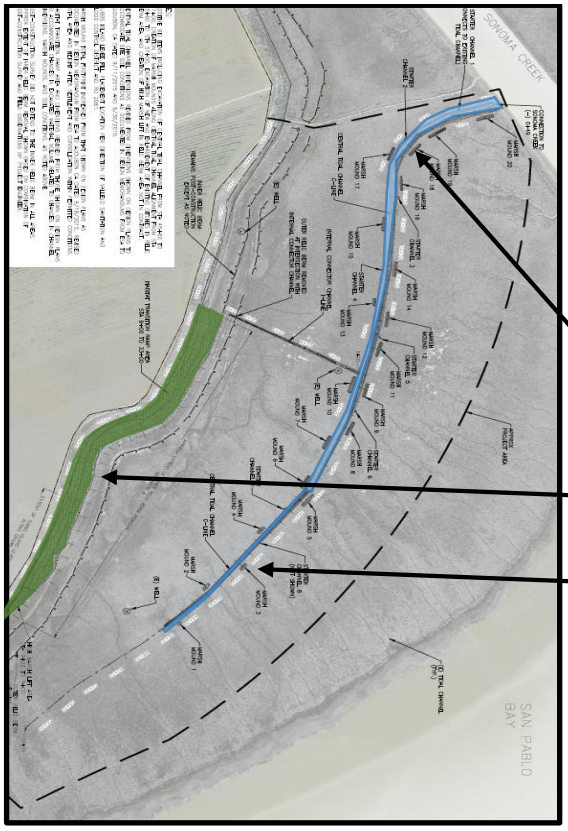

Figure 3. The three main features of the Sonoma Creek Enhancement Project include the 1) 4,560ft long main channel, 2) twenty marsh mounds, 3) 2,600ft long transition ramp (full length not shown in this image). Seven lateral channels and the access road channel were also constructed.

Parameters of the raised features, including the size and number of marsh mounds, the length of the transition ramp and the amount of surplus material allocated for levee enhancement, were all based off of estimates of how much material was to be excavated from the main channel and available for repurposing. The project team quickly learned that the amount of excavated material did not align with originally anticipated quantities. The high water-table present in the saturated marsh along with the marsh sediment's absorptive nature caused extreme shrinkage of soil amounts as soil was excavated out of the marsh and placed on top as marsh mound, transition ramp and

levee enlarging material (Figure 4). After de-watering, sediment was found to shrink by 50-60% of its excavated square footage (Figure 5). The Project team used this knowledge to guide adaptations to the original plans and specifications. Changes were made to the original design to account for the shrinkage while staying within permit requirements and project footprint.

Figure 4and 5. Show the extremely difficult conditions of the Sonoma Creek Enhancement Project. The Project team adapted quickly to difficult, flooded marsh conditions as well as unexpected soil shrinking rates to complete the project.

Difficulties also arose because of the flooded marsh conditions. Marsh mound parameters were expanded to account for both soil shrinkage as well as allow Hanford to dispose of material quickly in the "dead zone" where marsh conditions could not safely allow multiple vehicle trips to load and unload the material in further drop locations.

Weekly Project Partner Meetings

Figure 6. Weekly team meetings in the field were led by project partners. FWS biologist Meg Marriott pictured here conducting a salt marsh harvest mouse identification and flushing training.

Throughout the duration of the Project, the team remained in constant contact with our partners (San Pablo Bay National Wildlife Refuge and Marin/Sonoma Mosquito & Vector Control District) and secondary partners (Vallejo Sanitation District and local farmer). These partners held weekly meetings with the construction contractor, environmental monitors and construction monitors to ensure all activity was in compliance with active permits. The team also met to ensure that construction specifications were being met, and that adaptive management decisions made in the field were appropriate and effective.

Main Channel Alignment

The main feature of the Sonoma Creek enhancement project is the 4,560ft long main channel alignment (Figure 7). This aspect of the project was designed to replicate the success of a similar pre-existing centennial marsh enhancement project at Lower Tubbs Island (also at SPBNWR), where normal tidal flow and drainage was created for a 75-acre habitat after decades of marsh inundation and subsidence.

Excavating the marsh material for this 5-acre central channel was the most demanding construction feat of this project. Excavating within an existing marsh proved difficult because of lack of easy access to the marsh, the inundated marsh plane, and the weight of excavated material combined with construction machinery.

Authorized permits allowed four months for construction so as not to infringe upon listed species breeding windows. Any work in the marsh (south east of the levee) was to commence after rail nesting season (July 30th, 2015) and was to conclude before November 30th, 2015 (anadromous fish spawning season). USFWS biologist trained all staff on protective measures to ensure no salt marsh harvest mice or nests were taken during the project (explained in Marsh Access below).

Marsh Access

Project partners devised a unique plan to allow access to the excavation site by the construction of a "floating" permeable road. Hanford delivered 8,000 tons of 2 in. drain rock, over a mile of geogrid, and permeable heavy duty fabric to construct the road. This road was to be constructed from the levee (separating Sonoma Creek Marsh from the adjacent farmland) to the center point of the main channel alignment, point 24+00 or 2,400ft from the channel mouth (Figure 7). From there the road was going to be built from the northern (connection) point of the channel at Sonoma Creek, working its' way south to the channel end point. Before access road construction began, U.S. Fish and Wildlife Services performed a Rail survey to ensure there were no Ridgway's, California Black or Virginia Rails near the construction zone. The survey yielded an "infestation" of rails in the healthy portion of the marsh near the connection point with over 70 rails heard. SPBNWR biologist deduced that no rails were found near the 260 acre "dead zone," and this habitat was unsuitable for fall Rail nesting, therefore excavation could continue by starting at the southern end of the channel and working to the north.

Wildlife Flushing

Before any roadway material was laid down in the marsh, the biological monitors led the construction crew in exercising extreme caution and evasive tactics to flush wildlife from the construction zone (Figure 8). Teams of 2-4 trained staff flushed the 30ft wide roadway of wildlife using USFWS biologist mandated techniques. Densely vegetated marsh areas were even hand-picked through and examined to ensure no rodent and bird nests were found. Within 30 minutes of flushing the pathway, weed whackers were brought through to clear cut all standing vegetation to ensure no wildlife would return to the site (Figure 9). Within 30 minutes of that process, 30ft segments of permeable tarp was placed over the cut pickleweed (*Sarcacornia pacifica*, Figure 10). This process was repeated down the entire ¼ mile access road to the main channel alignment and then again along the ½ mile of main channel from center point to the southernmost end at 45+60.

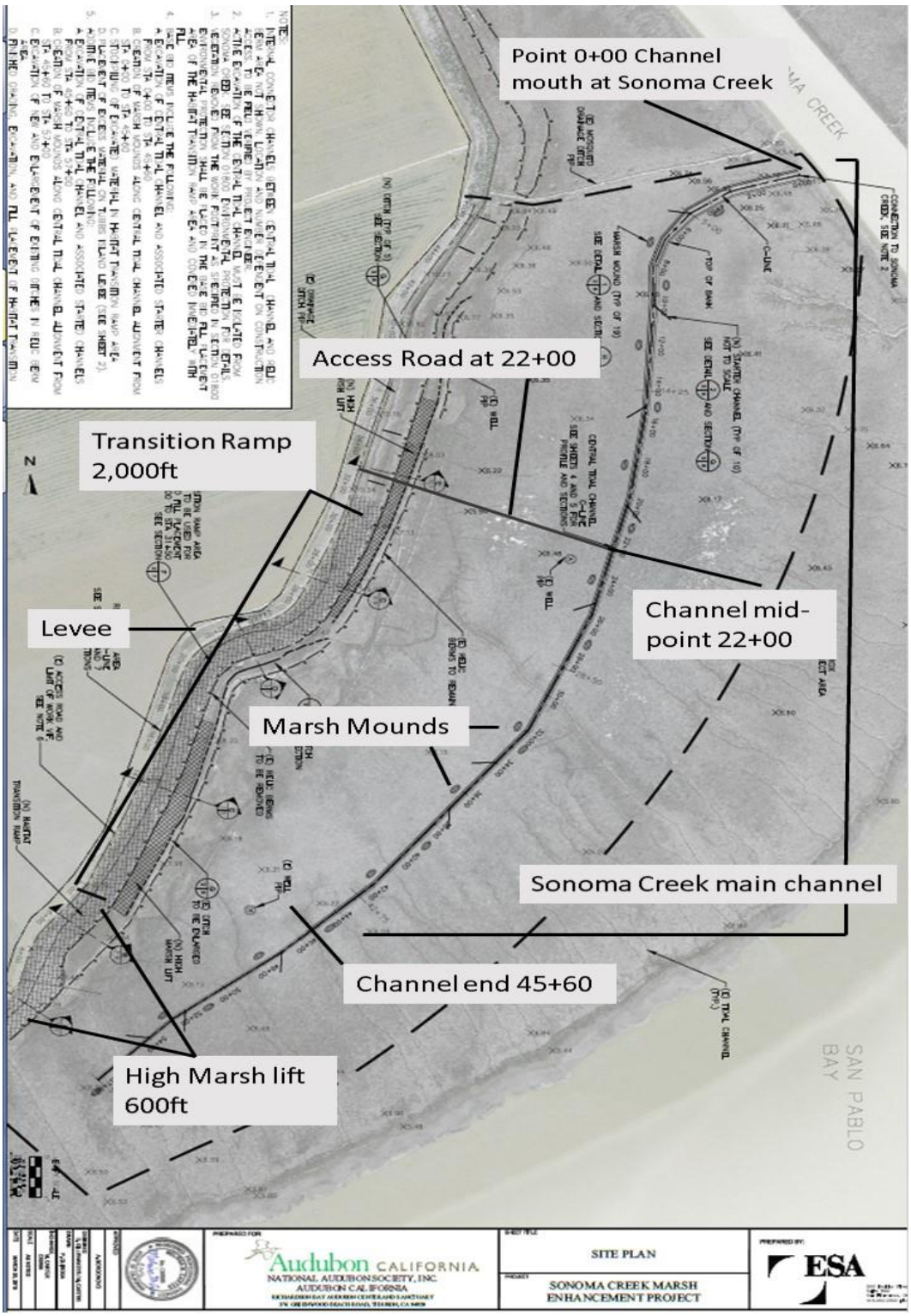

Figure 7. Sonoma Creek Enhancement Project final specifications as developed by ESA shows the main channel alignment, marsh mounds, transition ramp and construction points.

As 30ft segments of tarp was laid, the construction crew placed ample loads of drain rock onto the tarp 18-24in deep to ensure vehicles would stay above the marsh plane. Once drain rock was placed, geogrid was lain on top of the rock, after which the tarp ends were wrapped around the drain rock and brought together, creating a “burrito” effect. A subsequent layer of geogrid and 6in deep drain rock was then placed on top of the tarping for additional stability.

Road Construction and Channel Excavation Timeline Approximation (See Figure 7. for project points listed below)

- 7/30/15-8/15/15 Construction- Access road from levee to main channel alignment (levee to point 24+00)
- 8/15/15-8/30/15 Construction-Main channel center point to southern end (point 24+00 to 45+60)
- 8/30/15-9/30/15 Excavation- Main channel southern end to center point (point 45+60 to 24+00)
- 8/30/15-9/30/15 Construction-Main channel center point to mouth at Sonoma Creek (24+00 to 0+00)
- 9/30/15-10/30/15 Excavation -Main channel mouth back to center point (0+00 to 24+00)
- 10/30/15-11/15/15 Removal-Access road and channel excavation from center point back to levee (point 24+00 to levee)

Figure 11. Hanford crew create an 18in-36in thick permeable access

Channel Excavation

Once the access road was built overlaying the construction footprint of the main channel alignment, Hanford's team simultaneously excavated and transported away drain rock and tarping road material, then continued to excavate the channel as designed in the project plans and specifications. Throughout excavation of the channels, Hanford also constructed raised features both along the channel alignment (marsh mounds) and along the levee (transition ramp). The southern end of the channel is the narrowest portion of the main channel, and was excavated to a top of about 20ft at the top of the channel. Hanford then excavated the channel down to a depth of 0ft NAVD88 (elevation) and shaped a bench into the channel banks at a 1ft high: 1ft long (1:1) ratio, as designated in the project plans (Figure 12). The bench is a stair-step contour of the channel side banks to improve side stability with these extremely soft soils; thus reducing side bank slumping into the channel which could possibly block water flow through the channel. The Project team quickly realized, however, that even with the stepping effect, the channel banks were not stable enough to hold a 1:1 ratio. ESA engineers assisted Hanford in adjusting the channel geometry so that the side banks could be constructed at more stable ratios. With the adjustments, slopes of the channel bank ranged from 1:3 to 1:6. Final adjustments brought the channel bottom elevation down to -1ft NAVD88. Those two measurements were fixed excavation guidelines while channel top width varied along the main channel alignment from 20ft across at its tapered end at (point 45+60) to 30ft across at the channel's center point (24+00, Figure 13) and up to 50ft across at the channel's mouth where it connects to Sonoma Creek (point 0+00) (Figure 7). This process was continued for most of the channel excavation. When the two connection points were reached, Hanford connected the northern ½ channel alignment to Sonoma Creek, connected the northern and southern channel alignments and connected the main channel alignment to the access road channel.

Figure 12 and 13. Show the completed excavation of the southern half of the channel, points 22+00 to 45+60. Note the stair-step/bench effect shown in figure 12 to relieve slumping pressure of unstable marsh soils. Water shown filling the channel in these images has leached from the central basin top and marsh soil, this channel is not yet open to Sonoma Creek's natural tidal flow.

Connecting Main Channel and Sonoma Creek

When Hanford had finished excavation on the southern end of the channel and the northern half of the access road (which was now safely out of rail nesting season) they began excavation of the channel mouth at Sonoma Creek. To ensure that no wildlife would enter or become trapped within the construction zone, a 100ft long turbidity curtain was installed, arcing across the 50ft wide, 7ft deep channel mouth entrance. Once the turbidity curtain was installed, the excavator began to remove soil material from the low tidal marsh habitat along the Sonoma Creek marsh/Sonoma Creek bank. The excavator removed over 70ft of channel material, 50 ft wide and 7 ft deep, placing material at the nearest marsh mounds before the 100ft long, 10,000 gallon Aquadam was installed. This water-filled damn was chosen and installed by Hanford as the best way to discourage wildlife entrapment while allowing malleability when the channel banks, bottom sediment and tides were constantly changing. An additional hope was that the construction team would be able to pump some water out of the channel to enhance the visibility of digging in the creek. Unfortunately they channel banks proved too soft to securely hold the Aquadam in place without equal water pressure holding the dam between Sonoma Creek and the channel. A wildlife biologist monitored exclusion efforts for 3 days while the curtain was placed (Figure 14), channel connection dug and the temporary Aquadam installed (Figure 15). Once the Aquadam was successfully installed and secured, Hanford continued to excavate the main channel alignment back from the channel mouth to the center point at 22+00 (Figure 7).

Figure 14 and 15. Connecting the northern half of SCEP channel to Sonoma Creek was a feat requiring many installments including the set-up of an exclusionary curtain, excavating the first 70 ft of channel mouth, and then the placement of a temporary Aquadam. Both the curtain and Aquadam (pictured here) prevent wildlife from entering the worksite during construction, a biological monitor was onsite for the entirety of the installation.

Connecting Northern and Southern Channel Ends

Within a month, Hanford had excavated the northern half of the main channel alignment from 0+00 south to 21+80 (Figure 7). At this point, a 20ft wide plug of channel material was kept as a dividing line between the freely flowing tide water of the northern end of the channel and the stagnant, entrapped water table leaching from the southern end of the channel (Figure 16 and 17). In early November, Hanford's skilled excavators slowly began to remove the top 2ft soil plug that trapped remaining water in the channel. Once the plug was removed, for the first time water from trapped on Sonoma Creek marsh and in the sediment entered the channel. The last remaining soils were removed, and within a day of channel connection, the channel began draining the marsh and circulating tidal in-flows.

Hanford then began the small access road connection perpendicularly from the main channel back towards the levee to ensure water drainage across the construction footprint. Once a 20ft access channel mouth was dug into the main channel, a 1/32in mesh netting was placed across the opening to discourage fish entrapment. With this fish fence in place the Aquadam was removed and finally full tidal fluctuation was achieved in Sonoma Creek Marsh. Success of this channel and its function was observed immediately during and after construction as high tides brought water into and across the marsh's central basin, and falling tides rapidly drained water off the basin and into the channel. Relieving the basin of long standing water.

Figure 16 and 17 show the final excavation component of the channel. A 20ft soil plug was carefully removed to unite the southern and northern channel halves and allow trapped water from the central basin and southern channel half to finally flow out to Sonoma Creek. The team had to work carefully to regulate water release as the 1,000s of gallons of water could have forced through the plug, distributing the sediment into the channel and caused impediments to flow.

Access Road Channel

Figure 18. Staff walk along the lateral access road channel created to mitigate the depressions the weeks of heavy machinery traffic caused under the access road. This channel now stretches from the levee to the mid-way point of the main channel and ties in pre-existing MSMVCD channels to create an enhanced drainage network.

The access road section leading back to the levee left a deep depression in the marsh after months of heavy vehicle traffic from the center point of the main channel at 22+00 (Figure 7). The project team decided it best to excavate a small, lateral channel in its place. This channel would connect to the main channel, and run back towards the levee. A channel no wider than 20 ft top width, with a maximum depth of 5ft was excavated within a week (Figure 18). This access road channel also assisted in uniting and draining in 3 man-made channels that ran lateral to the levee between relic berms. These small channels had been cut in previous years by MSMVCD but had since filled with sediment and vegetation, and inhibited the flow of water off of the marsh once flooded. Uniting old channels with new, larger channels, has encouraged the drainage of vast areas of ponding water away from the levee and off of the marsh. To dispel wave and storm water activity coming up the access road channel towards the levee, Hanford left one relic berm in place to lessen the water's impact 100ft from the levee, just behind the very end of the lateral channel. A high marsh lift between this relic berm and the levee discourages water ponding and pressure on the levee and gently slopes southward into the transition ramp

Lateral Starter Channels

As material was excavated along the channel alignment, Hanford also excavated 7 lateral connector channels off of the main channel. These lateral starter channels will allow additional drainage of water off the basin and are expected to naturally progress into the marsh with future tidal action. Lateral channels alternated along both sides of the 4, 560ft main channel at points 37+00, 34+00, 25+00, 20+00, 15+00, 10+00, and 5+00

Figure 19. Seven, 20ft long lateral starter channels are expected to naturally extend into the marsh with annual tidal flow. These will be monitored for future development.

Marsh Mounds

SCEP was permitted up to 2 acres of high marsh fill within the marsh basin in the form of marsh mounds (Figure 20). These marsh mounds are expected to provide wildlife habitat and refuge from daily high tide events that consistently flood over 260 acres of the marsh, extreme high tide and storm events (such as King Tides), and eventual sea level rise. These 2 acres of marsh mounds, though elevated off of the marsh plane (which ranges in elevation of 6.0 NAVD88 to 6.4 NAVD88) were required to reach heights no greater than 8.4 NAVD88 after material shrinkage. Limiting mound heights to 8.4 NAVD88 ensures that they maintain their marsh habitat status and are not a conversion of tidal marsh to upland habitat.

Figure 20. In areas of living vegetation (not the "dead zone") marsh mounds were adorned with pickleweed, scrapped from the channel footprint. With vegetation placement such as this, marsh mounds are expected to fully re-vegetate faster than the 2 year expectancy for areas and features without pickleweed matts.

Twenty marsh mounds were placed no closer than 20 ft from the edge of the main channel. These marsh mounds were originally planned to be 25ft wide by 50ft long. With these dimensions, the accumulated footprint of these mounds would impact approximately 1 acre of poorly functioning tidal marsh. The marsh mounds at the southern end of the channel were the first to be constructed from the freshly excavated soil. Measurements were taken on the day of construction and every few days to determine soil shrinkage rates. The Project team originally estimated 30% soil shrinkage as water drained from the material and winter weather leveled out the mounds. Within the first two weeks of construction or team found that there was up to 50-60% shrinkage depending on soil saturation and external climate. This information, combined with the need to dispose of soil quickly in difficult construction environments (flooding in the central basin, high tides, saturated soil, and road sinking) and our 2 acres of permitted in-marsh high tide refuge, lead the decision to expand marsh mound dimensions. With this adaptive management plan, marsh mounds ranged from 50ft to 100 ft long with an accumulative footprint of just

under 1 acres of tidal marsh. Each mound maintained the 25ft width as a limitation of excavator reach from the access road (Figure 21).

Figure 21. Marsh mounds were placed approximately 20ft from the edge of the channel, noted by wood stakes with orange tops. Mounds are expected to shrink about 50% with sun/air exposure and winter storm events and tidal flow.

These high tide refuges within the marsh proved to be an important element within days of their construction. As construction continued to the north, wildlife started to occupy the mounds during both high tides and low tides. Small shorebirds such as Least/Western Sandpipers, Dunlin, and Killdeer were observed occupying the mounds during low tides, where it is expected that they are resting and seeking refuge from predators on the open "dead zone" plane. These same bird species were observed using the mounds during the King Tide events of November-January, where most of the Sonoma Creek marsh was flooded, except for the construction high tide refuges (Figure 22). Marsh mounds have been designated a new habitat type on post-construction bird surveys to collect data on bird species, number, and behavioral use of this new habitat.

Figure 22. November 24-26, 2015 put Sonoma Creek Enhancement Project's channel and high tide refuge to the test as tides reached record highs of 9ft NAVD88. At this level of sea level rise, only the top portion of the newly constructed marsh mounds remained above water as the rest of the marsh was flooded through to the adjacent levee at 9.2-10.0ft NAVD88. This is a critical problem facing the Bay Area marshes with respect to Climate Change.

Transition Ramp

The transition ramp is a gently graded, vegetated slope intended to provide refuge to threatened marsh wildlife in extreme storm events, king tides, and rising sea levels rise (Figure 23). The Project's transition ramp was designed to stretch 3,200ft along the levee from the mid-way point to the end of the main channel (Figure 7). Project costs, challenges of unforeseen material shrinkage rates, and the need to displace material quickly within the marsh (expanded marsh mounds) to lessen access road pressure allowed the completion of approximately 2,600ft of the original design plan. As material was excavated from the main channel it was placed into the transition ramp area, building up a surplus of material to eventually be shaped into its final dimensions. Temporary access points were built along the levee so that multiple front-loader trucks could continually rotate, receiving material from the main excavator and transporting and releasing it along the transition ramp site. A second excavator was placed on the levee to spread newly placed material as far into the marsh as possible from the levee top. A wildlife biologist was on-site during the entire material placement process to flush wildlife from the transition ramp footprint and ensure neither wildlife nor nests were taken in the construction of this element.

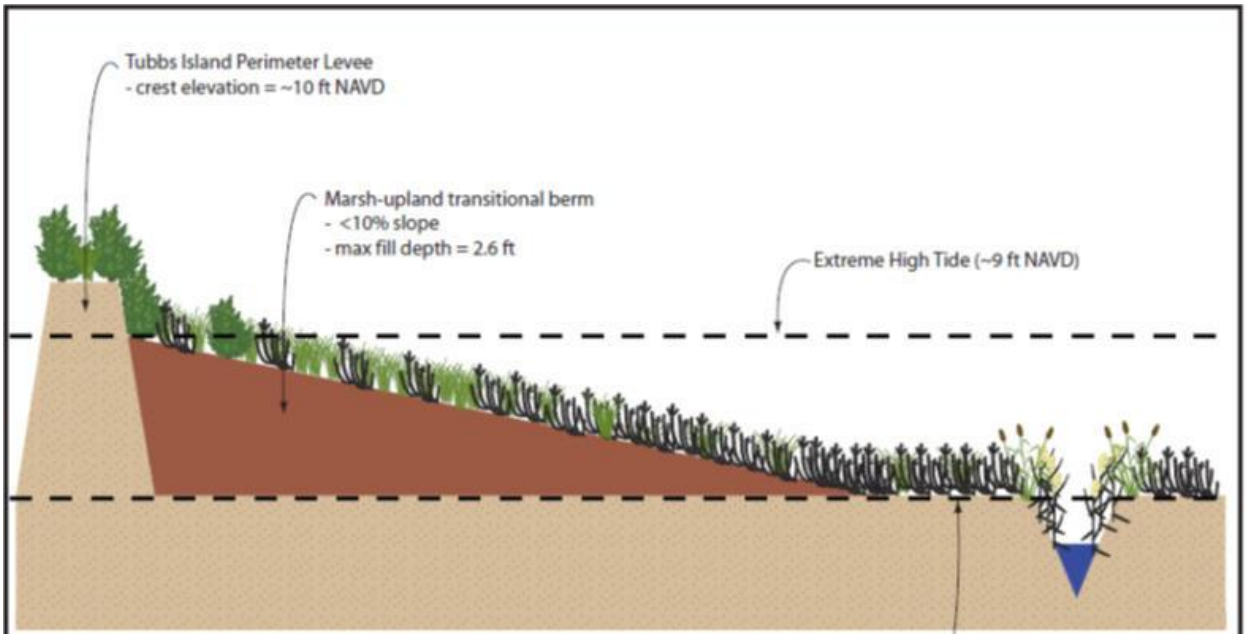

Figure 23. This diagram depicts the goal of the transition ramp. Once it has leached its salt water content the transition ramp will be seeded and planted by Point Blue's Students and Teachers Restoring A Watershed (STRAW) program. The transition ramp's habitats will be planted as follows: Upland habitat above the extreme high tide line (salt marsh baccarus), high marsh habitat between the extreme high tide and the lower line (pickleweed and alkaline heath), low tide marsh habitat will fill in the man-made and natural channels along the base of the ramp (saltmarsh cordgrass).

Pre-construction material calculations estimated more material excavated from the site than was needed to construct marsh mounds and the transition ramp. With these approximate estimates, any excess material was to be given to the adjacent farmer to manage and repair his levees. Approximately 1,000 cubic yards of material was given to the farmer in good faith to assist in levee maintenance, even though the preferred length of the transition ramp length was not achieved.

2017 Transition Shaping Complete

Hanford completed all features described in their contract by November 15th, 2015. Marsh access and work for this project was permitted until November 30th, 2015. With an excess of two weeks of construction time, Audubon and SPBNWR staff decided it favorable to fundraise and complete the first shaping of the transition ramp while machinery was still onsite, operators available, and Hanford under contract (Figure 24 and 25).

Figure 24 and 25. The left figure shows the original placement of the transition ramp's material. Material was placed as far as the excavator arm could extend from the levee on the left. The photo on the left shows the work done through Hanford's contract extension, originally proposed for 2017. With the help of a second excavator pulling from within the marsh, material is drug down 100-120ft from the levee creating a gently sloping habitat ramp which has already begun to naturally revegetate. High marsh revegetation by STRAW begins fall 2016.

The marsh habitat between the first relic berm and the levee has been targeted by SPBNWR and MSMVCD as a problematic, dysfunctional portion of the Sonoma Creek marsh, second in concern to the central basin's "dead zone." The functionality of this zone rapidly decreased as tidal water seeped into the marsh through low points and then was locked between the higher elevations of the relic berms and the levee. This pooled water created a similar affect, on a smaller scale, to that of the central basin where pooling water saturated the marsh plane and caused subsidence. For many years the MSMVCD has tried to maintain this area by cutting small channels, running parallel to the levee and relic berms to drain water away from the levee and dispel it towards Sonoma Creek or San Pablo Bay. Years of tidal flow through these channels had deposited sediment that now constricts water flow beyond MSMVCD's ability to maintain open channels.

The pre-existing marsh plane elevation in this area ranged between 6 and 6.5ft NAVD88, thus causing over 260 acres of water entrapment, prime mosquito breeding zones, and degraded wildlife habitat along marsh side of the levee. Between November 15th and 30th 2015, Hanford was able to shape material placed in the transition zone, disassemble the first interior relic berm, and connect the area between the two berms with a gentle slope. When complete, the transition ramp reached a consistent elevation of 9ft NAVD88 high (2.5-3ft above pre-existing marsh plane) and an average width of 100ft (and occasionally wider or narrower depending on material availability). The final slope along the transition ramp on average reached 40:1 (40ft wide: 1ft high). This ratio is the optimum transition ramp slope for small mammals and secretive marsh birds of concern in San Francisco Bay marshes (Baylands Ecosystem Habitat Goals Science Update, 2015). These parameters were carried out for approximately 2,000 linear feet of the originally proposed 3,200 linear foot transition ramp, from the access road channel to the south. Due to unexpectedly high material shrinkage rates and the need to dispose of material in the marsh to relieve road pressure, the full 3,200ft length of the transition ramp was not achieved. Where less material was

available, at the southern end of the transition ramp, Hanford gently transformed the available material into approximately 600 linear ft of "high marsh lift" to discourage water ponding in problematic areas and bring sunken areas along the levee back up to surrounding marsh plane height of 6-6.5ft NAVD88 (Figure 7).

POST- CONSTRUCTION INDICATIONS OF SUCCESS

Although sufficient monitoring data has not yet been collected to prove or disprove the success of this project quantitatively, there has been much qualitative evidence of such. In the three months post-construction Audubon and SPBNWR biologists have frequented the SCEP site to start post-construction shorebird and waterbird surveys, examine the site for changes in water drainage (Figure 26), and lead tours for granting agency staff, donors and SPBNWR associates.

Figure 26. USFWS Biologist Meg Marriott is ecstatic about the immediate response of the new channel as 1,000s of gallons of trapped water now flow, uninhibited, into the channel and out to Sonoma Creek and San Pablo Bay.

WILDLIFE USE OF NEW AND ENHANCED HABITAT

With five shorebird/waterbird surveys and all songbird surveys of year 1 post-construction complete, our team has observed some interesting newcomers to the marsh. In both December and January a Wilson's Snipe was observed and recorded along the banks of the main channel alignment. This is a newcomer to the Sonoma Creek marsh that was never recorded using the marsh pre-construction. On one survey date in February twelve Semipalmated Plovers, a less common shorebird to Sonoma Creek marsh, and over 1,600 Least and Western Sandpipers were recorded using the flooded marsh plain as foraging ground. Even more astounding is the almost immediate benefit that new high tide inner marsh refuge provided these small shorebirds during the winter King Tide events. In winter 2015-2016 King Tide water levels reached up to 9ft NAVD88, completely flooding the marsh plane. The significance of in-marsh high tide refuge such as the marsh mounds became obvious as hundreds of Sandpipers flocked to the only above water habitat in the marsh to wait out the rising tide.

Numerous birds as well as other wildlife have been found using new and enhanced habitats other than the marsh mounds such as the Grebes pictured below locomoting and diving in the new channel and the Killdeer found wandering along the new transition ramp (Figure 27 and 28). In one of this spring's songbird surveys, a Rock Wren

was observed foraging among the cracks and fissures of the drying marsh mound's material. Monitoring codes have been added to post-construction surveys account for bird use of newly formed high tide habitats in the construction of SCEP (including marsh mounds and transition ramp). Staff will continue to monitor bird species, number, behavior, location as it pertains to preexisting and new habitats in Sonoma Creek marsh.

Figure 27 and 28. Photos taken during construction of Grebes locomoting and foraging in the new 7-acre channel and Killdeer inspecting the transition ramp shortly after material was placed. These two new habitats will be monitored as part of the post-construction monitoring plan.

VEGETATIVE RE-GROWTH

Just a few weeks after construction ceased on the project site December and January winter rains brought fresh water to the marsh, new growth of Pickelweed and Alkaline heath (*Sarcacornia pacifica* and *Frankenia salina*) became visible in many exposed habitats. By January, areas where vegetation had been cleared to lay access road and excavate the main channels as well as the newly placed material of the marsh mounds and the transition ramp have already begun to show signs of life (Figure 29 and 30).

Figure 29 and 30. Vegetative regrowth of low marsh species in constructed transition ramp and channel edges.

In May this year, while completing songbird surveys, Audubon and Refuge staff were bedazzled by the resilience of the interior marsh "dead zone." Just six months after construction completion, old Pickleweed, thought to be dead, began to burst back to life in the desecrated central basin (Figure 31). Showing the first vibrant signs of life and great hope for the 260 acres of exposed material.

Figure 31. Pickleweed comes back to life after months of inundation as the new SCEP tidal channel drains once stagnant water off the basin, flushing out the algal mats and allowing the central basin's soil to dry.

NATURAL CHANNEL FORMATION AND EVOLUTION

Within just 3 months existing lateral channels excavated by MSMVCD as mosquito management have started to expand and lengthen and new, naturally sinuous channels have begun to form, draining 1,000s of gallons of water off of the once inundated central basin (Figures 32 and 33). These natural pathways are a new addition to our monitoring plan as Audubon and SPBNWR staff will continue to observe them, record monthly toe bank coordinates and measure their lateral progression back into the marsh. These new and expanding channels will provide daily drainage of the flooded plain and quickly revegetate. Deeper channels may revegetate with native *Spartina foliosa* and provide new channel habitat for secretive marsh birds.

Figure 32 and 33. The formation of new, natural channels becomes obvious as water drains off of the central basin through select pathways. These will continue their sinuous progression further into the marsh, relieving ponding water further away from the excavation site.

Above photos taken February 16, 2016 (only two and a half months post- construction) exhibit newly formed channels on the Sonoma Creek marsh from the SCEP. The left photos clearly shows the abundance of water that is flowing off of the plane and the progression of the toe further into the marsh (Figures 32 and 33).

Photos below show the importance of these channels in relieving flood conditions on the plane, allowing the mud flats to aerate and dry out which was impossible before the Project.

Figures 34 and 35. These revitalized MSVCD made channels have begun to expand and lengthen back into the marsh now that they are tied into the main channel.

TOURS

Five different tour dates were offered to patrons who have supported the SCEP as a chance for them to experience, first-hand, the completed project and new habitats created to drain the central basin (Figures 36 and 37). Up to 10 participants joined us for a boat ride each date during high tides above 5.0ft. Boats were brought partway into the channel to exhibit the main channel alignment, access channel, lateral channels and marsh mounds. Unfortunately the transition ramp was barely visible from this vantage point.


Figure 36 and 37. Thus far, Project partners have guided over 20 participants through the completed Sonoma Creek Enhancement Project showing off the creek (which the boats are easily able to maneuver down), marsh mounds and access channel.

Media coverage and Public Release

- Audubon California
  http://ca.audubon.org/conservation/conservation/seas-shores/san-francisco-bay/sonoma-creek-restoration
- National Audubon
  March 2016 "Giving a Marsh a Fresh Start"
- Birdlife International- 2015 Conference of Parties (COP) in Paris on Climate Change
  http://www.birdlife.org/datazone/sowb/casestudy/661
- San Francisco Bay Joint Venture
  http://www.sfbayjv.org/project-sonoma-creek-marsh-enhancement.php
- Estuary News- March 2016 "Skeeters Undone" by Joe Eaton,
  http://www.sfestuary.org/wp-content/uploads/2016/03/Est-Mar2016-v6web.pdf

Public Presentation

- Ocean Climate-Smart Summit, May 2016 poster exhibited
- Natural Areas Conference, October 2016, abstract submitted

Project Challenges

- High Water Table- The natural water table of Sonoma Creek marsh was extremely high because of years of inundation from entrapped tides and fresh rain water. This posed an extra challenge to Hanford's excavators who were removing soil from the main channel as water leached off of the central basin and out from the soil into the channel.

- Unexpected material shrinkage- Once excavated, material was found to shrink when exposed to dry air, heat and constant tidal and rain flushing. Marsh mound parameters were expanded to account for 50-60% material shrinkage.

- Daily high tides and seasonal king tides- Tides were the most challenging variable in the completion of this project (Figures 36 and 37). Daily tides made general work conditions difficult for Hanford on the ground and in maintaining their access road. Excavation of the channel was delayed by one week to allow repairs to the road way to ensure that work conditions were safe, machinery was not at jeopardy and that the project could be completed.

Figures 38 and 39 show the flooded marsh plane conditions the Hanford and project partner crew experienced throughout the construction timeline. At one point, the road sank up to 3ft below the marsh plane, luckily this compaction was within the footprint of the channel.

Future Work Planned (2016-2017)

Work highlighted here will not be paid for using the EEF grant.

Reshaping the Transition Ramp

Much of the shaping of the transition ramp that was expected to be completed 20NC16-2017 by SPBNWR was completed in 2015 by Hanford. Once the transition ramp has drained and settled over 2016, SPBNWR staff will make minor, final adjustments to the ramp before it is to be seeded and planted by Students and Teachers Restoring A Watershed (STRAW) program.

Extend Channel Network

Minor additions that fall under MSMVCD's tidal marsh management practices to control mosquito populations will continue as the organization sees fit. It is the project partners' hope that MSMVCD will be able to create small sinuous channels that extend into the marsh from the lateral starter channels and along the main channel alignment in subsequent years. This will encourage a more natural network of drainage channels to form across the marsh, emphasizing channel formations across the basin's "dead zone," for enhanced drainage.

Re-vegetation of the Transition Ramp

The revegetation of the transition ramp to high marsh and upland plant communities will take place in 2016 after a full year of soil drainage and leeching of salt content and minor reshaping by SPBNWR staff. Point Blue's Students and Teachers Restoring a Watershed (STRAW) program has been contracted by SPBNWR to plant the transition ramp with the help of local school classes, groups and volunteers.

Refuge staff will be working with STRAW between the years 2016 and 2020 to plant at least 2,000 native transition zone plants of approximately 10 species. This will involve training teachers during a week-long conservation biology and ecology training, to incorporate restoration and conservation biology into their annual curriculum. The teachers will incorporate what they have learned into their lessons, and STRAW staff will visit the classroom and teach students in depth lessons on San Francisco Bay watershed, tidal marsh ecology and the endangered species that live in the marsh. All of this teaching will culminate in the students (along with teachers and parents) coming out to Sonoma Creek to plant native plants (that have been grown from native seed by STRAW) into the transition ramp.

This will involve approximately 500 students, teachers and parents working approximately 5 hours each at a volunteer rate (this is very conservative) of $21/hour to provide approximately $49,000 in matching funds.

Monitoring

Vegetation, wildlife use, soil accretion, photo point, surface water hydrology and channel geomorphology monitoring of the Sonoma Creek Enhancement Project will be lead by Audubon for years 1 and 3 post-construction, and then continue on through 2035 by SPBNWR staff.

Contract work

- Post-construction hydrology research and analysis will be contracted out by summer 2016 for year 1 post-construction, and repeated with the same contractor for year 3 post-construction monitoring.
- Point Blue has been contracted to propagate, care for and plant new plants with local Sonoma County residents and youth through the Students and Teachers Restoring A Watershed (STRAW) program. Planting of the transition ramp will start in 2016 and continue through 2018.

Expenditures

View Appendix 1- Project Expenses

Literature Cited

Baylands Ecosystem Habitat Goals Science Update (2015) Science Foundation Chapter 4: Connections to the Watersheds: The Estuarine-Terrestrial Transition Zone. Ecological Connectivity pg.8.