APPENDIX F
Hydrology and Water Quality

F1. Sediment Dynamics and Sediment Budget Analysis

F2. Summary of Results from Sediment Sampling and Analysis in Area B – Ballona Marsh, Draft Technical Memorandum

F3. Final Report – Ballona Wetland Preserve – Area A Preliminary Geotechnical Investigation and Beneficial Use Assessment

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APPENDIX F1
Sediment Dynamics and Sediment Budget Analysis

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memorandum

date May 15, 2015 – *updated 6/28/15*

to Mary Small, California State Coastal Conservancy

from Lindsey Sheehan, P.E., Nick Garrity, P.E., and Bob Battalio, P.E.

subject Ballona Creek and Wetlands Sediment Dynamics and Sediment Budget Analysis

This Sediment Dynamics and Sediment Budget Analysis assesses potential effects of the Ballona Wetlands Restoration Project on long-term deposition, erosion, and sediment transport patterns in the Ballona Creek channel, restored wetlands, Marina del Rey harbor entrance channel, and Santa Monica Bay for the purpose of assessing potential environmental impact for the Project EIR/S. The analysis builds on the results of other analyses in the separate Hydrology & Hydraulics Report (H&H Report; ESA 2013), Sediment Transport Analysis (ESA 2014), and Preliminary Design Report (ESA 2013 – update pending). Note that additional hydrologic analysis is anticipated to be performed for the U.S. Army Corps of Engineers Section 408 permit application (i.e., Section 408 Submittal B) and approval.

This analysis includes hydrodynamic modeling, geomorphic analyses, and estimates of potential changes in on-site and off-site erosion and deposition. The results of these analyses and the Sediment Transport Analysis sediment transport modeling results for a range of typical and extreme storm events are used to develop a sediment budget to estimate sediment deposition, erosion, and transport rates; equilibrium conditions; and the long-term potential effects over a series of years and storm events. The results of this analysis are also used to assess potential water and sediment quality effects in the Water Quality Technical Study.

The analyses assess both existing and proposed Project conditions to evaluate potential changes due to the Project. The Project conditions analysis focuses on the Proposed Action (Alternative 1) as the greatest change from existing conditions, and also discusses changes for Alternatives 2 and 3 based on the results for Alternative 1.

Section 1 presents the historic context of the existing system. Section 2 and 3 describe the hydrodynamic and sediment transport modeling and Section 3 presents geomorphic analyses for the fluvial, tidal, and coastal sediment transport processes. Section 4 compares Ballona to local reference sites and lastly, Section 5 summarizes the results and overall morphological development that is expected for the Ballona Wetlands Ecological Reserve under restored conditions.

1. HISTORIC PROCESSES

A brief discussion of the geomorphology of the historic Ballona Wetlands system is included for context. A more detailed assessment of the site evolution over geologic time is included in the Ballona Wetlands Existing Conditions Report (PWA and others 2006), the Ballona Wetlands Hydraulics and Hydrology Report (ESA PWA 2013a) and the Ballona Wetlands Historic Ecology Report (SCCWRP 2011). The Ballona Wetlands system has developed over time due to geologic processes and human actions (see Attachment 1 for a detailed timeline from 1880 to 2012):

- Longshore sediment transport built a sand bar across the estuary as sea-level rise stabilized about 4000 years ago (4000 before present or BP).
- The Los Angeles River intermittently drained and delivered sediment to the Ballona estuary. There was frequent switching of its course between Long Beach and Ballona Creek. The sediment progressively filled in the estuary and formed wetlands (4000 – 200 BP).
- The Los Angeles River avulsed to its current location with its mouth at Long Beach (1825), where it was then channelized, which reduced storm flows and sediment delivery to Ballona (1884-1939). However, freshwater springs sustained much of the existing marsh (Dark et al 2011).
- The lagoon became constricted and seasonally closed due to longshore sediment transport, a smaller tidal prism (after establishment of the marshes), and the smaller storm flows (after the avulsion of the Los Angeles River). Attempts to create a harbor in the lagoon failed due to the large shoaling rates, which were greater than the available dredge capacity. Figure 1 shows the mouth of the lagoon located further south than the existing mouth.
- The Ballona Creek flood control channel and levees were constructed, disconnecting the remaining wetlands from tidal and fluvial inundation and sedimentation (completed in 1939). Shoaling occurred in the creek mouth before the jetties were constructed in 1938 (Figure 2 and Figure 3).
- The Marina del Rey breakwater and jetties were constructed (extending the Ballona Creek jetties), which reduced wave penetration and impacted the littoral sediment transport pathways (1959-1963)

The history of the Ballona Wetlands can be used to guide the design of the restoration; however, existing constraints must be considered as well. For example, although Ballona Creek was historically a seasonally closed lagoon system, the mouth of the Ballona Creek Flood Control Channel must be maintained open to protect the surrounding development from flooding.

2. HYDRODYNAMIC MODELING

ESA previously constructed an EFDC hydrodynamic model for the Ballona Wetlands to support the restoration planning process (PWA 2009, ESA PWA 2013a). The 2-D EFDC model was selected for application by the Project Management Team, Science Advisory Committee, the USACE, and ESA. The model was previously used in the Hydrology & Hydraulics Report to characterize the hydrodynamic response of various restoration alternatives, as well as to supplement 1-D hydraulic modeling analyses, the preliminary restoration design (ESA PWA 2013b), and to more closely examine some of the 2-D processes (plan-view, depth averaged), such as flow area, velocity, and bed shear stress (hydraulic) for Project Conditions. For model set up details, see the Hydraulics and Hydrology report (ESA PWA 2013a).

To further examine the 2-D processes effecting sediment transport, the model was run using the newest version of EFDC Explorer (version 7.1), which provides more model output and post-processing capabilities. The project conditions model was revised to use the project topography from the Preliminary Design Report (PDR; ESA PWA 2013b) and run for the 10- and 100-year storm events. Maps of hydraulic shear stress at the bed during the peak of the storm were exported to GIS for both runs (Figure 4) to use in the analysis of marshplain erosion (Section 4.1.4). Note that the high shear in the channel upstream of the site is due to a high point in the topography. During a major event, this will likely be flushed from the system.

3. SEDIMENT TRANSPORT MODELING

ESA conducted sediment transport modeling using HEC-RAS to look at sediment transport for the estimated effective discharge (Q_{eff}), 5-year discharge (Q5), 100-year discharge (Q100), and the channel design event (46,000 cubic feet per second (cfs) with a 7.63 ft NAVD tide boundary condition) to inform further design development (ESA PWA 2014). The following conclusions were drawn from the modeling:

- Sediment supply to the project site is low relative to the sediment transport capacity and the site can be characterized as generally sediment supply-limited. Sediment transport model results support this conclusion, with all sensitivity runs generally showing more potential for scour than for sediment deposition under existing conditions.
- Since the channel was constructed, the profile has been relatively stable, although some scour is observed immediately downstream of the end of the concrete channel lining.
- Baseline conditions model results over-predicted scour relative to the observed channel profile at the concrete to earthen channel bottom transition as well as in the vicinity of the existing bridges. This result suggests that either the grain size distribution of bed sediments is higher than what was sampled and modeled (Figure 5), or that other factors such as channel armoring and/or buried coarse sediments have historically mitigated scour potential during flood events.
- Project conditions model results show that at the channel bottom transition from concrete to earthen, the change in scour relative to existing conditions is within 0.1 ft for a 100-year event suggesting minimal changes between existing and project conditions.
- Project conditions model results demonstrate local increases in shear and erosion, caused by channel expansion and contraction at the upstream and downstream ends of the project reach.

4. SEDIMENT BUDGET AND GEOMORPHIC ANALYSES

ESA performed a geomorphic analysis to assess how the site will develop and evolve over time in response to the restoration and physical processes. Fluvial flood events, tidal action, and coastal sediment transport processes are examined below.

4.1 FLUVIAL FLOOD EVENTS

During a storm event, Ballona Creek conveys flood water and sediment from the watershed to Santa Monica Bay. The amount and size of the sediment, as well as historic scour and deposition analyses, can help determine where channel sediment is being transported, while hydraulic geometry relationships can provide estimates of channel equilibrium dimensions. These analyses are detailed below.

4.1.1 Ballona Creek Sediment Yield (Sediment Supply)

Sediment yield estimates for Ballona Creek vary widely in the literature (Table 1). The USACE (2003, 2009) presents values around 60,000 cy of sand per year, but it is unclear how these estimates were derived. Moffat & Nichol (1999) calculated a sediment yield value based off the Department of Water Resources 1969 report, which estimates the sand yield of Ballona Creek using a method that does not require sediment data and is based on discharge data from 1928-1950 only. Noble's 2013 Sediment Management Plan shows a sediment yield of

49,500 cy/yr, but details of the analysis are presented in the USACE's Coast of California Storm Waves and Tidal Study for Los Angeles Region, which is not yet available to the public.

TABLE 1
BALLONA CREEK SEDIMENT YIELD ESTIMATES

Source	Average Sediment Yield (cy/yr)	Method/Source	Note
ESA PWA	8,240	Based on channel surveys	Total load
ESA PWA	9,100	Based on suspended sediment rating curve derived from suspended sediment measurements collected by LACDPW (1999 - 2011) and SCCWRP (2001 - 2004) and USACE flood frequency analysis + 10% for bedload. Assumes a density of 1.15 ton/cy	Total load
Inmann & Jenkins, 1999	14,100	Based on suspended sediment rating curve of a similar watershed and gage data at USGS 11103500 (data from 1944-1995)	Total load
Leidersdorf, 1994	46,000	CA Dept of Naval and Ocean Development 1977 (update of 1969 report)	Fine sand
Noble, 2013	50,000	Analysis described in USACE's Coast of California Storm Waves and Tidal Study for Los Angeles Region, which is not yet available to the public	Fine grained sediment
M&N, 1999	46,000	Based off sand from SCCWRP, 1973, which was based off DWR, 1969	Sand
	5,000	Based off State of California, 1977	Silt
USACE, 2003	58,350	Method not documented; citation not included	unknown
USACE, 2009	60,000	Method not documented; citation not included	unknown

Inman and Jenkins (1999) estimated a sediment yield around 14,000 cy/yr using a sedimentation curve from a reference watershed and flow rates from Ballona Creek. In the Ballona Creek Hydraulics and Hydrology report (2013a), ESA calculated a sediment yield value of 8,530 cy/yr using a suspended sediment rating curve derived from suspended sediment measurements collected by LACDPW (1999 – 2011) and SCCWRP (2001 – 2004) and flow data from 1989 to 2009 and an estimate of bed (10% of suspended load). This assumed a density of 1.3 ton/cy.

ESA updated the sediment yield estimate for this analysis. Additional site data shows that the density is closer to 1.15 ton/cy at Ballona. Using the USACE flood frequency analysis (USACE 2010) combined with the rating curve, sediment transport for each storm was calculated and then weighted by the return frequency to find an average sediment yield that includes larger storms than in the 1989 to 2009 flow data used previously. Assuming an additional 10% of sediment is transported as bedload, this results in a sediment yield of 9,100 cy/yr.

ESA calculated a second value of 8,240 cy/yr of deposition in the Ballona Creek channel based on the difference between channel surveys from 1961 and 2012 (see Section 4.1.3). Since 1988, there have only been one Q5 event in 1998 and one Q10 storm event in 1994 in Ballona Creek. Hydraulic modeling shows that the channel bottom is relatively stable during storms of Q5 or smaller within the site (ESA PWA 2013), so since the Q10 storm in 1994, sediment has likely not been eroded out of the system. Assuming sediment from all storms since 1994 has accumulated in the channel, it can be estimated that Ballona Creek provided about 8,000 cy/yr between 1994 and 2012. Since some sediment leaves the system during storms, this is likely an underestimate.

Inman and Jenkins' and ESA's methods resulted in lower sediment yields than the other literature estimates, but use more recent, site-specific data. Since the ESA suspended sediment rating curve method uses the most recent data, a sediment yield of 9,100 cy/yr is used going forward in this memo.

The sediment transported via natural streams, creeks, and storm drains to the Santa Monica and Venice beaches is estimated to be 5,690 cy/yr (Moffatt and Nichol, 1999). Since the watershed surrounding Dockweiler beach has similar land uses, it is assumed that the same amount of sediment is transported to the littoral zone near Dockweiler beach as well.

The sediment yield from the Ballona Creek watershed is not expected to change under project conditions. In the future, climate change could increase storm frequency, which could increase sediment yield.

4.1.2 Sediment Size

As part of the Ballona Creek Sediment Control Management Plan (USACE 2003), the USACE collected a series of 20 sediment samples from Ballona Creek and its tributaries, and analyzed the samples for grain size distribution (GSD). A composite GSD for the creek was derived for sediment transport analyses and is shown in Figure 5. Sediments coming from Ballona Creek are 20% silt, 65% sand, and 15% gravel (USACE 2003).

Sampling data collected from 2007 – 2009 by SCCWRP, in 2011 and 2012 by the City of LA, and in 2012 by ESA show gravelly sediments upstream and sandy sediments with some silts downstream (Figure 5 and Figure 6). The proportion of sand in the samples increases going downstream, while the percentage of gravel decreases. Silt varies along the channel through time and may be dependent on storm and wave events.

Figure 7 shows the median diameter of sediment (D50) within the marina, based on sampling data from 2010-2012. The data show sediments in the north entrance tend to be sandier than those in the south entrance (more yellow, light orange in the north, indicating larger sediment sizes), as would be expected with net littoral transport to the south and the proximity of the entrance to the north beach (Kinnetic Laboratories 2010; AMEC 2012). However, silt is evenly spread through the mouth of the marina (equal reds, or smaller sediment sizes, throughout), and not just in front of Ballona Creek, as would be expected with a high sediment yield (Section 4.1.1).

Sand from the shoal in the mouth of the creek shows characteristics similar to the sand on the beach and the marina (Figure 5), suggesting that the shoal is formed from the tides and the occasional southern swells (Section 4.3.4). While fluvial events likely contribute sand of a size consistent with the shoal, the pattern of deposition in the channel indicates the primary drivers are waves and possibly flood tides (see Section 3.3). Note that when river flow rate is sufficient to transport sand all the way to the mouth, there is no physical reason for the sand to stop moving within the jettied creek channel under river flows only- the sand should deposit in a deltaic or splay pattern beyond the jetties. Hence, the contribution of sand-sized sediment by creek sediment yield is not really pertinent to shoal formation.

4.1.3 Fluvial Channel Scour and Deposition

The locations of fluvial scour and deposition in a channel are dependent on sediment yield or availability (Section 4.1.1), channel dimensions and materials, storm events, and tidal action (see Section 4.2). The effect of waves on channel morphology is considered negligble except at the mouth where the sand shoal exists (Section 4.3). This section examines historic data (Section 4.1.3.1), channel hydraulic geometry relationships (Section 4.1.3.2), and sediment transport modeling (Section 4.1.3.3) to predict how Ballona Creek will change in response to storm events under project conditions.

4.1.3.1 *Historic Data*

Change in bathymetric surveys over time can help identify locations of scour and deposition. The Ballona Creek as-built survey from 1961 and the 2012 survey by PSOMAS (USACE 2003; ESA PWA 2013b) were compared to look at accretion within the channel. Figure 8 presents the five different historic sediment transport reaches:

- A slightly depositional reach exhibiting both erosion and deposition (Station 23070 to 16500)
- An erosional reach immediately downstream of the terminus of the concrete channel lining (Station 16500 to 14350), which includes a scour hole at the transition to the earthen channel bottom
- A depositional reach (Station 14350 to 7850)
- A slightly depositional reach exhibiting both erosion and deposition (Station 7850 to 2200)
- A depositional reach with channel shoal in the mouth of the creek (Station 2200 to 0)

The existing conditions sediment transport modeling in the H&H report (ESA PWA 2013a) shows similar patterns.

4.1.3.2 *Hydraulic Geometry Relationships for fluvial transport*

Another method used to predict channel geomorphology is to calculate the equilibrium channel dimensions using hydraulic geometry relationships. Empirical hydraulic geometry relationships between channel size (cross-section dimensions) and flows provide an estimate of the equilibrium channel dimensions that would form in sediment transport-limited conditions (i.e., with enough sediment in the system to deposit in the channel and reach equilibrium with tidal and fluvial flows).

Two methods were used to determine the predicted channel size under fluvial conditions: estimation of dominant discharge based on fluvial sediment transport analysis and the use of regional regressions to estimate bankfull channel width and depth for fluvial regimes. More details about this analysis can be found in Appendix 3 of the Ballona Wetlands Hydraulics and Hydrology Report (ESA PWA 2013a).

The set of fluvial-based methods produces a range of estimated channel cross sections from approximately 103 feet wide, based on dominant discharge, to 105 – 170 feet wide based on empirical regression equations. Channel depths range from 5-6 feet. The existing channel is much larger than these estimates (about 300 feet between levees and about 12.7 feet deep at high tide (MHHW)), and if there was more sediment in the system (under sediment transport-limited conditions), the channel would be expected to fill in to these dimensions.

TABLE 2
FLUVIAL ESTIMATES FOR CHANNEL DIMENSIONS

	Cross-sectional Area (ft^2)	Width (ft)	Bankfull Depth (ft)
Existing Conditions	4,500 – 5,000	350 - 400	10 - 15
Existing Conditions with “unlimited” sediment supply (i.e., sediment transport-limited conditions)	518	105 - 171	5.1- 6.4

Since fluvial flows are not expected to be altered by the project, these channel dimension estimates are the same for project conditions.

4.1.3.3 *Sediment Transport Modeling*

The sediment transport modeling (Section 3) was used to estimate how accretion and erosion in the channel might change under project conditions due to the widened channel cross sections across the marsh. Figure 9 presents the sediment transport reaches under project conditions:

- An erosive reach just upstream of the Culver and Lincoln bridges (Station 11600 – 10200). When flood waters enter the site just downstream of this reach, the water expands across the marsh and slows down. This causes water behind it to "pile-up" and cause erosion.
- A depositional reach downstream of the Culver and Lincoln bridges (Station 10200 – 7200). When the waters expand across the marsh, they slow and sediment can deposit.
- An erosive reach at the channel convergence caused by the levee peninsula in Area B and the south Marina del Rey levee at the downstream end of Area A (Station 7200 – 4900). As the water is forced back into the channel at this point, velocities increase and cause scour.
- A depositional reach in West Area B (Station 4900 – 3800). Waters expand into West Area B and slow, allowing sediment to drop out.
- An erosive reach at the channel convergence at the downstream end of the site (Station 3800 – 2250). The water is forced back into the channel again, causing velocities to increase and the channel to scour.

The erosion and deposition in these areas were quantified from the model and are included in the sediment budget in Section 6.1.

4.1.4 Fluvial Marshplain Scour and Deposition

Under existing conditions, the marshplain in Area B is protected from erosion due to fluvial events by the levee and self-regulating tide (SRT) gate. This is because the SRT gate does not allow high river flows to enter the Area B. Similarly, the SRT gate limits the amount of sediment that can enter the wetland system from the creek, so deposition is minimal. The following sections describe the scour and deposition analyses for project conditions.

4.1.4.1 *Scour*

On the marsh plain and along the channel banks, some erosion is expected during major storm events. The hydrodynamic modeling in Section 2 calculated where the highest areas of shear stress are expected to occur during the 100- and 10-year events (Figure 4). Ganthy (2011) and Simon and Hanson (2001) derived equations relating shear stress to erosion based on lab tests of field cores and in situ jet-testing measurements respectively. Ganthy proposes:

$$\boldsymbol{E = E_0\left(\frac{\tau_0}{\tau_{cr}} - 1\right)^{\alpha}}$$

where E is erosion in g/m^2-s, E_0 is erosion at the critical shear stress in g/m^2-s, τ_0 is shear stress in pascals (Pa), τ_{cr} is the critical shear stress in Pa, and α is an empirical constant. Simon and Hanson propose:

$$\boldsymbol{E = k_d(\tau_0 - \tau_{cr})}$$

where E is erosion in m/s, k_d is an erodibility coefficient in m^3/N-s, and τ_0 and τ_{cr} are in Pa. The erodibility coefficient can be calculated based on the critical shear stress as:

$$k_d = 0.2\tau_{cr}^{-0.5}$$

where k_d is in cm^3/N-s and τ_{cr} is in Pa.

Table 3 shows the critical shear stresses estimated for Ballona as well as values found in the literature. In 2012, Sea Engineering collected cores from North Area B and in the creek upstream of the Culver Blvd bridge to analyze in the lab (2013). Using the Sedflume analysis, varying flows were passed over the cores and erosion was measured. Additional samples taken throughout the site by Group Delta (2013) were analyzed for sediment characteristics in the lab, including bulk density and grain size distribution. Grabowski (2011) and Ahmad (2011) propose methods for using these characteristics to estimate the critical shear stress of the materials. Ganthy (2011) and Simon and Hanson (2001) offer estimates of critical shear stress for other sites, which provide a comparison to the Ballona estimates.

TABLE 3
CRITICAL SHEAR STRESS RANGES

Method	Critical Shear Stress (Pa)	Source	Note
Lab tests of field cores at Ballona	0.16 – 0.8	Sea Engineering (2013)	Critical shear stress increased with depth of core
Based on wet bulk density	0.51 – 0.8	Grabowski (2011)	Based on bulk density of samples from Ballona
Based on sand size and % mud	0.09 – 0.14	Ahmad (2011)	Based on sand size and % mud of samples from Ballona
Lab tests of field cores along French Atlantic coast	0.18 – 3.04	Ganthy (2011)	
In situ jet-testing in the Midwestern USA	0.38 – 400	Simon and Hanson (2001)	

Combining the equations above with the estimates of critical shear stress for Ballona provides a method to calculate erosion from the modeled shear stresses. Figure 10 presents the maximum erosion rates (Ganthy equation with a critical shear stress of 0.18 Pa- the lowest value applied by Ganthy) spatially at the peak of the 100- and 10-year storms. The high shear in the channel upstream of the site is due to a high point in the topography, which will likely be flushed from the system under a major storm event. Shear stress time series (Figure 11) were extracted to look at the total erosion over the course of the storms at the points marked in Figure 10. The Ganthy method was applied with the lower end critical shear stress to the point along the channel bank where modeled shear stress is highest to yield a conservatively high estimates of erosion assuming no vegetation on the marsh (Table 4). These conservatively high estimates show erosion of of 34 and 26 in over the duration of the 100- and 10-year storms, respectively.. The Simon and Hanson equation predicts up to 15 and 11 in of erosion during the 100- and 10-year storms respectively, so the Ganthy equation was chosen as the more conservative estimate.

During a 100-year event, erosion is expected, however, the erosion analysis shows that even under such extreme conditions and using conservatively high assumptions, the highest shear stresses are limited to areas along the channel banks and are estimated to cause less than 3 ft of erosion. Additionally, once vegetated, erosion on the marsh will be limited by vegetation, as the roots will help hold the sediment in place. Fischenich (2001) estimated the critical shear stress of short vegetation to be 40 Pa and tall vegetation to be 65 Pa. This would reduce the highest estimated amount of erosion on the marshplain to 26 and 19 in under the 100- and 10-year storms respectively, assuming short vegetation (Table 4). Additionally, the project design includes armoring with three different levels of protection, and these estimates do not consider any armoring, which would decrease channel bank erosion.

TABLE 4
MAXIMUM EROSION USING GANTHY (2011)

	No vegetation		With Vegetation	
Location (Figure 9)	**10-year erosion (in)**	**100-year erosion (in)**	**10-year erosion (in)**	**100-year erosion (in)**
South bank at first channel meander (upstream expansion)	26	34	19	26
South bank at channel reconvergence	23	24	18	20
Marsh south of reconvergence	6	8	0	7

Notes: These rates use the Ganthy (2011) equation and a critical shear stress of 0.18 Pa for No Vegetation. With Vegetation, a critical shear stress of 0.8 Pa is used to represent vegetation until 40 Pa is reached and the vegetation is expected to erode away (Fischenich 2001). Then the critical shear stress drops to 0.18 Pa to represent unvegetated sediment.

The shear stress time series extracted from the points in Figure 10 were applied across the site to calculate the total erosion during the 10-year and 100-year events. The time series from the point at the channel reconvergence, which had the longest inundation duration of the three points, was applied to the entire low marsh, where flood waters would remain the longest (hatching in third panel of Figure 12 and Figure 13). The time series from the point on the south bank at the first channel meander was applied to the entire south bank at the meander (cross-hatch in third panel of Figure 12 and Figure 13). The shortest duration time series was from the point on the marsh south of the reconvergence and this time series was applied to the higher marsh elevations (outlined in black in the third panel of Figure 12 and Figure 13). The Ganthy equation was applied across the site using the these durations of erosion and the spatial grid of peak modeled shear stress and accounting for the effect of vegetation on reducing erosion (as described in Table 4 notes). The resulting erosion map (third panel) was used to analyze the habitats that would remain after a 100-yr and 10-year event (Figure 12 and Figure 13 respectively- second panel). During the 100-year event, erosion would lower parts of West Area B and along the channels in Area A and North Area B from mid marsh elevations to low marsh elevations and transition zone to high marsh elevations. During the 10-year event, erosion would result in similar changes between habitat types/elevations but to a lesser extent.

4.1.4.2 *Deposition*

In certain areas of the marsh where the velocities are slow, some deposition is expected during storm events. Most of the sediment that enters the wetland system will be brought in during storm events, and in areas experiencing velocities slower than the settling velocity of the sediment, the sediment is expected to drop out onto the marsh. Cahoon et al (1996) estimated that 0.64% of sediment yield was deposited on the marsh during storm events for creek mouth tidal wetlands. To roughly (and conservatively for erosion) approximate the amount of sediment being deposited at different locations at Ballona, the estimate of 0.64% was applied to the total sediment yield to estimate the volume of deposition. The total was then divided among the different slow-flowing marsh areas (Table 5). The areas in the marsh were roughly weighted based on the relative shear stresses during the 10-year storm event (Figure 4). For example, the high marsh at the upstream end of Area A experiences a slow moving eddy during large storms, which would result in more sediment dropping out than in areas where the flow moves faster, so 1/3 of the sediment in the system was attributed to this area. Similarly, in West Area B, shear stresses are low, so 1/3 of the sediment was attributed to that area. The remaining 1/3 of the sediment was split between the downstream half of Area A and the part of West Area B along the channel, both of which experience slightly greater shear stresses (Figure 14). Because Ballona Creek is a sediment-limited system (Section 4.1.1), deposition is predicted to be minimal.

TABLE 5
MARSH DEPOSITION BY STORM EVENT

	Qeff-4650 cfs (cy)	Q2 (cy)	Q5 (cy)	Q10 (cy)	Q25 (cy)	Q50 (cy)	Q100 (cy)	Average Year (cy)
Total (based on 0.64% of sediment yield)	12	36	54	66	78	94	106	53
Area A, upstream high marsh (1/3 total)	4	12	18	22	26	31	35	18
Area A, downstream high marsh (1/6 total)	2	6	9	11	13	16	18	9
Area A, along channel	0	0	0	0	0	0	0	0
Area B, upstream along channel	0	0	0	0	0	0	0	0
Area B, downstream along channel (1/6 total)	2	6	9	11	13	16	18	9
Area B, west (1/3 total)	4	12	18	22	26	31	35	18

Note: Total marsh deposition based on Cahoon et al 1996.

4.2 TIDAL ACTION

Under exiting conditions, the tides at Ballona Creek contributed to sedimentation in the oversized creek. Under project conditions, tidal channels will be sized to accommodate the equilibrium tidal prism based on hydraulic geometry relationships, which will limit marshplain erosion.

4.2.1 Tidal Channel Scour and Deposition

Tidal channels deposit or scour in response to the size of the tidal prism that the channels convey. Tidal hydraulic geometry relationships provide an estimate of the equilibrium channel size (cross-section dimensions) in relationship to the tidal prism (the volume of water between MLLW and MHHW) or marsh area. These relationships were developed based on channels in historic marshes in San Francisco Bay, where sediments are cohesive, wave power is low, and fluvial inflow is minimal. At Ballona Creek, where sediments are sandier, the aspect ratio of width to depth is likely shallower and more braided than in more cohesive sediments.

Since Ballona Creek is oversized and has a low sediment supply, the tidal prism relationship was used to predict long term channel width, depth, and cross-sectional area (Table 6). Appendix 3 of the Ballona Wetlands Hydraulics and Hydrology Report (ESA PWA 2013a) contain further information on the tidal hydraulic geometry analysis.

The existing Ballona Creek flood control channel is oversized compared to predicted equilibrium dimensions. This suggests that the existing channel is depositional during normal tidal conditions and more frequent channel-forming storm flows, but that deposition is limited by sediment supply. Since the project will reconnect the channel to the marsh, the tidal prism will be increased from existing conditions and a slightly larger equilibrium channel would be expected. However, due to the low sediment supply, the channel is not expected to fill in to these dimensions; the values in Table 6 are estimates of the smallest size channel that would form if there were adequate sediment available.

TABLE 6
TIDAL ESTIMATES FOR CHANNEL DIMENSIONS

	Cross-sectional Area (ft^2 below MHHW)	Width (ft at MHHW)	Depth (ft below MHHW)
Existing Conditions	4,500 – 5,000	350 - 400	10 - 15
Existing Conditions (unlimited sediment supply)	600 – 1500	110 – 200	10 – 12.7
Project Conditions (unlimited sediment supply)	600 – 1700	110 – 220	10 – 13.2
Historic channel (T-sheet)		~180	
Fluvial estimate (unlimited sediment supply)	518	105 – 171	5.1- 6.4 (bankfull depth)

The tidal estimates for channel dimensions (Table 6) are much larger than the fluvial estimates (Table 2) and, within the site, the tides dominate sediment transport except for during storms of Q10 or above. Figure 16 shows the existing Ballona Creek channel cross-section compared to predicted tidal equilibrium dimensions for a natural unleveed creek channel, and the project design. Some scour may occur in the channel due to tidal conditions, however, since the equilibrium dimensions are based on cohesive sediments and Ballona has sandier sediments, the channel may stay shallower and wider, as designed. Since the channel is wider than the equilibrium dimensions, some deposition could occur in the channel, but the sediment supply is limited and storm events are expected to scour out the system periodically.

4.2.2 Tidal Marshplain Scour and Deposition

Under existing conditions, the SRT gate protects the marshes in Area B from any tidal scour by muting the tides, which limits tidal velocities. Similarly, the SRT gate limits how much sediment can enter the wetlands, so deposition is limited.

Undersizing channels can cause marshplain erosion, since tidal channels will scour to equilibrate with the tidal prism. However, when tidal channels are sized to convey the tidal prism of the marsh, as the restoration channels are (ESA PWA 2012a), the marshplain is not expected to erode under tidal conditions, once vegetated. Additionally, since little sediment is expected to come into the marsh on high tide, marshplain deposition is expected to be minimal.

Post-construction and before vegetation has established, some channel sloughing and sediment transport is expected. The design uses marshplain slope to guide the flow to the channel tributaries before discharging to the creek. This will focus shear stress in the channel rather than on the marshplain under tidal flows, however, some marshplain scour is expected until vegetation is established.

4.3 COASTAL SEDIMENT TRANSPORT

The coastal processes near Ballona Creek transport sediment mostly downcoast, where much of it deposits in the northern entrance to Marina del Rey (Figure 17). The marina breakwater creates a wave shadow that encourages deposition, which, without the jetties and with enough sediment, could form a tombolo, where a sand spit grows out to reach the wavebreak. However, regular dredging keeps the entrance open for boat access. Although the wave power is lowered by the breakwater, a wave-built shoal has formed in the mouth of Ballona Creek. The project is not expected to impact the coastal processes.

4.3.1 Longshore Transport, Surrounding Beaches

The historic longshore transport in Santa Monica Bay has been disrupted by the construction of a series of coastal structures in the recent past. In the vicinity of Marina del Rey, the alignment of the coastline and the associated prevailing waves create a predominant net sediment transport to the southeast (downcoast; Figure 18). This is reversed when southern swells approach the coastline during the summer, and occasionally under other conditions. The construction of the Marina del Rey jetties and breakwater created a littoral barrier that limits sediment transport. The sediment that accumulates in the marina entrance has been dredged and bypassed to Dockweiler Beach and, less frequently, backpassed to Venice Beach, in order to prevent the surrounding beaches from eroding (see Section 4.3.3). The construction of the King Harbor jetties downcoast of Dockweiler Beach in 1958 helped keep the majority of sediment in the system by preventing losses down into the Redondo Submarine Canyon. Leidersdorf (1994) found that coastal structures combined with sand placement (aka "beach nourishment") in the central and southern parts of Santa Monica Bay have created compartmentalized, wide, stable beaches.

4.3.2 Shore Planform

Like the longshore transport, the shore planform is influenced by the coastal structures in the bay, as well as by human intervention like sand placement. Beach nourishment began in 1938, and the beaches have widened by about 600 ft since then. Figure 19 and Figure 20 show shore lines collected by the County of Los Angeles Beaches and Harbors (Leidersdorf 1994) and the USGS (2006) respectively, and illustrate the beach width change over time. As mentioned in Section 4.3.1, beach nourishment and coastal structures have created compartmentalized beaches that are wider than historic conditions and relatively stable.

Within these compartmentalized beaches, breakwaters influence the shore planform without physically blocking longshore sediment transport like jetties. Breakwaters create wave shadows that slow transport and allow sediment to deposit behind them. The Venice breakwater, which is less than 2 miles upcoast of Marina del Rey, has produced a tombolo behind it from the sand that has deposited in the wave shadow. Due to the proximity of the Marina del Rey and Venice breakwaters and the nearly identical shoreline orientation, it can be assumed that the wave conditions are similar at both sites and the Venice breakwater can be used as a reference for the processes at work at Marina del Rey harbor.

The 600 ft-long Venice breakwater was built in 1905, and after the first large sand placements in the 1930s, supported a salient, which later developed into a tombolo. The average width of the tombolo based on aerial photographs spanning 1994-2012 is 238 ± 101 ft. Using the methods of Ming and Chiew (2000), which relates the length of the breakwater and the distance to shore with the area of sand deposition, about 126,000 ft^2 of sand was calculated to be behind the Venice breakwater. This relationship combined with geometric similarity predicts that a hypothetical tombolo at Marina del Rey (without the jetties) would be 1,040 ft wide and cover 2.02 million ft^2 (Figure 21). Assuming a depth of 20 ft (the federally designated dredge depth), the tombolo could contain 1.5 million cy of sediment.

When the same calculation is performed with the jetties in place (assuming that velocities between the jetties would lessen the amount of sand depositing in that area), the amount of sediment is reduced to approximately 460,000 cy. This result is the same order of magnitude as the dredging records of 1969 (390,000 cy; see Section 4.3.3). Because the breakwater provides wave protection, the area behind it (the entrance to the marina and creek) naturally tends to accumulate sand that is transported along shore by waves.

This analysis confirms that dredging is required to maintain the channels between the jetties. Without dredging, wave driven transport would likely close off the mouth of Ballona creek, resulting in a perched drainage outlet that would allow only limited tidal exchange, primarily only after the mouth scoured, during high fluvial flows (Behrens et al, manuscript).

4.3.3 Dredging History

A history of dredge events for Marina del Rey from 1969-2009 is provided in Table 7. Dredging is conducted as-needed to keep the entrances of the marina open for traffic. Surveys are conducted to evaluate conditions in the harbor before dredging (pre-dredge), after dredging (post-dredge), and in between dredging events (conditions). These surveys can be used to examine the shoaling rates in the marina entrance and creek mouth. Figure 22 shows these surveys from 2000 to 2012, and illustrates the salient or tombolo that might form without regular dredging (the red, higher elevations at the mouth; Section 4.3.2).

TABLE 7
DREDGE EVENTS AT MARINA DEL REY

Date[1]	Location	Material	Method	Destination	Quantity (cy)	Source[2]
1969	Ballona Creek mouth		Hydraulic dredge	Dockweiler Beach	389,800	3,4
1973	South side of north jetty		Hydraulic dredge	Venice Beach	16,100	3,4
1981	Entrance channel; Ballona creek mouth		Hydraulic dredge	Dockweiler Beach	217,400	3
1987	Jetty tips; Ballona Creek mouth		Hydraulic dredge	Dockweiler Beach	35,300	3
1992	Ballona Creek mouth	Chemically challenged	Dragging	in situ	21,500	2
1994	Entrance channel	Chemically challenged	Clamshell	Port of LA shallow water habitat	55,000	2,4
1996	Entrance channel	Beach quality	Hydraulic dredge	Dockweiler Beach	238,000	2
1998	Entrance channel	Chemically challenged	Clamshell	LA-2 Disposal Site	52,000	3
		Beach quality	Clamshell	Dockweiler State Beach	73,800	3
1999	Entrance channel	Chemically challenged	Clamshell	Port of Long Beach	390,000	4**
		Beach quality	Clamshell	Redondo Beach	282,000	4**
2007	North entrance	Beach quality	Clamshell	Dockweiler Beach	327,000	4
2009		Beach quality	Hydraulic dredge	Dockweiler Beach	4,700	4
2012		Chemically challenged	Clamshell	Port of Long Beach	471,000	
		Beach quality	Clamshell	Dockweiler Beach Redondo Beach	150,000 157,000	5

1. Indicates year project was started
2. Quantities from Source 2 are pay volumes; quantities from source 3 and 4 are unspecified, although volumes agree (with rounding) for 1969-1998

** There is a large discrepancy between source 2, 3 and 4. Source 4 was the middle value and the most recent report, so those values are included.

SOURCES:
1. USACE 2003, Draft EIR/EIS for the Ballona Creek Sediment Control Management Plan,
2. USACE 2003, Marina Del Rey and Ballona Creek Feasibility Study, Ballona Creek Sediment Control Management Plan, Dredging Analysis Appendix
3. USACE 2004, LA Regional Dredged Material Management Plan Feasibility Study, Baseline Conditions (F3) Report Technical Appendix
4. Kinnetic Laboratories, Inc, Halcrow Inc, 2011. Marina Del Rey Maintenance Dredging Project Follow-Up Sediment Tier II and III Investigation, Final Report
5. USACE 2014, DRAFT Maintenance Dredge History

In 2003, Moffat and Nichol (M&N) and USACE calculated shoaling rates at the marina using dredge maps spanning 1991 to 2001, using two different methods. In the first method, they calculated the sediment difference between the last and first map, added in the dredge quantities, then divided by the total years, and found a rate of 93,670 cy/yr. The second method subtracted each subsequent map, added in the dredge quantities, divided by the years between each survey, and then averaged all of the rates. The second method resulted in a rate of 142,640 cy/yr. M&N also looked at four different areas within marina entrance. Figure 23 presents the accretion rates for these four areas using the dredge surveys from 2000 to 2012. The much higher accretion rate in Area H confirms that the longshore transport is largely downcoast from north to south, transporting the largest quantities of sand into the northern entrance of the marina (Section 4.3.1).

4.3.4 Shoal Formation

Tidal and wave processes largely drive the morphology of a tidal creek mouth. Walton and Adams (1976) examined the relationship of the tidal prism and inlet size to estimate the size of ebb shoals for different wave climates:

$$V = aP^b$$

where V is volume of the ebb shoals, P is the tidal prism, and a and b are correlation coefficients decided by the wave climate. Estimates of the size of potential shoals for the existing Ballona Creek system are 3,300-4,300 cy.

Additionally, work by Battalio and others (2006) on inlet closures expanded on the idea that the inlet morphology (cross-section area and thalweg elevation among other factors) will determine the location of sediment deposition in the inlet mouth. Since the Ballona Creek mouth is oversized (see Section 4.2.1), it is likely that sediment will deposit if transported into the mouth from the adjacent shore. Based on Battalio and others (2006), the size of the inlet relative to the volume of water (and sediment) exchange suggests that shoals inside the channel are to be expected. Aerials from 1937 and 1938 show shoaling in the channel entrance before the channel jetties were finished (Figure 2 and Figure 3) and surveys from 2006 and 2012 (Figure 15) confirm the presence of a shoal under existing conditions. However, the pattern and location of the shoal imply that waves may have more of an effect than tidal currents. Indeed, hydrodynamic modeling indicates the flood tide currents are less than 1 ft/sec most of the time and hence the flood tide may not be the dominate driver of this sand shoal at the entrance to Ballona Creek. Moreover, if the sand transport was driven by flood tides, the shoal should prograde up the channel: there is no evidence that the shoal is building upstream at a rate associated with daily flood tides, and hence it is more likely that the shoal is wave driven and limited in proportion to wave dissipation up-channel.

The sediment size of the shoal matches that of the beach (Section 4.1.2), indicating that the shoal is formed by coastal processes. The pattern of deposition in the present, as well as historic photos (e.g. the 1937 photo, Figure 2) indicate a coastal source with deposition near the end of the jetties.

Under project conditions, the restoration plan will increase tidal prism of the site by reconnecting Ballona Creek to the wetlands, and could potentially increase sediment transport into the channel from the ocean. However, the project will only increase the potential tidal prism by 60 ac-ft or 15%. Initial modeling shows that this increase in tidal prism does not significantly change tidal velocities in the mouth of the creek (H&H report). Under normal tidal conditions, velocities at the mouth changed from 0.76 ft/s under existing conditions to 0.96 ft/s under project conditions. Assuming a 15% increase in tidal prism translates to a 15% increase in the flood shoal volume, the shoal height could increase by 1.1 ft to a depth of -3.4 ft NAVD. However, flood shoal growth is primarily lateral under tidal action, with growth into the basin dominating, rather than accretion. Additionaly, low tidal currents in the creek are too low to move much sand (less than 3 ft/s), and hence it is unlikely that the tidal flows drive the shoal morphology.

4.4 SEDIMENT BUDGET

This section combines the analyses from the previous sections to build a sediment budget for the Ballona Creek system. As discussed above, the fluvial, tidal, and coastal processes determine how sediment is transported in and around the Creek and harbor entrance channels. Sections 4.1.1 and 4.1.2 discuss the sediment yield and size from Ballona Creek watershed, while Sections 4.1.3 through 4.2.2 examine where the sediment ends up in the channel and the marsh. Section 4.3.1 discusses littoral sediment transport in Santa Monica Bay, while Sections 4.3.2 through 4.3.4 examine how the sand builds the beaches and shoals and is dredged from the marina. These processes can be combined to build a sediment budget to quantitatively analyze the system around Marina del Rey, including Santa Monica, Venice, and Dockweiler Beaches.

Table 8 provides a sediment transport timeline. In 1934, the Santa Monica Breakwater was constructed and a tombolo formed, which limited the sand transport downshore to Venice and Dockweiler Beaches. However, large sand placements from the Hyperion facility more than replaced the sand lost in the tombolo. Shoreline profiles in 1935 and 1946 (Figure 19) show that the beaches grew 75 ft, adding approximately 916,600 cy of sand to the system. Large placements of sand continued through the early 1960s, building the beaches out 500 ft from the 1935 shoreline. With the deterioration of the Santa Monica breakwater in the 1960s, which allowed sand to move downshore to Venice Beach, and the construction of the King Harbor jetties downshore of Dockweiler Beach, which kept sand from being lost to the Redondo Submarine Canyon, the beaches have stabilized (Section 4.3.1).

In 1999, Moffat & Nichol constructed a sediment budget for the USACE to help evaluate shoaling in the mouth of Marina del Rey. However, more recent data and analyses show that some of their assumptions should be revised. For example, Moffat & Nichol assumed that no sediment is transported from Dockweiler Beach into Ballona Creek and the southern habor entrance and that no sediment is transported through the marina. However, as described in Sections 4.1.2 and 4.3.4, the shoal in the mouth of Ballona Creek shows sand characteristics that are similar to the sand on the beach, which is likely transported during southern swell events.

Table 9 presents a new sediment budget using the analyses presented in the previous sections of this memo. The budget is organized by storm return and tidal conditions, based on the data available from the sediment yield curve (Section 4.1.1) and the sediment transport modeling (Section 4.1.3.3). The different reaches of the channel are based on the reaches reported in the Sediment Transport Analysis (Appendix F10 of the EIR/S). Erosion and deposition in the channel were calculated from the sediment transport model for the Qeff, Q5, and Q100, and interpolated for the remaining storm returns. Sediment export from the system was then calculated by adding the eroded volume to the watershed input and subtracting any deposited material.

TABLE 8
SEDIMENT TRANSPORT TIMELINE NEAR MARINA DEL REY (CY)

	Santa Monica and Venice Beach			Marina del Rey			Dockweiler Beach				Notes and Sources
Year	In (From North)	Change	Out (To South)	In (From North)	Out of System (Removed)	Out (To South)	In (From North)	Change	Out (To South)	Rate Out (To South) CY/Yr	
1935-1946	2,581,106	208,922					2,644,774	458,300			Transport from the north (M&N 1999) and shoreline change (Leidersdorf 1994)
	62,590						62,590				Stream and Storm Drain yield (M&N 1999)
	210,000						1,800,000				Beach Fill (1938-1939, 1945) (Leidersdorf 1994)
							78,430				From Ballona Creek, rating curve minus channel deposition
Total 1935-1946	2,853,696	208,922	2,644,774				4,585,794	458,300	4,127,494	375,200	
1947-1953	1,642,522	4,540,078					11,042,274	3,055,600			Transport from the north (M&N 1999) and shoreline change (Leidersdorf 1994)
	39,830						39,830				Stream and Storm Drain yield (M&N 1999)
	13,900,000						240,000				Beach Fill (1946-48, 1951) (Leidersdorf 1994)
							49,910				From Ballona Creek, rating curve minus channel deposition
Total 1947-1953	15,582,352	4,540,078	11,042,274				11,372,014	3,055,600	8,316,414	1,188,100	
1954-1974	4,927,566	1,527,800		4,315,356			4,021,387	-458,300			Transport from the north (M&N 1999) and shoreline change (Leidersdorf 1994, USGS 2006)
	119,490						119,490				Stream and Storm Drain yield (M&N 1999)
	796,100						12,889,800				Beach Fill (1956, 1957-1958, 1960-1962, 1963, 1969, 1973) (Leidersdorf 1994, Kinnetic 2011)
				155,631							From Ballona Creek, rating curve minus channel deposition
					43,700						Shoal in Ballona Creek (assuming 100% from littoral transport)
					405,900						Dredging (1969, 1973) (Leidersdorf 1994, Kinnetic 2011)
Total 1954-1974	5,843,156	1,527,800	4,315,356	4,470,987	449,600	4,021,387	17,030,677	-458,300	17,488,977	832,800	
1975-1990	3,754,336	-672,300		4,517,676			4,371,387	213,900			Transport from the north (M&N 1999) and shoreline change (Leidersdorf 1994, USGS 2006)
	91,040						91,040				Stream and Storm Drain yield (M&N 1999)
							407,700				Beach Fill (1981, 1987, 1988) (Leidersdorf 1994, Kinnetic 2011)
				106,411							From Ballona Creek, data minus channel deposition
					252,700						Dredging (1981, 1987) (Leidersdorf 1994, Kinnetic 2011)
Total 1975-1990	3,845,376	-672,300	4,517,676	4,624,087	252,700	4,371,387	4,870,127	213,900	4,656,227	291,000	
1991-1998	1,877,168	0		1,922,688			1,565,878	0			Transport from the north (M&N 1999) and shoreline change (Leidersdorf 1994, USGS 2006)
	45,520						45,520				Stream and Storm Drain yield (M&N 1999)
							311,800				Beach Fill (1996, 1998) (Leidersdorf 1994, Kinnetic 2011)
				61,990							From Ballona Creek, data minus channel deposition
					418,800						Dredging (1994, 1996, 1998) (Leidersdorf 1994, Kinnetic 2011)
Total 1991-1998	1,922,688	0	1,922,688	1,984,678	418,800	1,565,878	1,923,198	0	1,923,198	240,400	
1999-2012	3,285,044	0		3,364,704			2,474,220	0			Transport from the north (M&N 1999) and shoreline change (assumed 0)
	79,660						79,660				Stream and Storm Drain yield (M&N 1999)
							481,700				Beach Fill (2007, 2009,2012) (Leidersdorf 1994, Kinnetic 2011, USACE 2013)
				113,216							From Ballona Creek, data minus channel deposition
					1,781,700						Dredging (1999, 2007, 2009, 2012) (Leidersdorf 1994, Kinnetic 2011, USACE 2013)
Total 1999-2012	3,364,704	0	3,364,704	3,477,920	1,781,700	1,696,220	2,257,580	0	2,257,580	161,300	

TABLE 9
SEDIMENT BUDGET NEAR MARINA DEL REY FOR EXISTING CONDITIONS (CY)

Area	Tidal	Qeff (4,650 cfs bankful discharge)	Q2 (15,700 cfs @ Sepulveda)	Q5 (22,690 cfs @ Sepulveda)	Q10 (27,130 cfs @ Sepulveda)	Q25 (31,160 cfs @ Sepulveda)	Q50 (36,740 cfs @ Sepulveda)	Q100 (40,960 cfs @ Sepulveda)	Average Year	Average Year (based on 1959-2012) for comparison	Notes
Watershed input	0	2,020	6,120	9,230	11,310	13,390	16,090	18,280	9,100	9100	From sed yield curve x 10% for bedload (assumes storms are 1 day)
Littoral transport from southern swell	820								820	820	Difference between 2012 -1959 divided by the years
Channel bed											
Upstream of I-90 erosive reach	0	370	-998	-5,100	-5,358	-6,132	-7,421	-10,000	-2,180	80	From sed transport modeling
On-Site/Upstream erosive reach	0	720	-560	-4,400	-4,353	-4,211	-3,974	-3,500	-1,160	-50	
Downstream aggradation reach	0	220	2,440	9,100	8,889	8,258	7,205	5,100	4,670	1,610	
Channel mouth	820	0	525	2,100	2,058	1,932	1,721	1,300	1,010	1150	
Area B Managed Wetlands	0	0	0	0	0	0	0	0	0	0	Assume negligble
Export	0	710	4,713	7,530	10,074	13,543	18,559	25,380	6,750	7130	
Exported From Ballona Creek	0	710	4,713	7,530	10,074	13,543	18,559	25,380	6,750	7130	
Deposited in MdR from Ballona Creek	0	569	3,686	5,783	7,656	8,166	9,576	8,172	4,930	5560	Trapping efficiency based on EFDC modeled velocities in marina and F4 Sed Control Management Plan (USACE 2003)

5. REFERENCE SITES

Coastal wetland habitats in southern California exhibit a broad range of morphologies, as well as degrees to which physical and ecological conditions and processes have been impacted by human activities (Grossinger et al. 2011). The morphology of a given coastal wetland is largely governed by the interactions between antecedent geology, fluvial processes (e.g. watershed size and characteristics, storm hydrology, and sediment transport), and coastal processes (e.g. tides, wave/swell exposure, littoral sediment transport, and dune movement), as well as vegetation communities that can have feedback effects on physical processes. The study of reference systems with similar physical and ecological conditions to those proposed for the Ballona restoration provides insight into how future Ballona habitats are anticipated to persist in the near-term. This section describes conditions at the Seal Beach Wetlands, just south of the Los Angeles County border in Orange County, and the San Elijo Lagoon wetlands, in northern San Diego County.

5.1 SEAL BEACH WETLANDS

The Seal Beach wetlands are located within Seal Beach National Wildlife Refuge, entirely within the boundaries of the Naval Weapons Station Seal Beach (Figure 24). Prior to western settlement, the Seal Beach wetlands were part of an extensive backbarrier wetland system of over 2,000 ac that included large areas of tidal salt marsh as well as freshwater marsh further inland. Mapping of the area from 1873 indicates a subtidal inlet (Grossinger et al. 2011), which when coupled with the significant size of the system, implies that the tidal prism was large enough to maintain an open inlet under most conditions. The open nature of the inlet stands in contrast to many other coastal wetland systems in southern California (including Ballona) which had seasonally closed inlets prior to western settlement (ibid). The wetlands have a watershed of approximately 38,000 acres (USFWS and US Navy 1990), compared to 57,000 acres at Ballona, and receive limited inflows from the Bolsa Chica and Wintersburg flood control channels as well as local runoff (Table 10; CDFG and USFWS 1976).

The development of the Naval Weapons Station and Huntington Harbor have significantly altered the local landscape, resulting in the loss of half of the system’s wetlands as well as permanently anchoring an open inlet through the construction and armoring of Anaheim Bay (Figure 25). In addition, watershed urbanization and the construction of hydrologic impediments such as roads have altered circulation at the site; portions of the wetlands that were once fully tidal now have a muted tidal regime (USFWS 2013). Additionally, the channelization of the Santa Ana River redirects freshwater flow and sediment away from the marsh. Nonetheless, a comparison of existing habitats to historic habitats indicates that the planform of the remaining Seal Beach tidal salt marshes has remained remarkably consistent since the late 1800s.

Erosion has occurred in the constructed tidal channels, in areas where the marsh tidal prism is larger than the channel can convey. Some of these channels have reached equilibrium and erosion has diminished (USFWS 2011). At Ballona, the tidal channels have been sized to correspond to equilibrium conditions to avoid erosion (Section 4.2.1). At Seal Beach, additional erosion has occurred in Forrestal Pond, where the deeper water and longer fetch length has allowed waves to erode the northeast corner. At Ballona, the fetch within the site is not large, so erosion due to wind waves in not expected. Under sea-level rise conditions, this fetch may increase and cause erosion.

Due to the loss of fluvial sediment input, the periodic dredging of Anaheim Bay to remove sand deposited by littoral (longshore) transport, and the periodic dredging of Sunset/Huntington Harbor to remove sediment from the Bolsa Chica Channel, there has been a net loss of sediment from the wetland in the last 100 years (USFWS 2011).

Ballona Creek, although sediment poor, is still expected to contribute some sediment to the marsh (Section 4.1.4.2).

5.2 SAN ELIJO LAGOON

The coastal wetlands of San Elijo Lagoon are located within the San Elijo Lagoon Ecological Reserve, a regional park comprised of lands owned by San Diego County, the state of California, and the San Elijo Lagoon Conservancy (Figure 26). The reserve is 915 acres in size; approximately 600 of these acres are wetlands that include tidal salt marsh, brackish and freshwater wetlands, mudflats, and shallow open water habitats (Laton et al. 2002). The full extent of historic tidal habitats is not clear, as the earliest mapping in 1888 occurred after railroad development and diking activities throughout the basin (Grossinger et al. 2011). The lagoon shares a similar morphology with other lagoons within the Oceanside littoral cell, including Buena Vista, Agua Hedionda, and Batiquitos Lagoons to the north; its historic habitats likely were similar to these systems as well as the San Dieguito and Los Penasquitos lagoons to the south (ibid). The primary freshwater inflow to the lagoon is Escondido Creek, which has a watershed of approximately 54,000 ac (SELC 2013).

Like the Ballona and Seal Beach wetlands, the wetlands of San Elijo Lagoon have been significantly altered by human activity, including watershed urbanization, diking and draining of wetlands, road/berm construction across the lagoon, and the anchoring of the tidal inlet at the lagoon's northern end (Figure 27, Grossinger et al. 2011). As a result of this urbanization, increased sedimentation within the wetland basin has reduced the tidal prism relative to historic conditions (Laton et al. 2002), necessitating the annual dredging of the inlet to maintain open tidal conditions (SELC 2013). Proposed enhancement activities within the lagoon are largely aimed at decreasing sedimentation and increasing tidal exchange throughout the lagoon's wetlands and subtidal habitats. Despite the extensive alterations to the system, tidal wetlands in the lagoon have continued to persist, and in some locations have expanded due to sedimentation. The highly sinuous planform of the wetlands' main tidal channel has remained relatively unchanged, though this may primarily be due to the anchoring of the inlet location as evidence indicates the inlet was formerly farther south (Laton et al. 2002). Since Ballona Creek also has an anchored inlet, this may indicate that channel migration at Ballona will be minimal.

TABLE 10
REFERENCE SITE CHARACTERISTICS

Site	Watershed Area (acres)	100-Yr Streamflow (cfs)	Sediment Supply (cy/yr)	Inlet Condition	Depositional or Erosional?
Ballona Wetlands	57,328	44,270	9,380	Open Dredged	Expected to be stable
Seal Beach Wetlands	38,000[1]	Negligible input[2]	Negligible input[2]	Open Dredged	Erosional- due to tidal currents in undersized channels, wind waves over areas of long fetch, and negligible sediment input.[2]
San Elijo Lagoon wetlands	54,112[3]	22,255[4]	21,700 – 26,100[4]	Open Dredged	Depositional- due to urbanization: increased freshwater flows and sediment transport[4]

1. USFWS and US Navy 1990
2. USFWS 2011
3. Moffatt & Nichol 2012
3. Laton et al 2002

6. ASSESSMENT AND RESULTS

The coastal sediment transport around Ballona Creek and Marina del Rey is a complex system. Historically, seasonal wave action closed off the creek to the tides (Section 1). With the construction of the jetties and the concrete channel, sand continued to deposite in the mouth and impeded tidal connection. However, the offshore breakwater has reduced the wave-driven transport potential and maintenance dredging has prevented accumulation to the point of a beach building across the mouth, and the creek remains open year round. The construction of the breakwater would typically encourage sand to deposit in the marina and creek mouth and form a tombolo (Section 4.3.2): While regular dredging keeps the entrances open (Section 4.3.3), the dredging does not prevent or remove all wave-driven transport and a shoal exsists in the creel channel. Normal tidal action in the mouth of the creek may contribute to sand transport into and deposition in the creek, but wave transport is likely the main process. Additionally, sand moves south into the northern entrance of the marina, except during southern swell events when sand likely moves north into the southern marina entrance and the mouth of Ballona Creek (Section 4.3.1). Furthermore, large storm events bring both coarser and finer sediments down the creek to deposit in the mouth or marina entrance adding to the deposition in that area (Section 4.1). Figure 28 illustrates these processes. Note that Figure 28 differs from Figure 8 because Figure 8 shows the net change between 1961 and 2012, while Figure 28 shows the average change per year.

6.1 FUTURE SEDIMENT BUDGET

The analyses discussed in Section 4 were used to develop a future sediment budget for project conditions, presented in Table 11. The budget is organized by storm return and tidal conditions, based on the data available from the sediment yield curve (Section 4.1.1) and the sediment transport modeling (Section 4.1.3.3). Erosion and deposition in the channel were calculated from the sediment transport model for the Qeff, Q5, and Q100, and interpolated for the remaining return-period storm events. Marsh erosion was calculated from the hydrodynamic model for the Q10 and Q100, and interpolated or extrapolated for the remaining storm returns. Erosion volumes were developed by multiplying erosion depth by area (see Section 4.1.4.1). Marsh erosion and deposition (as described in Section 4.1.4.2) were then combined. Sediment export from the system was then calculated by adding the eroded volume to the watershed input and subtracting any deposited material.

Trapping efficiencies for each storm event were calculated for the marina mouth based on modeled velocities from EFDC (Section 2) and the USACE F4 Sediment Control Management Plan (2003). This was used to estimate how much of the exported sediment in Ballona Creek may end up in the mouth of Marina del Rey.

The sediment budget, shown in Figure 29, shows an increase in export from the Ballona Creek system, and an increase in the amount of sediment deposited in the marina mouth. For events below the Q10, this translates to roughly a 40% increase in the volume deposited in the marina, but only 8% of what is dredged annually. The larger events produce more sediment, but would occur less frequently.

TABLE 11
FUTURE SEDIMENT BUDGET (CY)

Area	Tidal	Qeff (4650 cfs bankful discharge)	Q2 (15,700 cfs @ Sepulveda)	Q5 (22,690 cfs @ Sepulveda)	Q10 (27,130 cfs @ Sepulveda)	Q25 (31,160 cfs @ Sepulveda)	Q50 (36,740 cfs @ Sepulveda)	Q100 (40,960 cfs @ Sepulveda)	Average Year	Notes/Tools
Watershed input	0	2,020	6,120	9,230	11,310	13,390	16,090	18,280	9,100	From sed yield curve x 10% for bedload (assumes storms are 1 day)
Littoral transport from southern swell	943								943	Tidal prism increases 15% from existing conditions, so assumed 15% increase in shoal volume.
Channel bed										
Upstream of I-90 erosive reach	0	730	-603	-4,600	-4,900	-5,800	-7,300	-10,300	-1,463	
Stable reach in historically aggradational reach	0	70	0	-100	-100	-100	-100	-100	30	
Aggradational reach upstream of site	0	120	400	1,400	1,400	1,400	1,400	1,300	840	
Erosive reach upstream of Culver and Lincoln	0	10	-1,100	-4,300	-4,400	-4,800	-5,500	-6,900	-2,210	
Depositional reach downstream of Culver and Lincoln	0	60	1,700	6,600	7,000	8,200	10,200	14,300	3,610	From sed transport modeling
Erosive reach at convergence at D/S end of Area A	0	10	-600	-2,500	-2,600	-2,900	-3,300	-4,200	-1,270	
Depositional reach at U/S end of West Area B	0	0	800	3,200	3,300	3,400	3,700	4,200	1,620	
Erosive reach at convergence at D/S end of West Area B	0	0	-100	-500	-800	-1,800	-3,500	-6,900	-440	
Channel mouth shoal/tombolo	943	0	300	1,200	1,100	800	300	-800	1473	
Area A wetlands										
Upstream	0	12	36	54	-63	-337	-538	-742	0	
Downstream	0	4	12	18	-3511	-4284	-4868	-5452	-660	
Along channel	0	2	6	9	-17973	-18721	-19286	-19851	-3,120	
Area B wetlands										Marsh deposition minus erosion (Section 4.1.4)
Upstream	0	0	0	0	-13003	-14134	-14989	-15844	-2,320	
Convergence	0	0	0	0	-15111	-18245	-20615	-22986	-2,880	
West	0	2	6	9	11	-140	-252	-366	-10	
Area B managed wetlands	0	0	0	0	0	0	0	0	0	Assume no erosion or deposition
Export	0	1,000	5,264	8,741	60,959	70,851	80,739	92,920	16,850	
Exported From Ballona Creek	0	1,000	5,264	8,741	60,959	70,851	80,739	92,920	16,850	
Deposited in MdR from Ballona Creek	0	802	4,116	6,713	46,329	42,723	41,661	29,920	11,680	Trapping efficiency based on EFDC modeled velocities in marina and F4 Sediment Control Management Plan (USACE 2003). Difference = 760 – 1,080 cy
Exported From Ballona Creek Under Existing Conditions		710	4,713	7,530	10,074	13,543	18,559	25,380	6,750	
Difference from Project Conditions		290	551	1,211	50,885	57,308	62,180	67,540	10,623	
Deposited in MdR Under Existing Conditions		569	3,686	5,783	7,656	8,166	9,576	8,172	4,930	
Difference from Project Conditions		233	431	930	38,673	34,557	32,085	21,748	6,750	

6.2 CONCLUSIONS

The analyses assess both existing and proposed Project conditions to evaluate potential changes due to the Project. Under existing conditions, storm events in the existing Ballona Creek channel transports approximately 9,100 cubic yards (CY) of sediment per year on average[1] from the Ballona Creek watershed. The reach of Ballona Creek downstream of the Marina Freeway and within the Ballona Wetlands Ecological Reserve is depositional, with approximately 1,900 CY of sediment deposition per year on average, representing about 20% of the watershed sediment load. A total of approximately 100,000 CY of sediment has deposited in this reach of the channel since it was constructed in 1961.

Under existing conditions, sediment is expected to continue to deposit in the channel until the channel cross-section is reduced to the point that deposition reaches an equilibrium with tidal and fluvial scouring (i.e., equilibrium channel dimensions) or until channel maintenance is performed to remove deposited sediment.

The Project conditions analysis focuses on the Proposed Action (Alternative 1) as the greatest change from existing conditions, and also discusses changes for Alternatives 2 and 3 based on the results for Alternative 1. In Alternative 1, the proposed restoration project would create a new realigned Ballona Creek channel downstream of Lincoln Boulevard through Area A and North Area B, remove the existing levees along Area A and Area B (to be replaced by new setback perimeter levees), and restore a natural marsh habitat channel bank and expanded marsh wetland floodplain. The channel banks and bed would only be armored in locations where higher rates of channel scour are expected.

During storm events under Project conditions, a pattern of channel deposition and erosion is expected to occur as the storm flows expand into the restored wetlands and contract into the existing channel downstream. The wetlands along the channel would experience erosion due to out-of-bank storm flows over the wetland floodplain; however, channel bank armoring would reduce erosion along the channel banks that would experience the highest erosive stress. The backwater wetland area in the northeast portion of Area A would experience some minor deposition, while other wetland areas farther from the channel may experience erosion during larger storm events. The following discussion further describes these on-site erosion and deposition patterns over a range of storm events, resulting changes in off-site erosion and deposition, and recommended measures to offset potential negative effects of the project.

6.2.1 On-site Erosion and Deposition

6.2.1.1 *Ballona Creek channel.*

Comparison of sediment transport model results for existing and Project conditions for typical storm events (< 5-yr event) show a slight decrease in channel deposition under Project conditions and a small potential increase in erosion at the Lincoln and Culver Blvd. bridges, with a potential for net erosion of up to about 300 CY/yr for the effective discharge (Q_{eff}); however, the magnitude of these changes is small and the proposed armored sill at the bridges is expected to offset the increase in erosion at the bridges. The slight decrease in deposition anticipated in

[1] Sediment erosion and deposition in the Ballona Creek channel and Ballona Wetlands Ecological Reserve (BWER) occur in response to Ballona Creek storm events (fluvial processes), as well as coastal and tidal processes; however, fluvial processes dominate sediment dynamics within the system. Fluvial processes are driven by rainfall-runoff storm events, which vary in intensity from typical seasonal events to infrequently-occurring extreme events. Infrequent extreme events have the potential to cause greater erosion and deposition; however, more frequently occurring events can have a greater cumulative effect on sediment dynamics over time. The analysis results include rates of erosion, deposition, and sediment transport for a range of storm events (i.e., 10-year and 100-year creek discharge events and the effective discharge, which is the flow rate at which the channel is full of water (bankfull)), as well as average annual rates. These average annual rates are weighted-averages that account for the chance of occurrence of extreme events and represent an annual average that could be expected over a series of years.

the channel during typical storm events is not expected to have a considerable effect on the restored channel, which is expected to be stable in response to typical storm events.

During the 5-year storm event, the Project would increase the gross amount of erosion and deposition within the restored channel compared to existing conditions (with a 25% increase in erosion from 9,500 CY under existing conditions to 12,000 CY under Project conditions and a 10% increase in deposition from 11,000 CY to 12,000 CY). The net change is expected to be a decrease in net channel deposition (70% decrease from 1,700 CY under existing conditions to 500 CY under Project conditions). Therefore, the sediment transport model results for the 5-year storm event show that the proposed channel would respond and adjust through erosion and deposition and would change from net depositional under existing conditions to slightly depositional under Project conditions.

During the 100-year storm event, the sediment transport results show that the existing channel is net erosional. Under Project conditions, results show that the proposed channel would experience a large increase in both erosion and deposition compared to existing conditions, increasing net channel erosion (from 7,000 CY net erosion under existing conditions to between 9,000 and 20,000 CY depending on whether sediment deposition is assumed to be confined to the channel or across the wetland floodplain in the model). As discussed above, the proposed armored sill at the bridges is expected to reduce the increase in erosion.

Overall, the restored channel is expected to be stable to slightly depositional in response to typical storm conditions, which is similar to the existing channel. During large infrequent storm events (5-year storm event and greater, or 20% or less annual chance of occurrence), the channel would experience erosion and deposition, with an increase in net erosion and sediment export from the channel compared to existing conditions. Infrequent erosion and deposition within the channel is expected to be compatible with the habitat and flood management objectives. The new proposed levees would be setback from the channel and the channel bank and levees would be armored in key locations to protect the levees from erosion (see PDR). Channel maintenance is not expected to be necessary for Alternative 1 because channel deposition due to storm events would not be large enough to increase flood levels.

Deposition is not expected beyond the predicted equilibrium channel dimensions because tidal and more frequent storm flows occurring between larger infrequent storms would maintain the equilibrium dimensions. The Project reach including the Area A meander up to the Culver Blvd bridge is expected to have the highest rate of deposition (approximately 3,600 CY/yr on average). This reach could aggrade until it reaches equilibrium channel dimensions over about 50 years, at which point tidal channel scour due to daily tidal flows would likely maintain equilibrium dimensions between depositional storm events and further net aggradation over time would not be expected. The depositional reaches downstream of Area A and at the mouth of Ballona Creek could also aggrade to equilibrium tidal channel dimensions over a longer period of time. Further analysis would be necessary to determine if deposition is actually expected to reach equilibrium tidal channel dimensions because storm events could possibly scour deposited material from the channel before it reaches the equilibrium tidal channel dimensions. These analyses could include performing sediment transport modeling for scenarios with the equilibrium tidal channel dimensions in depostional reaches to assess whether the deposition in these reaches would erode in response to frequent storm events.

The Preliminary Hydrology and Hydraulics Report Addendum (Appendix F8 to the EIR/S) modeled flood levels with the equilibrium tidal channel dimensions throughout the entire Ballona Creek channel as a conservatively high channel deposition scenario. The results for Atlernative 1 show that positive levee freeboard above the design flood event is maintained in this scenario. As deposition is not expected to reach or exceed the equilibrium tidal channel dimensions and the modeling indicates that the channel would convey the design flood with these dimensions, channel maintenance to remove deposition is not expected to be required. The Preliminary Hydrology and Hydraulics Report Addendum model results show that in Phase 1 of Alternative 1 and Alternative 2, where the existing West Area B levee would remain at its existing elevation, flood levels would overtop the West Area B levee with the equilibrium tidal channel dimensions throughout the entire channel. Modeling of lower amounts of deposition (2 ft and 4 ft of deposition in the bottom of the channel) indicates that the channel would convey the design flood with up to 4 ft of deposition in the channel. Further analysis would be performed in subsequent steps of the project, including the USACE Section 408 approval, to assess the potential need for channel maintenance in Alternative 1, Phase 1 and Alternative 2. These analyses could include modeling the equilibrium tidal geometry in only reaches that are expected to be depositional and evaluating erosion of deposited material during more frequent storm events.

6.2.1.2 *Restored wetlands*

This analysis shows that some wetland deposition would occur during more frequent storm events; however, based on conservatively high estimates of potential wetland erosion, a relatively large amount of sediment could be eroded from restored wetlands along the channel during more extreme storm events (with a range from 50,000 CY of sediment erosion from wetlands during the 10-year storm to 70,000 CY of erosion during the 100-year event). During a 10-year event, results show that some wetland vegetation could scour away, with 4 to 12 inches of sediment erosion over a portion of the restored wetlands in Area A and 0 to 4 inches of erosion over a portion of the west Area B wetlands. Erosion of vegetated wetland area would result in a temporary loss of vegetated wetland; however, the estimated pattern of erosion would maintain the wetland surface at an elevation at which the wetland vegetation could re-establish and recover following the storm erosion event. During a 100-year event, results show 0 to 12 inches of erosion for a portion of Area A wetlands and 0 to 8 inches of erosion in West Area B. This pattern of erosion could lower mid marsh areas to elevations where low marsh would re-establish following the event, causing a conversion from mid marsh to low marsh habitat. The potential for mid to low marsh conversion due to erosion is relatively small in Area A. In West Area B, the results show the potential to convert some of the mid marsh to low marsh habitat because the West Area B mid marsh is only about 6 inches above the low marsh elevation range. Note that sea-level rise is also expected to convert West Area B from mid marsh to low marsh by about 2030 (based on a high-range sea-level rise projection) and it is therefore likely that the loss of mid marsh habitat could occur due to sea-level rise before a 100-year (1% annual chance of occurrence) event occurs. In summary, these conservatively high erosion results indicate that erosion and temporary loss of wetland may occur in response to large infrequent storm events, but that wetland vegetation could recover following the storm event. Conservatively high estimates of erosion are used to provide an upper end of the potential wetland erosion. Further refinement of the analysis would likely show less erosion due to better spatial representation of shear stress and consideration of a mid-range estimate of the critical shear stress for erosion, a range of erosion equations, and deposition of eroded material within the wetlands during the erosion event. Additionally, the project design includes armoring with three different levels of protection, and these estimates do not consider any armoring, which would decrease channel bank erosion. Furthermore, the degree of erosion estimated for Project during extreme events has not been observed or documented at other similar California river estuaries, such as San Elijo Lagoon. This degree of erosion is therefore not likely to occur, but provides an upper end estimate for the purpose of evaluating and planning for potential environmental effects.

Note that immediately after restoration, before vegetation has fully established, the potential for erosion is greater and pre-establishment of vegetation prior to breaching the levees is therefore recommended.

6.2.2 Off-site Erosion and Deposition

6.2.2.1 *Ballona Creek channel upstream of Lincoln Boulevard bridge*

Results from the Sediment Transport Analysis show that upstream of BWER and the Marina Freeway, no noteworthy changes in erosion and deposition are expected due to the Project. The modeled increase in erosion at the Lincoln and Culver Blvd. bridges would be offset by the proposed armored sill across the channel under the bridges.

6.2.2.2 *Ballona Creek channel mouth*

Large amounts of shoaling farther upstream of the mouth of the channel and within BWER due to coastal and tidal sediment transport is not expected. Mutliple lines of evidence indicate that the shoal at the mouth of Ballona Creek is controlled largely by waves with some fluvial and tidal influence. Grain size analysis showed that the sands within the shoal are similar in size and distribution to the sands on Dockweiler beach to the south. Longshore transport to the north likely moves these sediments into the mouth of the creek from the beach. Hydrodynamic modeling confirmed that tidal velocities were well below the 3 ft/s required to effectively move sand. Additionally, the shoal has not prograded up the channel as would be expected with a tidal shoal, and instead appears to be limited by the extent of the propagation of waves up the channel. While some deposition in the mouth of the creek is expected during fluvial storm event, materials also drop out upstream or continues out into the bay; the shoal feature is not likely built by fluvial processes.

The project will increase the tidal prism of the site by approximately 15%, which will increase tidal velocities which could increase the shoal size. However, under project conditions, tidal velocities are still below 3 ft/s, so sand movement due to the tides will be limited. Because the shoal is likely wave-built, rather than tidally-built, the project will not cause an increase in the size of the shoal.

6.2.2.3 *Marina del Rey harbor entrance channel*

Under existing conditions, approximately 7,000 CY/yr of sediment is exported from the mouth of Ballona Creek, of which about 70% or 5,000 CY/yr is estimated to deposit in the Marina del Rey harbor entrance channel. Coastal or littoral sand transport along the coast deposits about 48,000 CY/yr of sand in the entrance channel. Sediment deposited in the entrance channel (total volume of about 55,000 CY/yr from littoral transport and Ballona Creek) is dredged from the entrance channel. Since 1999, the following major dredge events have occurred:

- 1999: 670,000 CY dredged
- 2007: 330,000 CY dredged (8 years after 1999)
- 2012: 780,000 CY dredged (5 years after 2007)

For Project conditions, conservatively high estimates of potential erosion from the restored channel bed and wetlands show an increase in the amount of sediment exported from Ballona Creek and a corresponding increase in Ballona Creek deposition in the harbor entrance channel, particularly due to wetland erosion during extreme storm events (10-year event or 10% annual chance of occurrence and greater). The increase in export and deposition for more frequent events is expected to be low relative to littoral sand transport, deposition, and dredging in the entrance channel (range of 200 to 900 CY increase in deposition from the 1-year to 5-year event compared to average dredging of 55,000 CY/yr or 300,000 to 800,000 CY every 5 to 8 years). More extreme storm events have the potential to increase dredging amounts by about 20% (10-year to 100-year events deposit an additional 20,000 to 40,000 CY of sediment in the entrance channel compared to dredging of 300,000 to 800,000 CY every 5 to 8 years). Accounting for the chance of occurrence of extreme events, the annualized average rate of entrance channel deposition has the potential to increase from 5,000 CY/yr under existing conditions to 12,000 CY/yr under Project conditions, which represents a 7,000 CY/yr or 12% increase in the annualized average dredging of 55,000 CY/yr. The results of this analysis therefore show the potential to increase the amount of dredging by about 12%, with corresponding increases in dredge event frequency, volumes, and costs. Note that as discussed in Section 6.2.1.2, the estimate of wetland erosion and resulting deposition in the entrance channel are conservatily high and not likely to occur, but provide high estimates for the purpose of evaluating and planning for potential environmental effects.

An erosion monitoring and adaptive management plan is recommended in which weltand erosion inspections and surveys are performed to assess whether erosion occurs. If erosion is observed, the Project could coordinate with LA County and the USACE to evaluate whether surveys of the Marina Del Rey entrance channel show a corresponding increase in sediment deposition in the entranct channel. Placing suitable-quality dredged material from the Marina del Rey entrance channel in the BWER restored wetlands could be considered as one adaptive management measure to offset the potential for extreme storm events to increase deposition in the entrance channel. Material dredged from the entrance channel could be barged up the Ballona Creek channel and sprayed onto the restored wetlands. Spray-dredging is a common practice in other parts of the U.S. and a similar spray-dredging pilot project is being planned for the Anaheim Bay entrance channel and Seal Beach National Wildlife Refuge by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service. This type of dredge material placement in the wetlands would also help to offset wetland erosion during extreme events (discussed above) by effectively returning the eroded sediment that is deposited in the entrance channel back to the wetlands.

6.2.2.4 *Santa Monica Bay and beaches*

The potential increase in sediment export from Ballona Creek to Santa Monica Bay and deposition of fine-grained sediment at Dockweiler Beach and Venice Beach during typical storm events is expected to be low; however, as discussed above, conservatively high estimates of potential wetland erosion in response to larger infrequent storm events show an increase in the amount of sediment exported from Ballona Creek to Santa Monica Bay. During a 10-year event, results show 2,500 CY of sediment would be exported to the Bay under existing conditions and that the amount of exported sediment could increase to 14,500 CY under Project conditions. During a 100-year event, results show an increase from 17,000 CY to 63,000 CY. These events have a low probability of occurring in a given year (1% to 10% annual chance of occurrence). Increased deposition of fine-grained sediment on the adjacent beaches is expected following these infrequent storm events; however, the effects on the beach would be temporary because the fine sediment would be washed out by subsequent wave action. These conditions are expected to be similar to many other California river estuaries because the sediment export to the coast by rivers is a naturally occurring geologic process. At the Tijuana River Estuary, placement of fine-grained dredged material from the estuary on the beach has been tested and monitored and the results indicate that the effects are temporary. In summary, increased sediment export from Ballona Creek and deposition on the adjacent beaches is likely to occur infrequently and only temporarily, similar to conditions that occur at other California river estuaries.

6.2.3 Discussion of alternatives

6.2.3.1 *Alternative 2*

In Alternative 2, the existing levee along West Area B would remain and the West Area B wetlands would not experience erosion. The effects of Alternative 2 on on-site and off-site erosion and deposition would be similar to Alternative 1, but the changes would be less in magnitude.

Ballona Creek channel. Ballona Creek channel deposition and erosion would be similar to Alternative 1 in the realigned reach in Area A and North Area B. As in Alternative 1, changes in channel deposition and erosion are not expected to negatively affect flood performance or require channel maintenance.

Restored wetlands. Erosion and deposition patterns in the Area A and North Area B wetlands would be similar to Alternative 1, with the potential for large infrequent storm events to scour away vegetation and cause sediment erosion and temporary loss of vegetated wetland habitat until vegetation re-establishes. ***As in Alternative 1, pre-establishment of vegetation prior to breaching the levees is therefore recommended in the restored wetlands in Area A and North Area B to reduce the potential for erosion immediately after restoration in Alternative 2.***

In Alternative 2, wetland erosion would not occur in West Area B; however, loss of vegetated wetland habitat would occur over time because rising sea-levels would convert the managed tidal wetlands to a non-tidal pond.

Ballona Creek channel upstream of Lincoln Boulevard bridge. As in Alternative 1, no significant changes in erosion and deposition are expected upstream of BWER and the Marina Freeway due to the Alternative 2. Also as in Alternative 1, the potential increase in erosion at the Lincoln and Culver Blvd. bridges would be offset by the proposed armored sill across the channel under the bridges.

Ballona Creek channel mouth. As in Alternative 1, any change in shoaling at the channel mouth is not expected to be notable and shoaling farther upstream of the mouth of the channel and within BWER due to coastal and tidal sediment transport is not expected.

Marina del Rey harbor entrance channel. As in Alternative 1, Alternative 2 could potentially result in increased deposition and dredging in the harbor entrance channel; however, in Alternative 2, sediment would not be eroded from West Area B during extreme storm events. The potential increase in dredging in Alternative 2 would therefore be less than Alternative 1, with perhaps a 5-10% increase in dredging in Alternative 2. ***As in Alternative 1, consideration of placing suitable-quality dredged material from the Marina del Rey entrance channel in the BWER restored wetlands is recommended to offset the potential for extreme storm events to increase deposition in the entrance channel in Alternative 2.***

Santa Monica Bay and beaches. As in Alternative 1, increased sediment export from Ballona Creek and deposition on the adjacent beaches is likely to occur infrequently and only temporarily in Alternative 2, similar to conditions that occur at other California river estuaries. The potential increase in Alternative 2 could be about half of the increase in Alternative 1 because wetlands erosion would not occur in west Area B in Alternative 2.

6.2.3.2 *Alternative 3*

In Alternative 3, the existing levees and channel would remain and restored wetlands in Area A would be connected to Ballona Creek by open culverts through the existing levee. During large storm events, creek discharge would flow into the restored wetlands, but flow in the channel would otherwise be unaffected. Alternative 3 is therefore not expected to change existing patterns of erosion and deposition in any notable manner. Note that updated hydraulic modeling in progress for Alternative 3 will be used to confirm and support this conclusion.

Figures

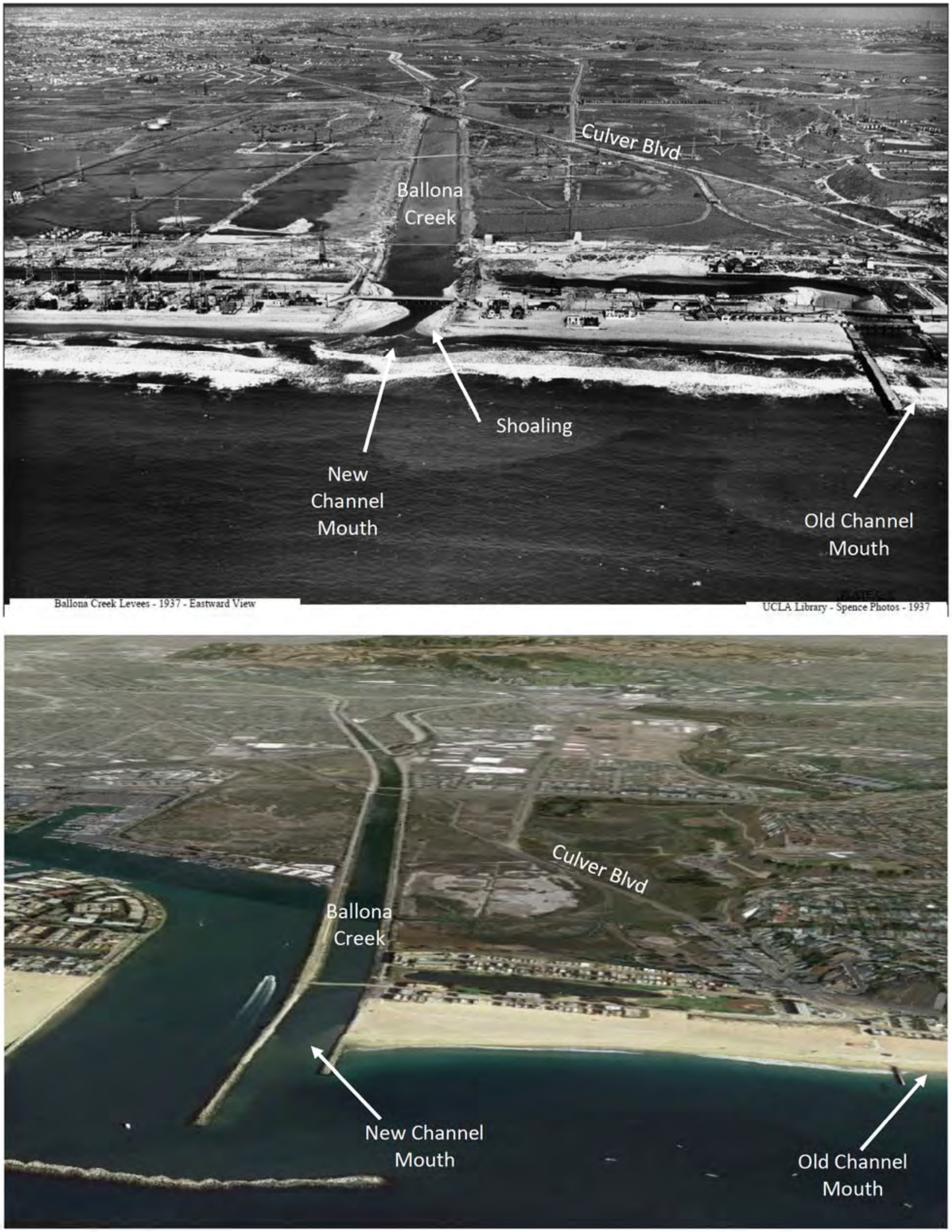
Attachments

SOURCE: UCLA Library, Spence Photos; Google Earth

Ballona Wetlands . D120367

Figure 1
Ballona, 1933 and 2012

ESA PWA



SOURCE: UCLA Library, Spence Photos; Google Earth

Ballona Wetlands . D120367

Figure 2
Ballona, 1937 and 2012

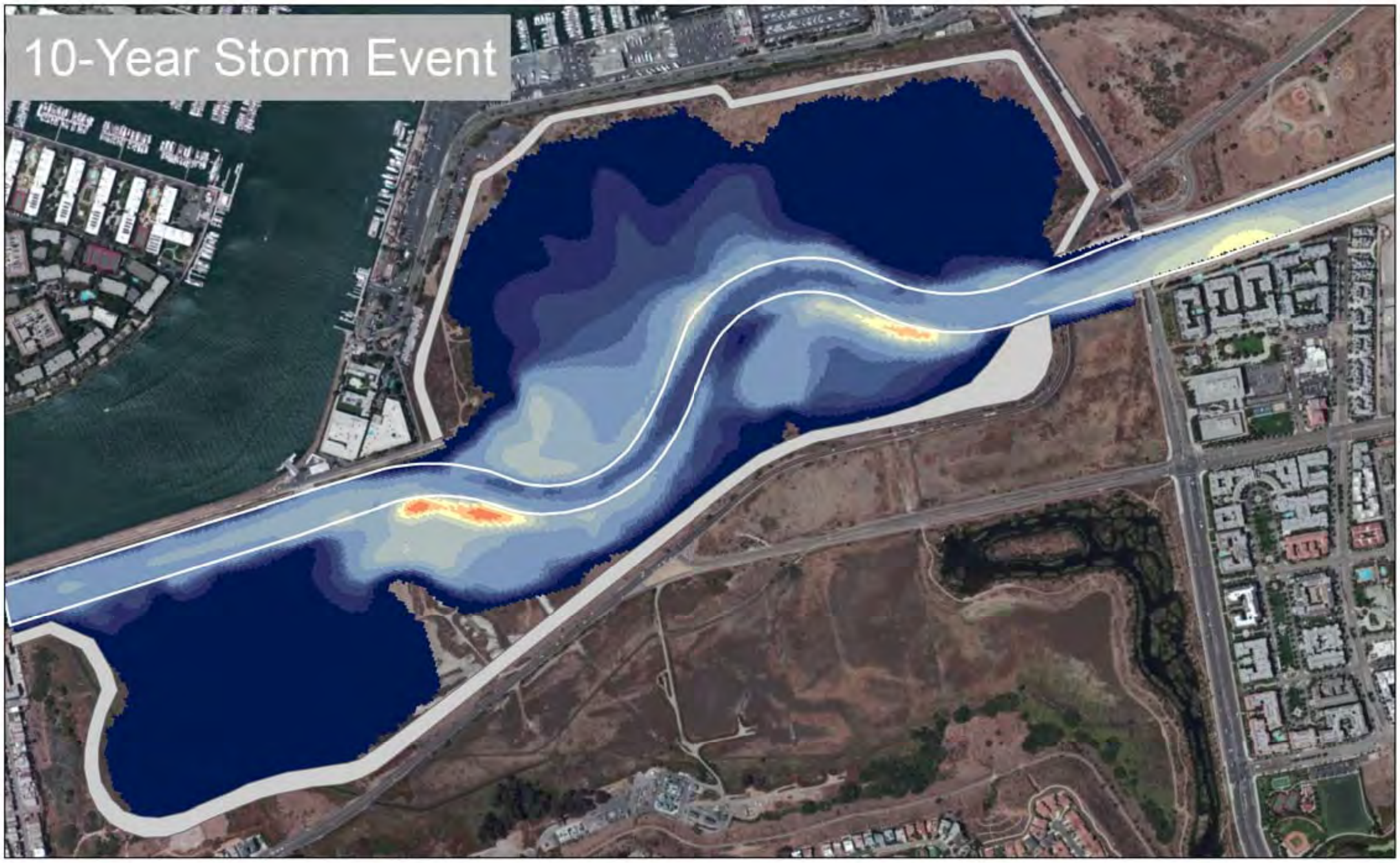
ESA PWA

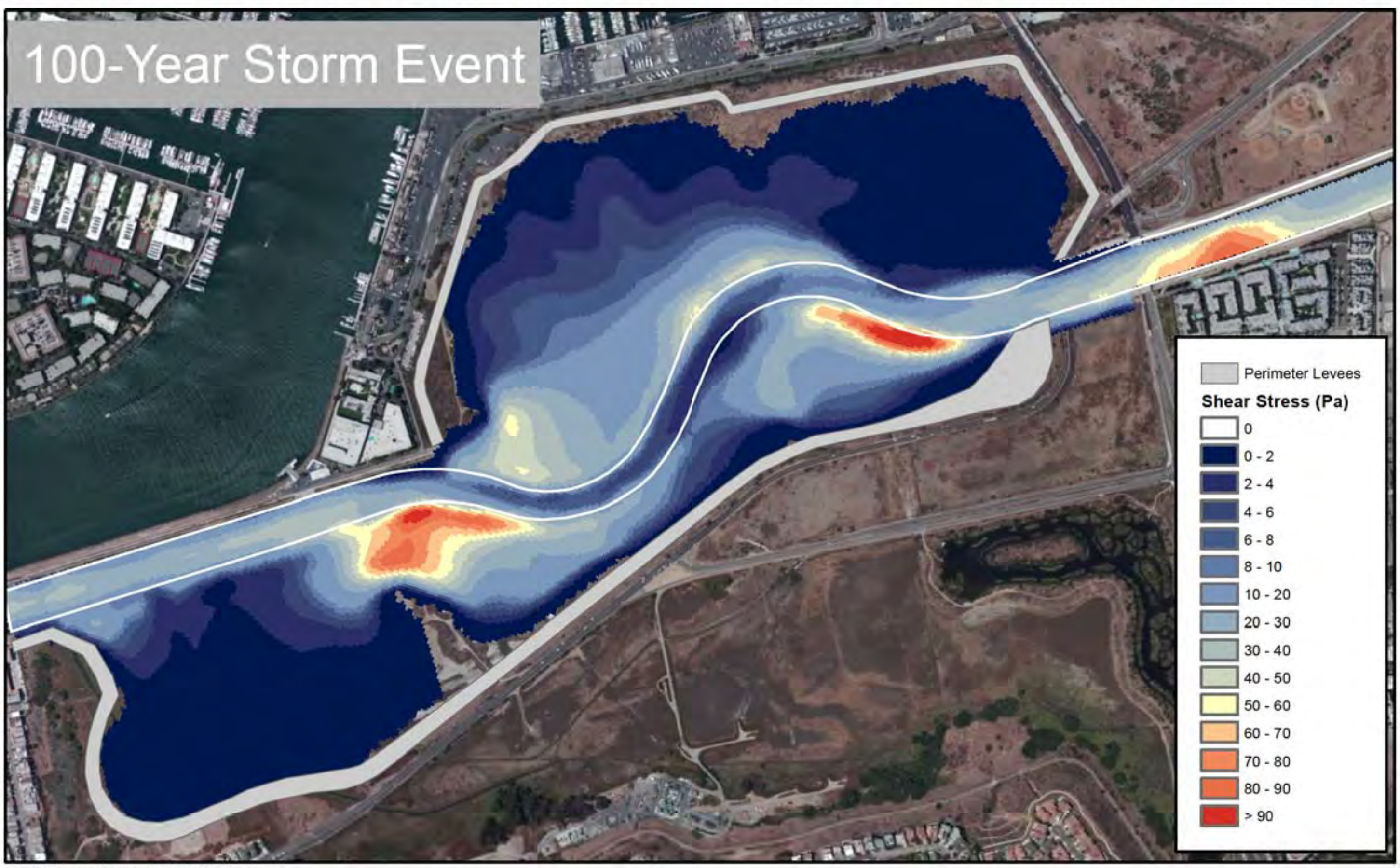
SOURCE: UCLA Library, Spence Photos; Google Earth

Ballona Wetlands . D120367

Figure 3
Ballona, 1938 and 2012

ESA PWA





G:\1793_Ballona\Modeling\EFDC\ShearMap.mxd

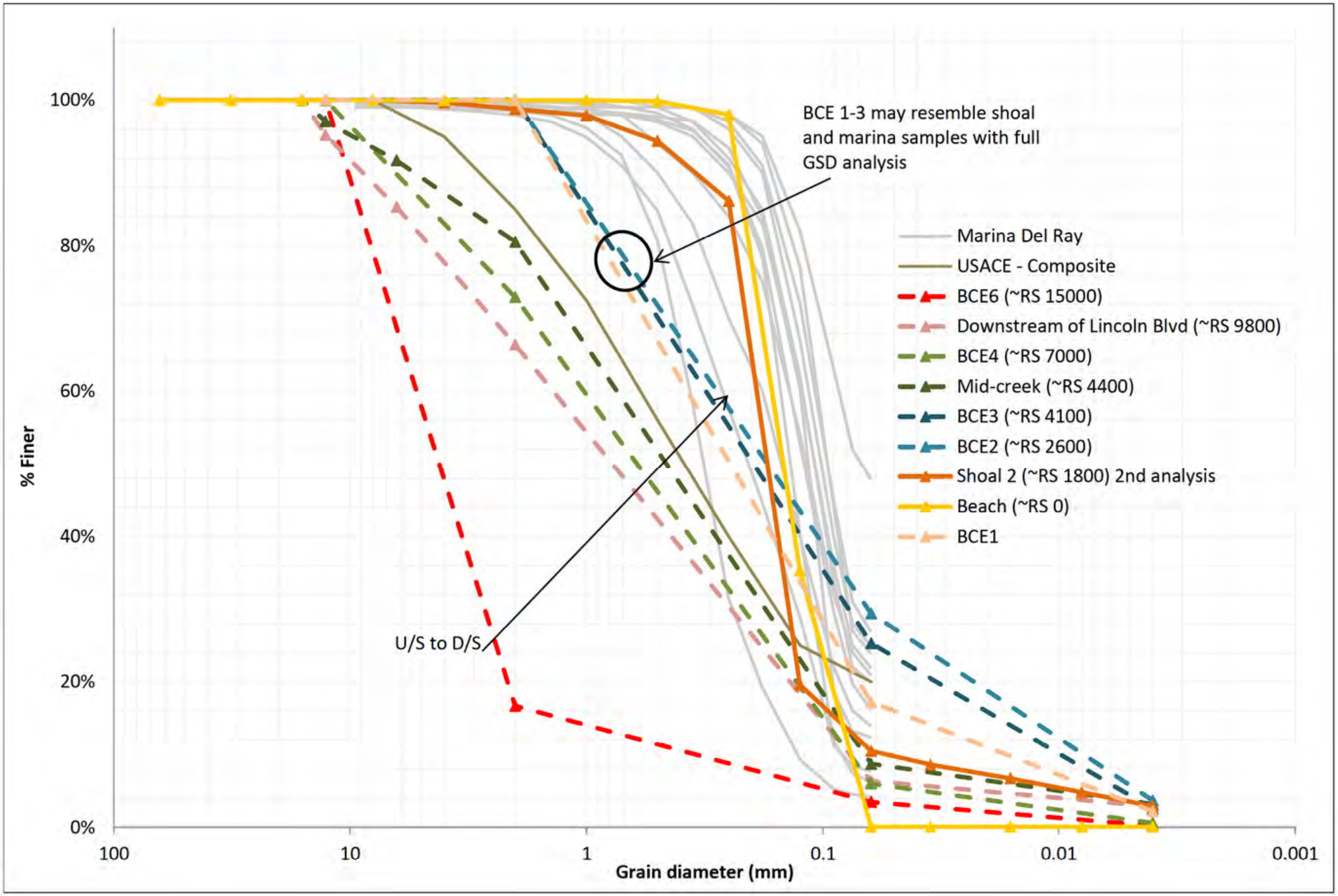
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Ballona Wetlands. D120367

Figure 4

Modeled Shear Stress

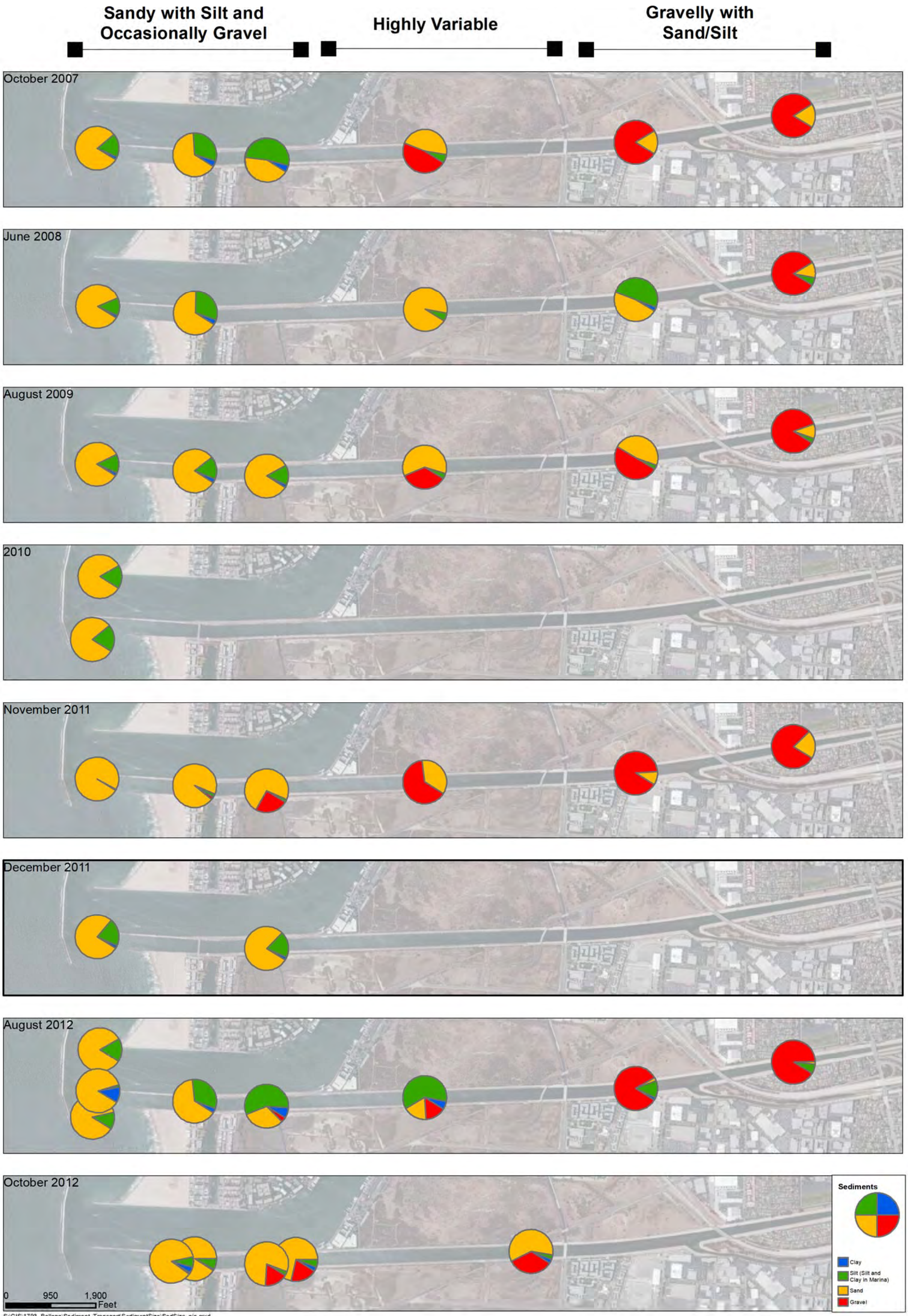
ESA PWA



SOURCE: USACE 2003; Wallace Labs 2013; SCCWRP 2010.
NOTES: Solid lines indicate complete grain size analysis, while dotted lines indicate only clay/silt/sand/gravel categorization.

Ballona Creek Wetlands . D120367

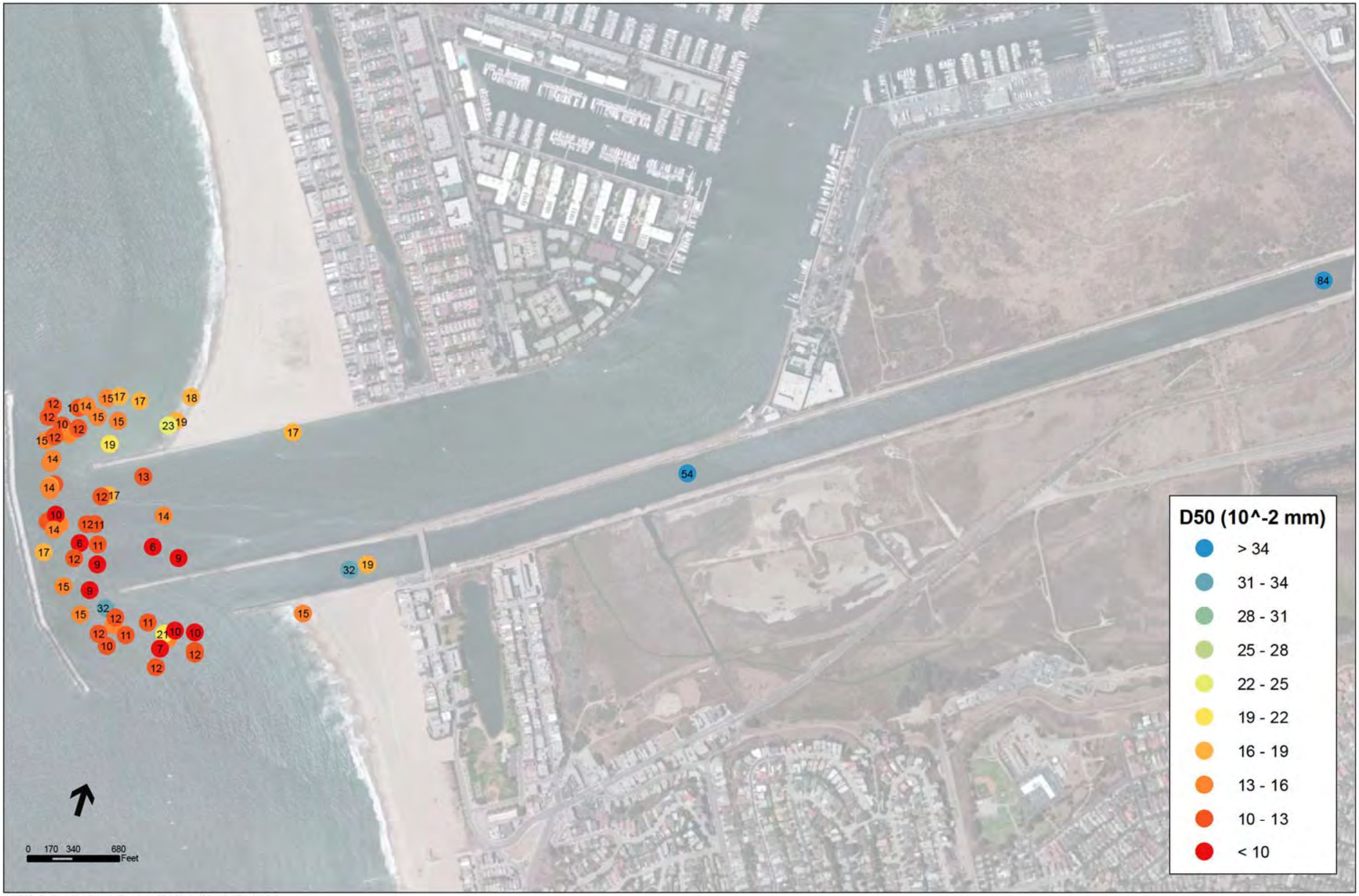
Figure 5
Ballona Creek Grain Size Distribution Curves



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community, Channel data from 2007-2009 from SCCWRP (2010), Marina data from 2010 from Kinnetic Laboratories (2010), channel data from 2011 and 2012 from City of LA (2012, 2013) at the same SCCWRP stations, Marina data from 2012 from AMEC (2012), ESA PWA survey (2012); Data from the marina is averaged by entrance over a season.

Ballona Wetlands. D120367
Figure 6
Sediment Transport Data

ESA PWA



J:\1793_Ballona\Sediment_Transport\SedimentSize\SedSize.mxd

Source: Kinnetic Laboratories (2010), AMEC (2012), ESA PWA survey (2012) Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

ESA PWA

Ballona Wetlands. D120367

Figure 7

Sediment Size Map

J:\1793_Ballona\Accretion.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community; USACE (2003), PSOMAS (2012)
Notes: Figure shows net change from 1961 to 2012.

ESA PWA

Ballona Wetlands. D120367

Figure 8
Ballona Creek Accretion between 1961 and 2012

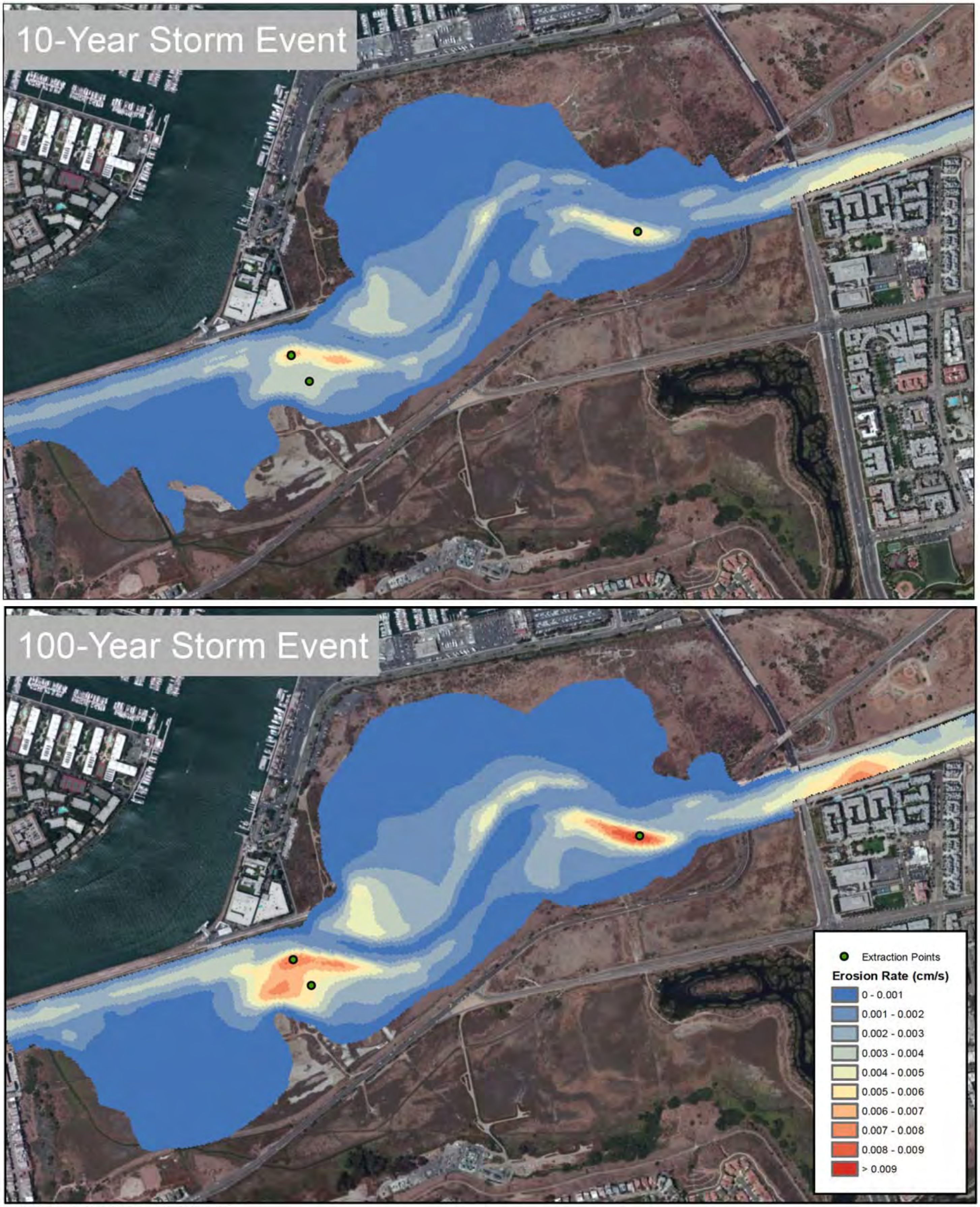
J:\1793_Ballona\Project_channel.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community; USACE (2003), PSOMAS (2012)
Notes: Figure shows net change from 1961 to 2012.

ESA PWA

Ballona Wetlands. D120367

Figure 9
Projected Accretion and Erosion during Q100 Storm



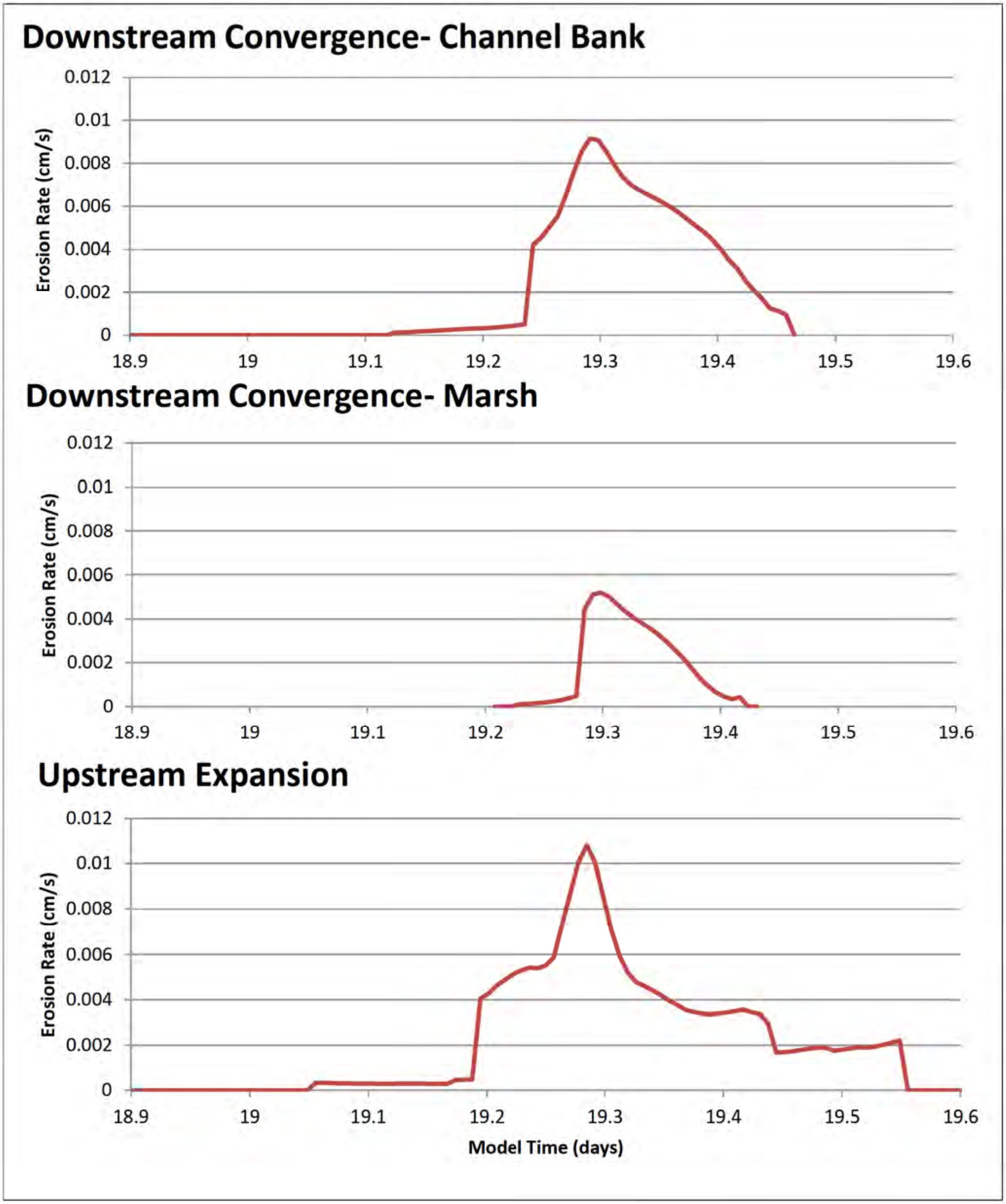
G:\1793_Ballona\Modeling\EFDC\Max_ErosionMap.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Ballona Wetlands. D120367

Figure 10
Maximum Erosion

ESA PWA

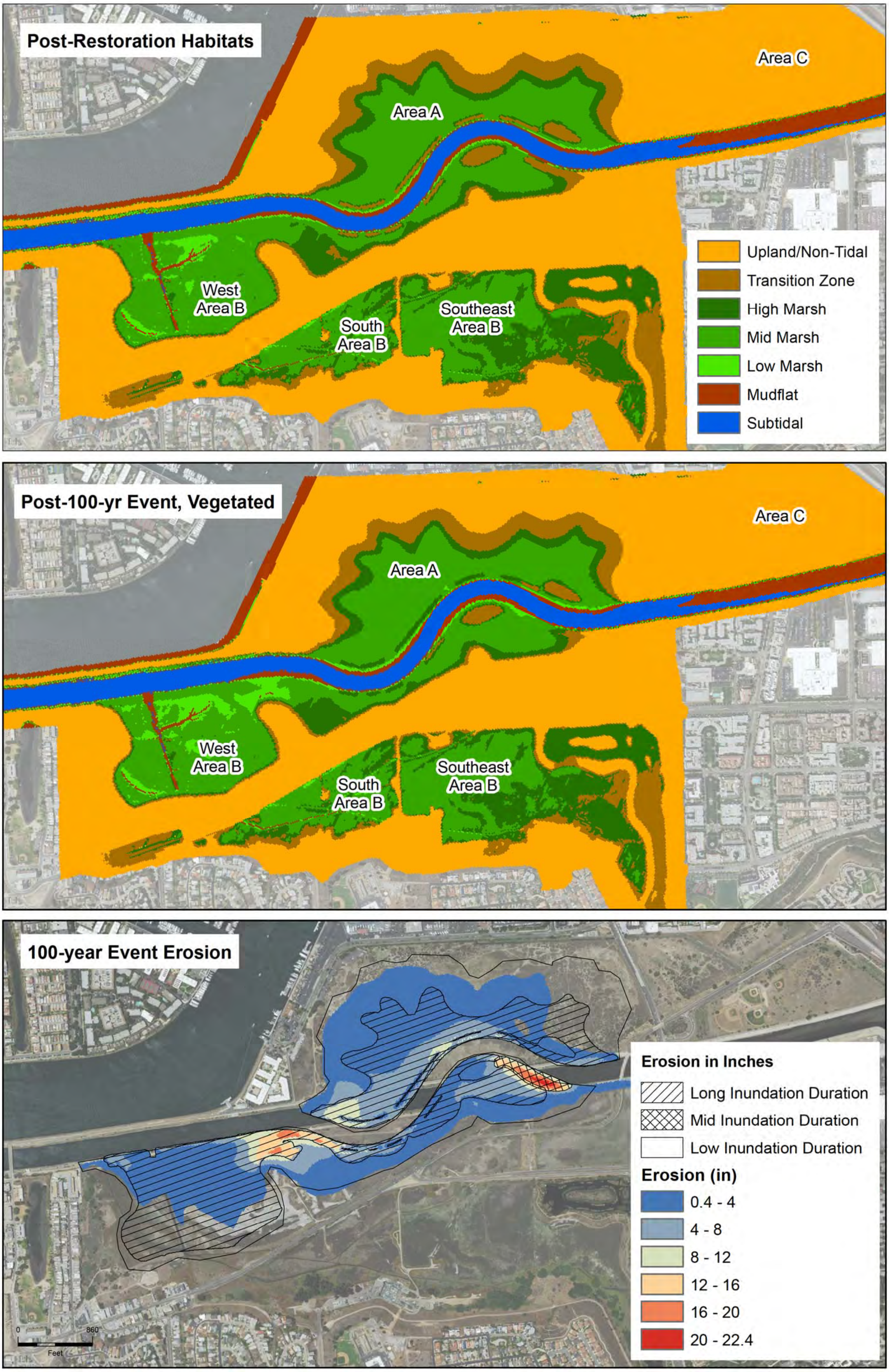


Notes: Rates are based on Ganthy (2011) equation with a critical shear stress of 0.18 Pa.

Ballona Creek Wetlands . D120367

Figure 11

Q100 Erosion Time Series

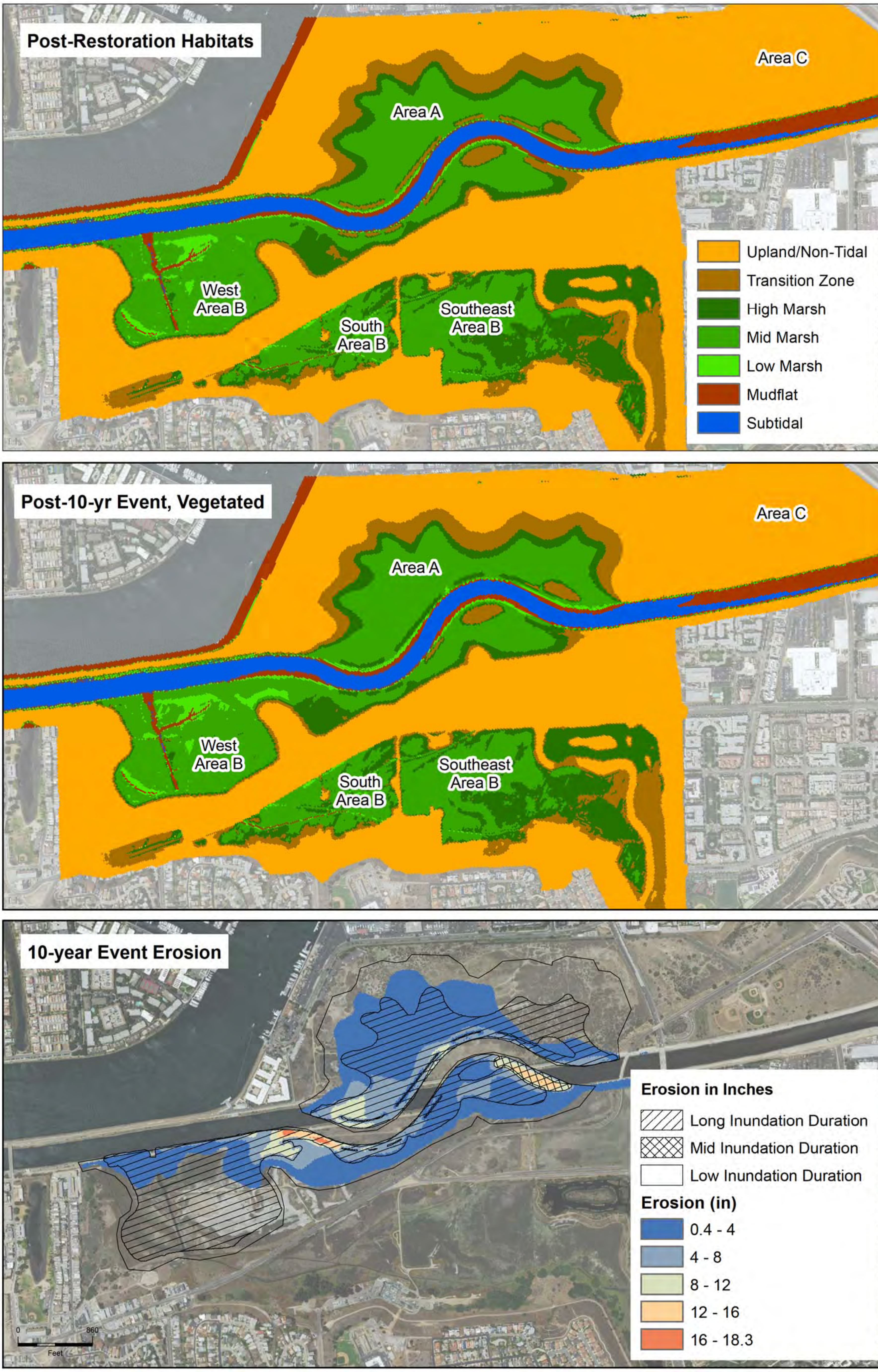


NOTES: Vegetation included. Armoring not included.

Ballona Wetlands. D120367

Figure 12

Q100 Erosion Map

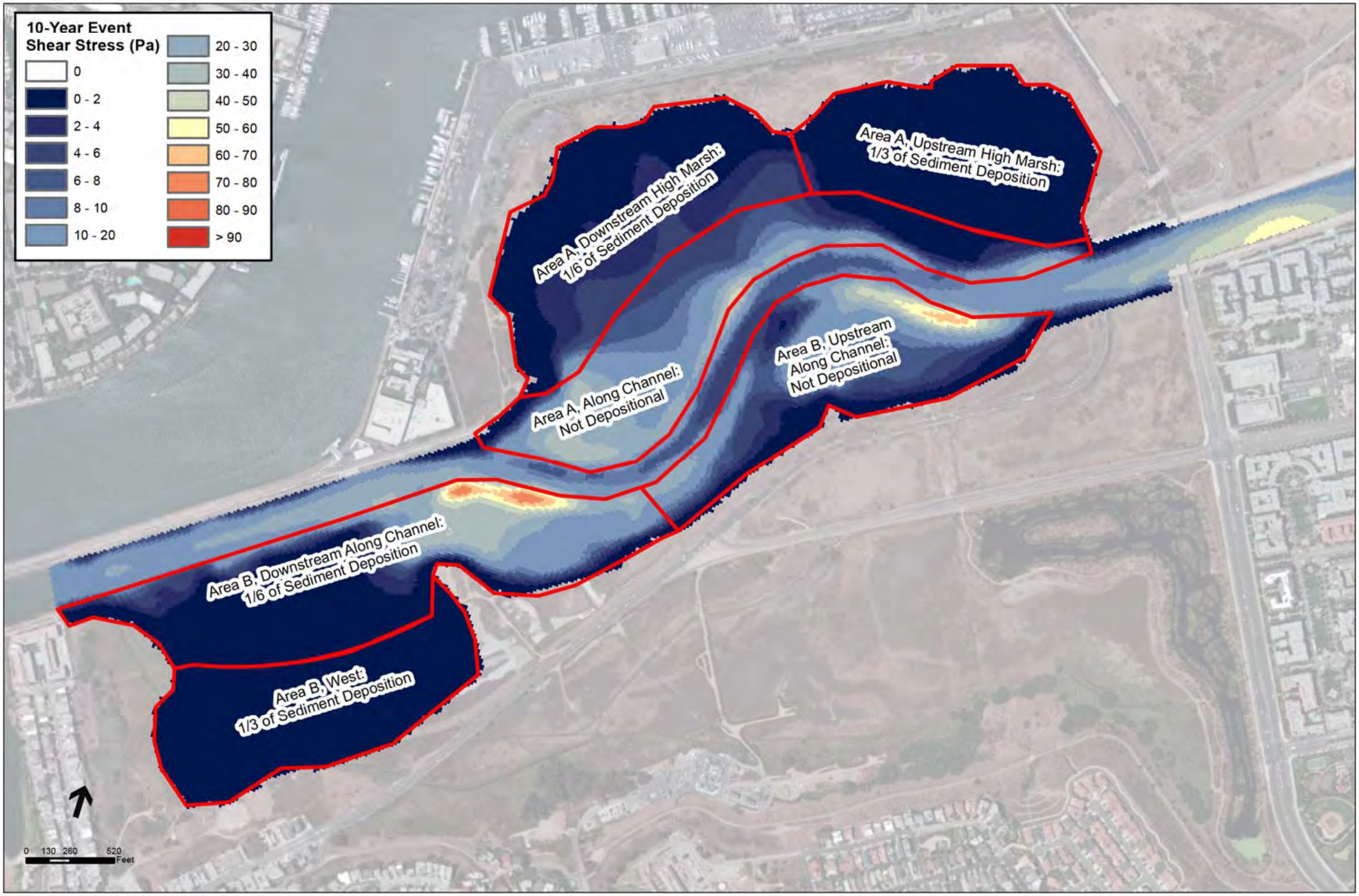


NOTES: Vegetation included. Armoring not included.

Ballona Wetlands. D120367

Figure 13

Q10 Erosion Map



G:\1793_Ballona\Modeling\EFDC\DepositionMap.mxd

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community The shear stress is from the 10-year storm event.

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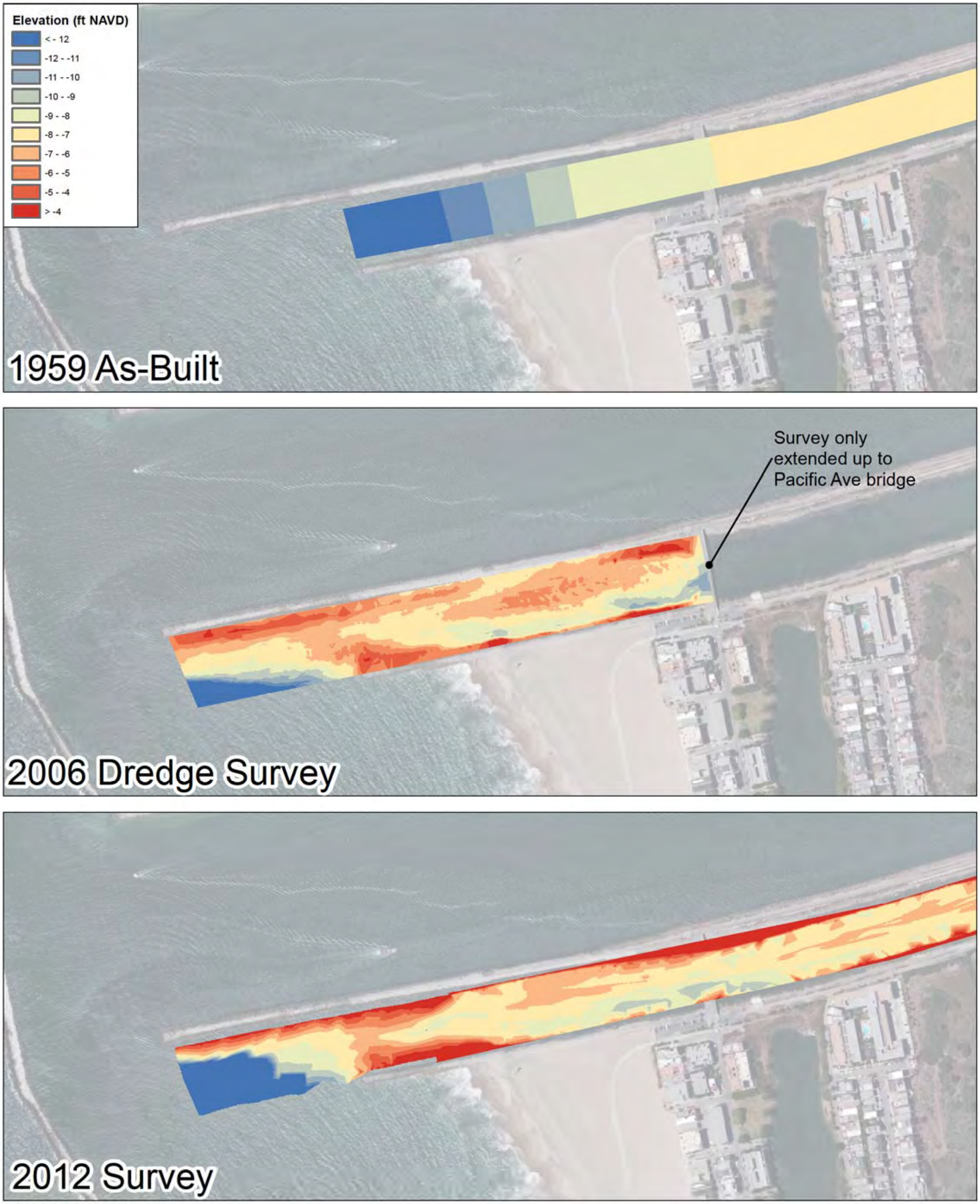
Figure 14
Marsh Deposition Locations



J:\1793_Ballona\Sediment_Transport\Shoal.mxd

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
USACE (2003), USACE (2006), PSOMAS (2012)

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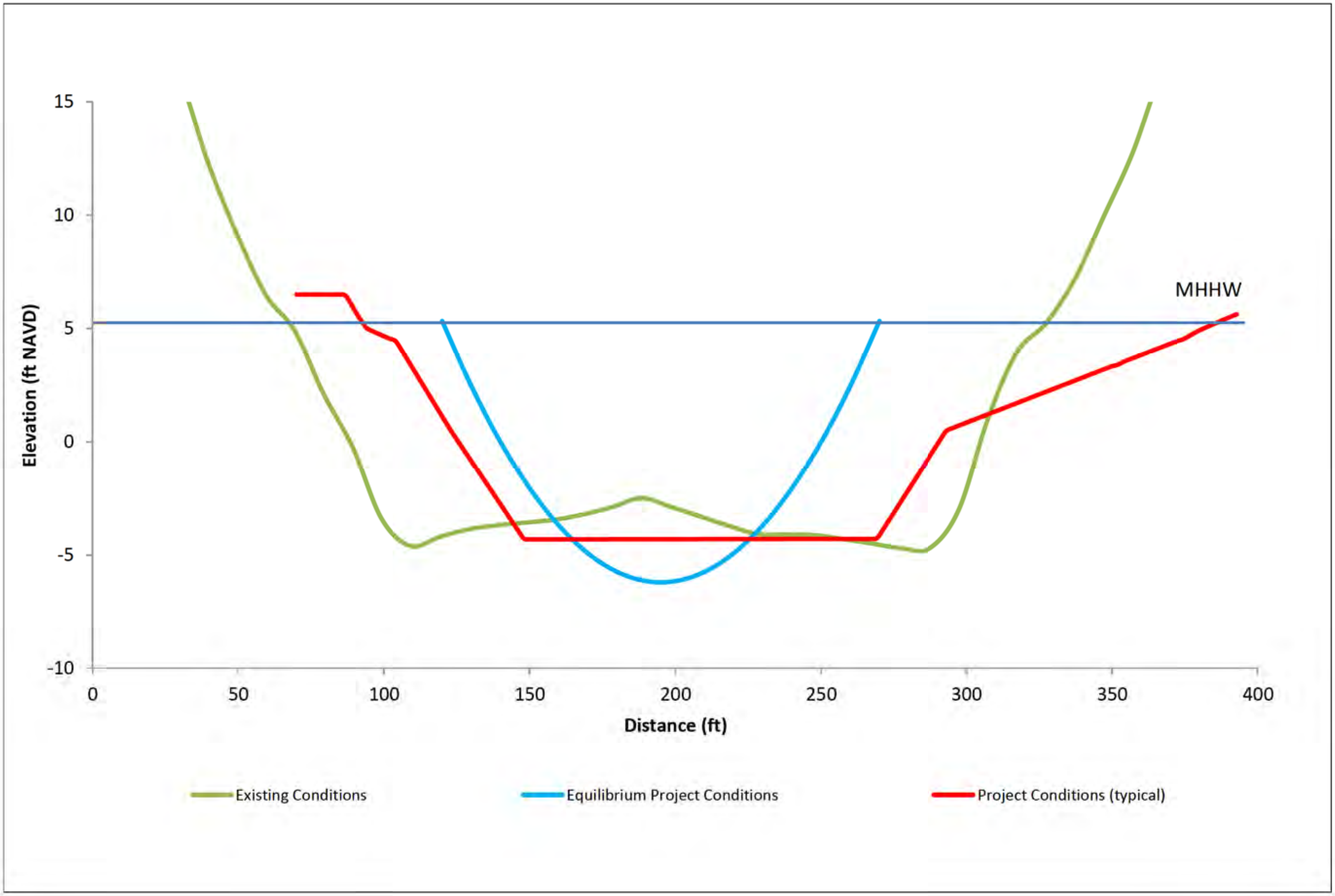
Ballona Wetlands. D120367

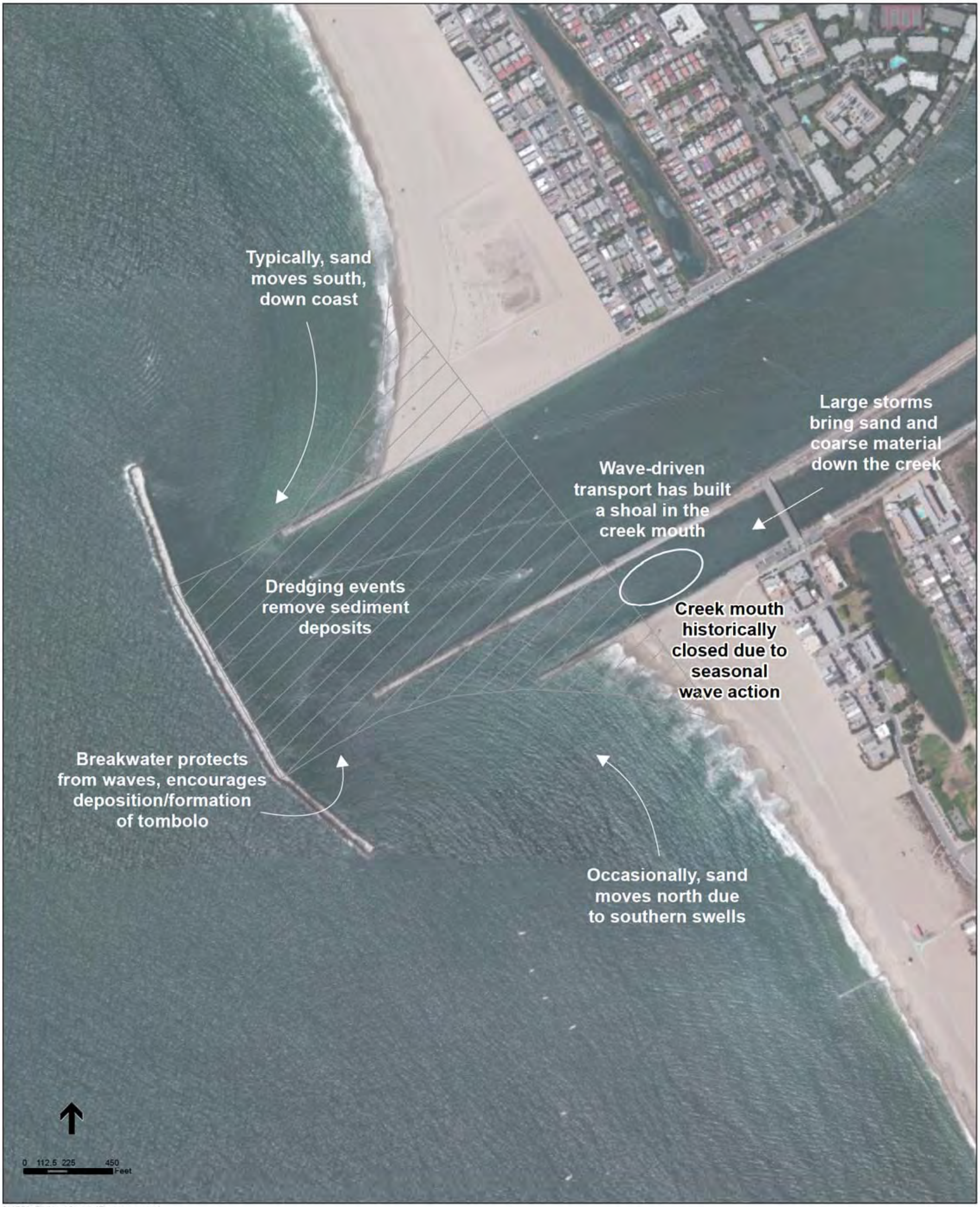
Figure 15

Ballona Creek Shoal



SOURCE: ESA PWA (2012)

Ballona Wetlands. D120367
Figure 16
Ballona Creek Channel Cross Section
Mid-Meander



J:\1793_Ballona\CoastalProcesses.mxd

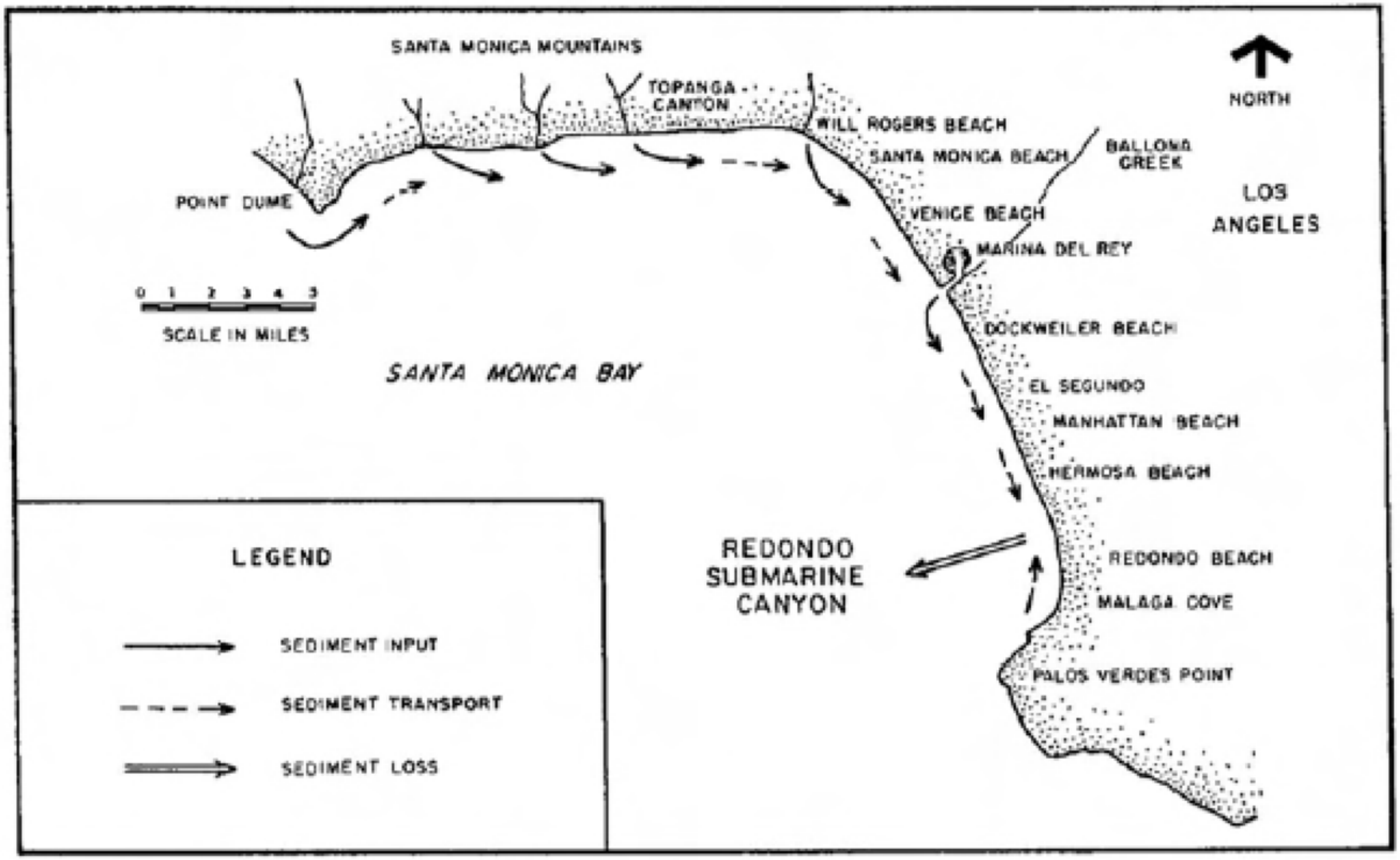
Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP,

ESA PWA

Ballona Wetlands. D120367

Figure 17

Coastal Processes Near Ballona Creek



SOURCE: Figure 2, Leidersdorf, Hollar, and Woodell (1994).

Ballona Wetlands . D120367

Figure 18
Santa Monica Littoral Cell

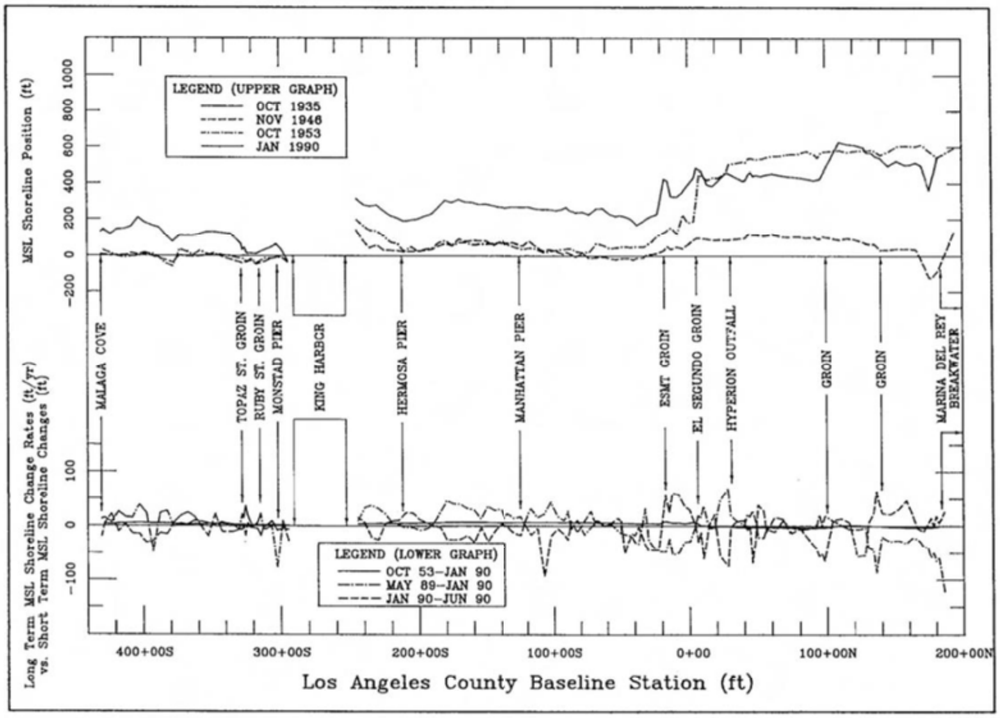


Figure 3a. MSL Shoreline Positions Relative to 1935, and Long Term MSL Shoreline Change Rates vs. Short Term MSL Shoreline Changes, between Malaga Cove and Dockweiler Beach.

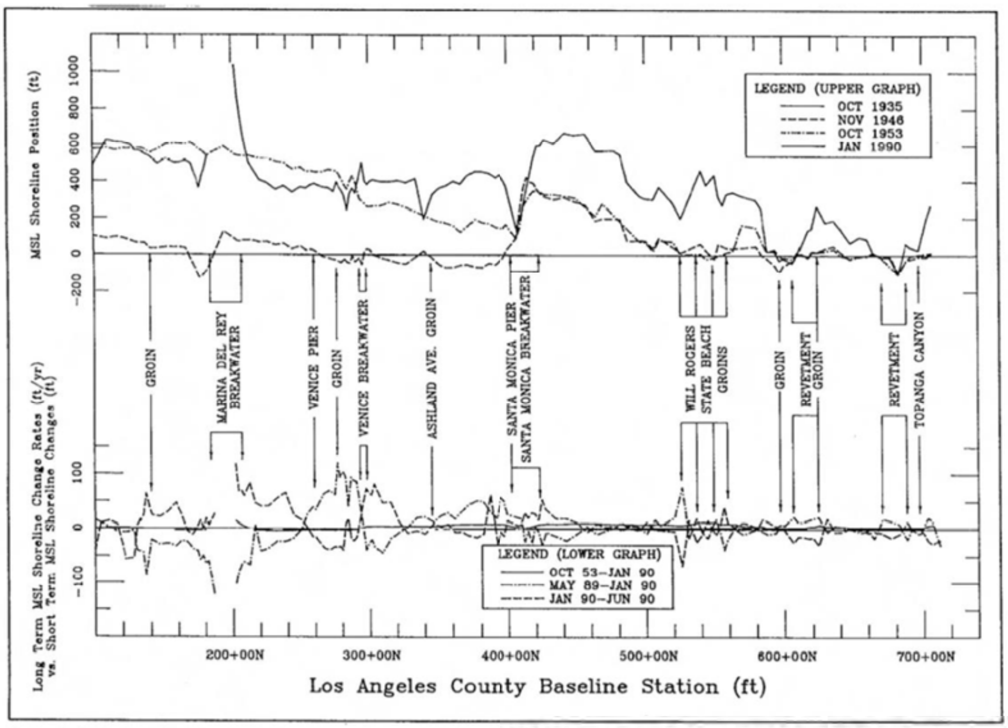
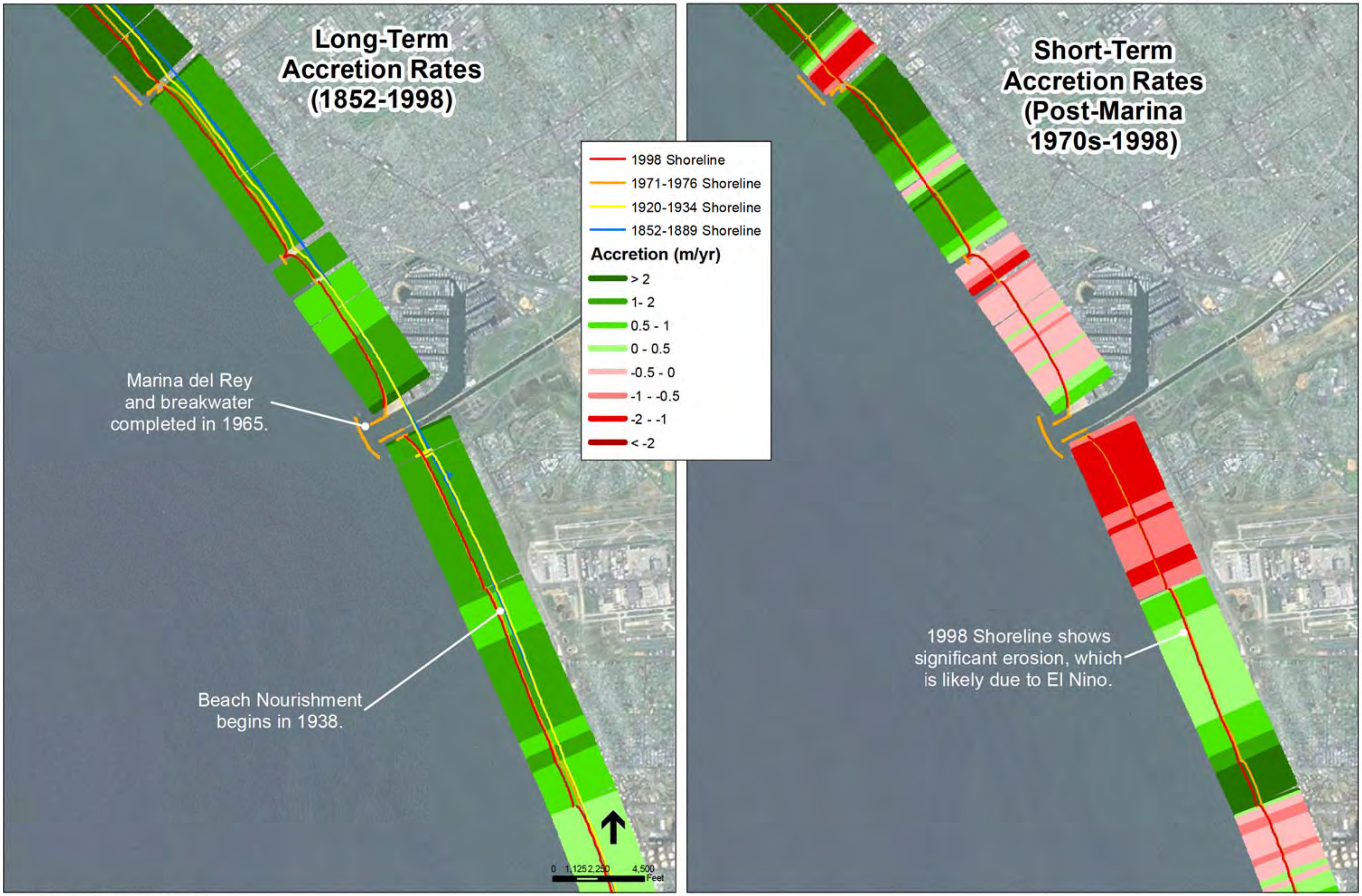


Figure 3b. MSL Shoreline Positions Relative to 1935, and Long Term MSL Shoreline Change Rates vs. Short Term MSL Shoreline Changes, between Dockweiler Beach and Topanga Canyon.

SOURCE: Reproduced from Figure 3, Leidersdorf 1994.

Figure 19
Shoreline Change Profiles
(Leidersdorf 1994)



J:\1793_Ballona\Coastal_ShorelineChanges.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community
Shoreline data from USGS 2006

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Ballona Wetlands. D120367

Figure 20
Coastal Shoreline Change Rates

J:\1793_Ballona\Accretion.mxd

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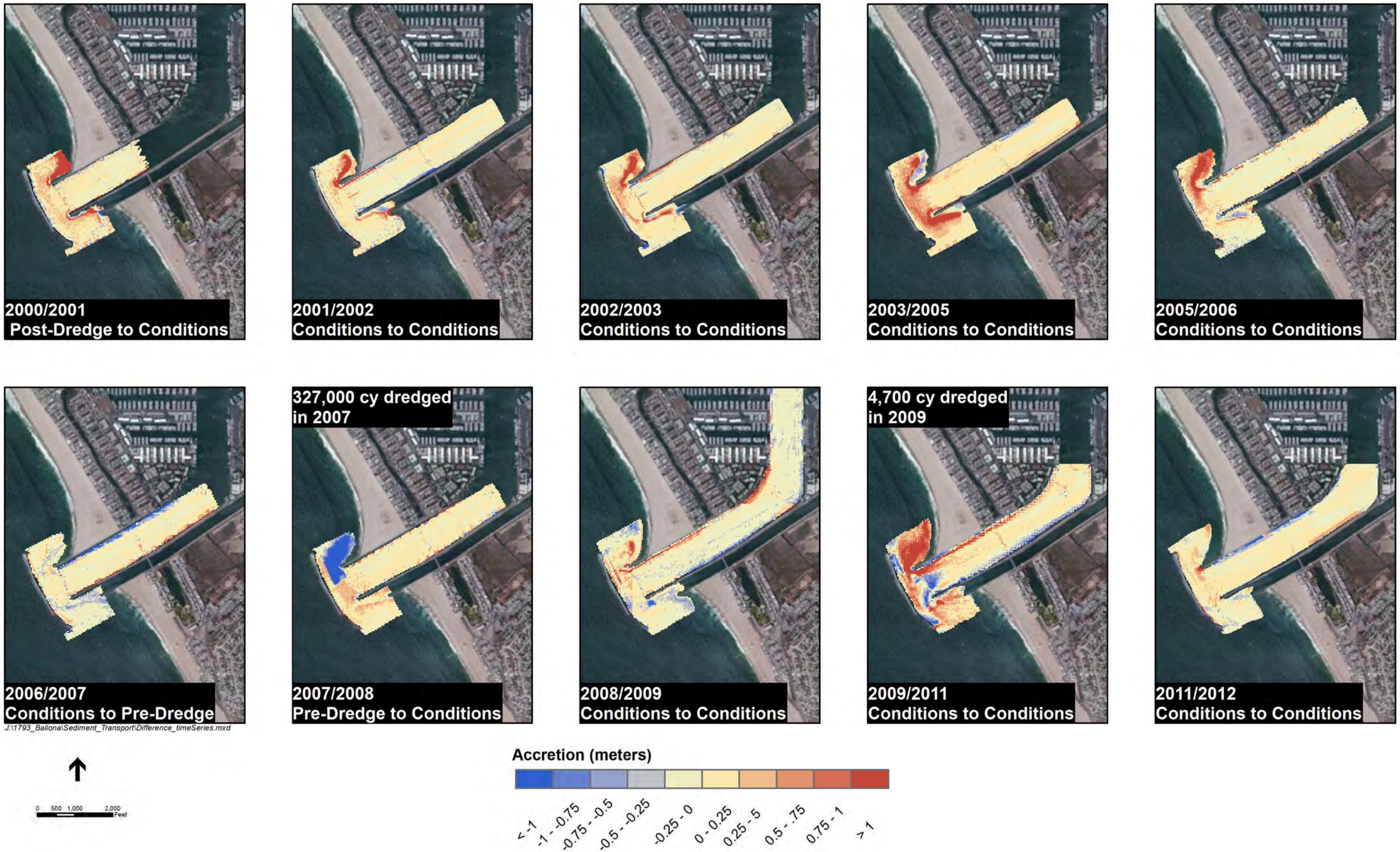
Ballona Wetlands. D120367

Figure 21
Breakwaters and tombolos



ESA PWA

Ballona Wetlands. D120367

Figure 22
Marina del Rey
Bathymetric Difference Maps

J:\1793_Ballona\Sediment_Transport\Areas_A_B_G_H_rates.mxd

Source: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Ballona Wetlands. D120367

Figure 23

Marina del Rey Accretion Rates

ESA PWA

Seal Beach location_2014-0411ct.mxd

Service Layer Credits: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Ballona Wetlands. D120367

Figure 24
Seal Beach Wetlands Location

ESA PWA

Seal Beach historic habitats_2014-0410ct.mxd

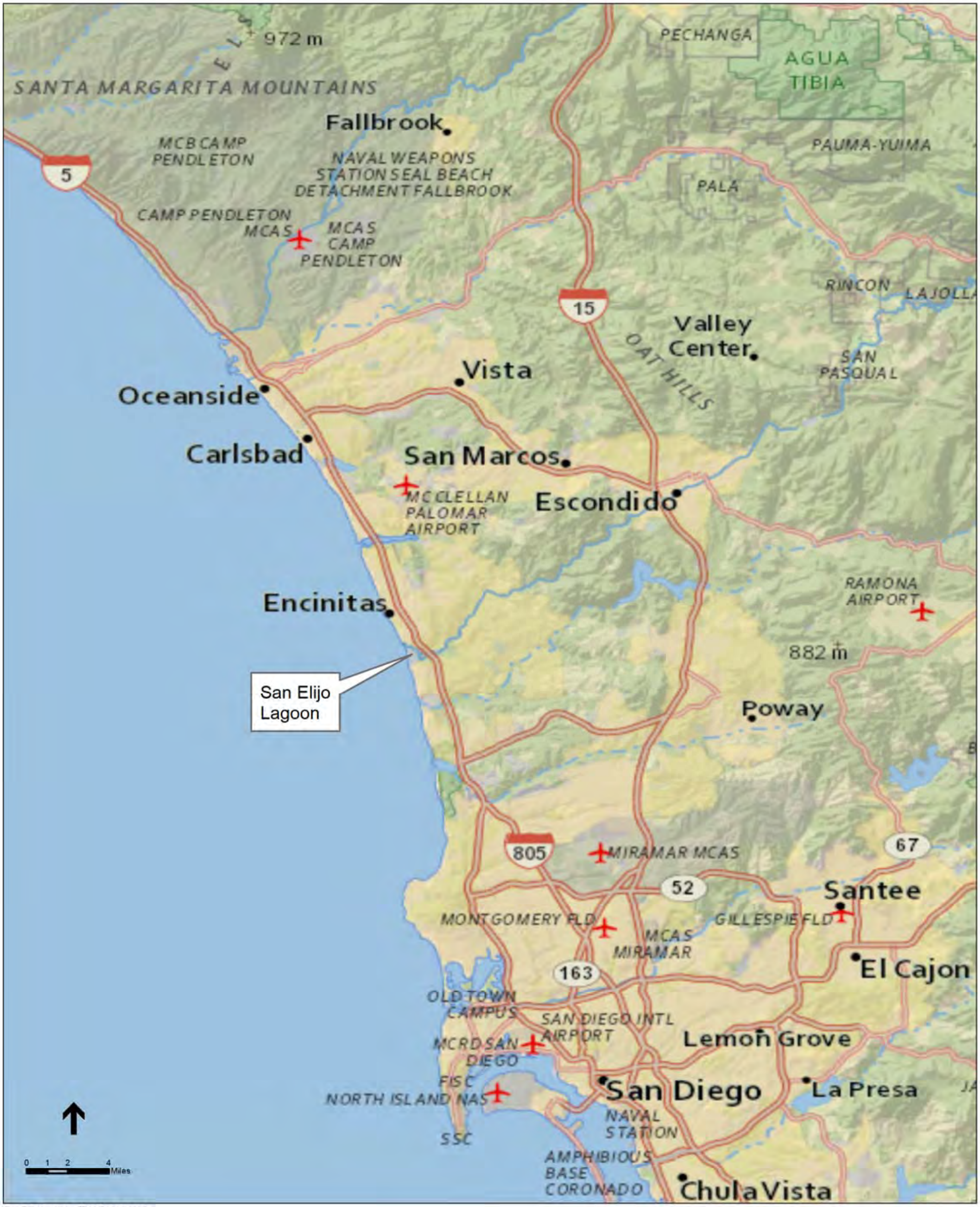
SOURCE: USDA 2012 (LA County air photo), USDA 2009 (Orange County air photo), SFEI 2011 (historic habitats)

Ballona Wetlands. D120367

Figure 25

Historic and Existing Habitats - Seal Beach Wetlands

ESA PWA



San Elijo location_2014-0411ct.mxd

Service Layer Credits: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Ballona Wetlands. D120367

Figure 26
San Elijo Lagoon Location

ESA PWA

San Elijo historic habitats_2014-0410ct.mxd

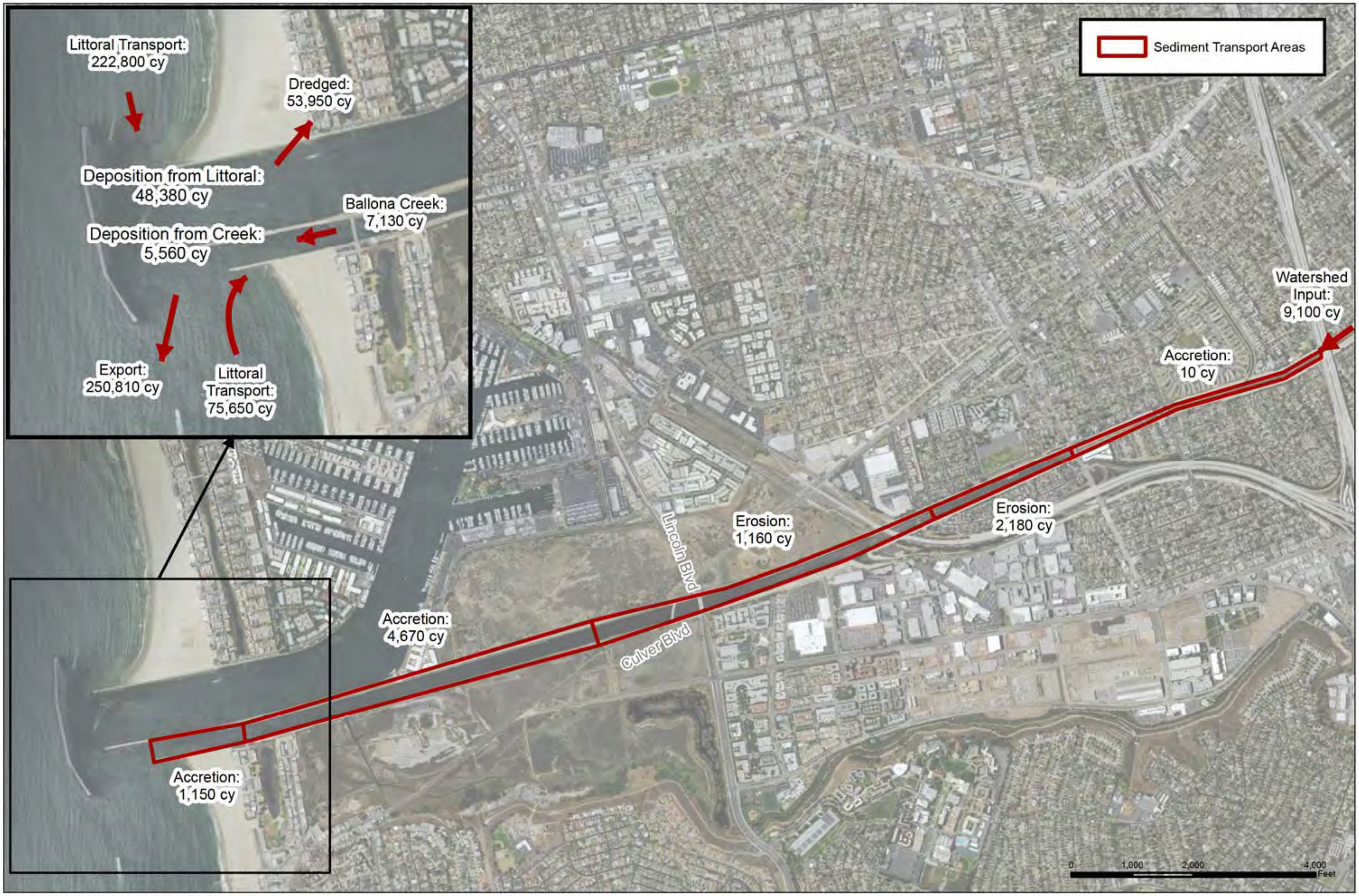
SOURCE: USDA 2010 (San Diego County air photo), SFEI 2011 (historic habitats)

ESA PWA

Ballona Wetlands. D120367

Figure 27

Historic and Existing Habitats - San Elijo Lagoon



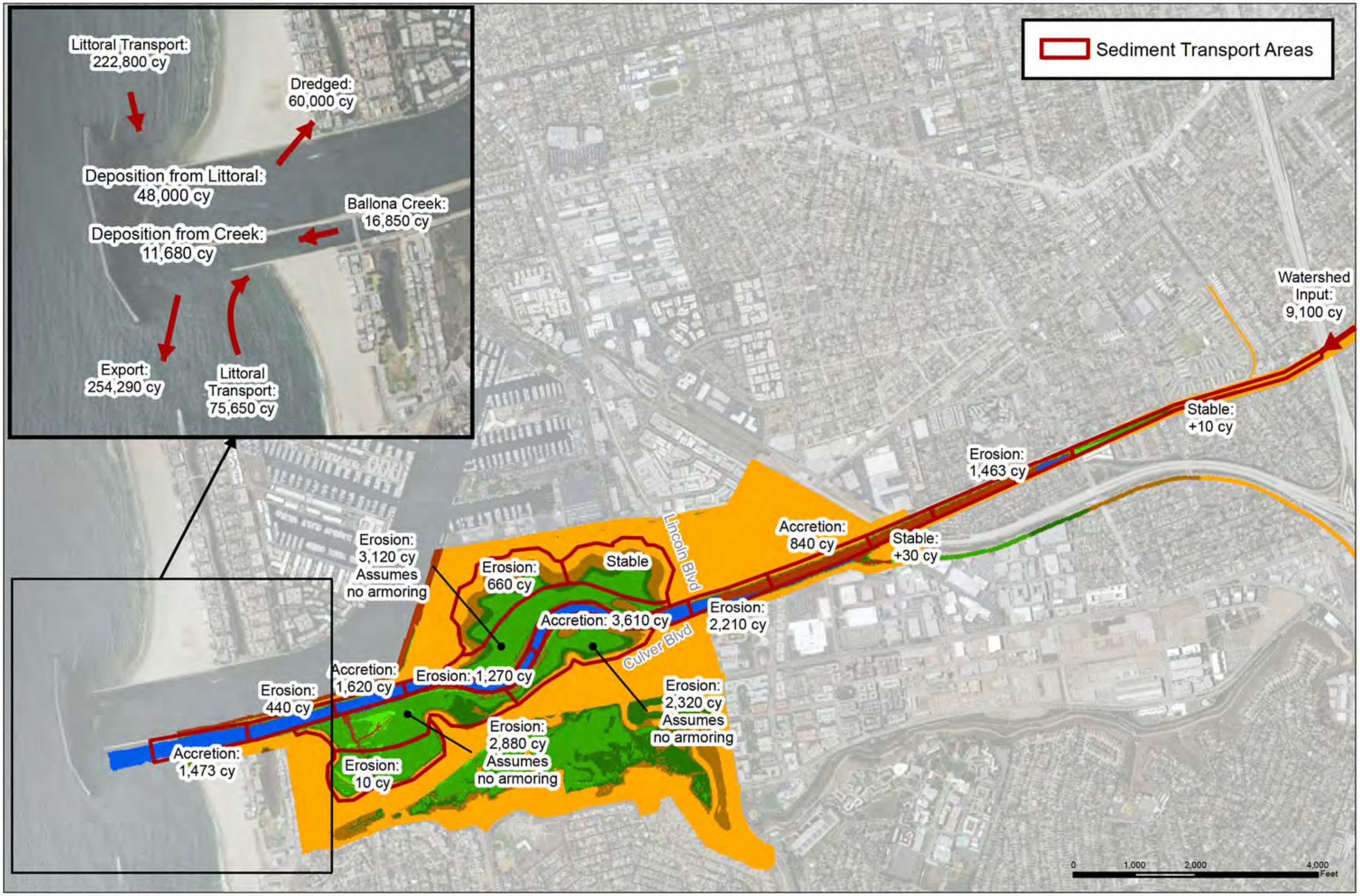
G:\1793_Ballona\Sediment_Transport\BudgetBoxes_EC.mxd

SOURCE: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

ESA PWA

Ballona Wetlands. D120367

Figure 28
Sediment Budget Under Existing Conditions (Average Year)



G:\1793_Ballona\Sediment_Transport\BudgetBoxes_EC.mxd

SOURCE: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

ESA PWA

Ballona Wetlands. D120367

Figure 29
Sediment Budget Under Project Conditions (Average Year)

ATTACHMENT
TIMELINE FOR BALLONA CREEK AND MARINA DEL REY AREAS

Green- In Wetlands/Upstream
Orange- Coastal Structures
Blue- Storm Events
Purple-Dredging/Beach Nourishment
Yellow-Coastal Processes

Year	Item	Reference
1880 (earliest)	Rail lines constructed in wetlands	EPA, 2012
1887	Timber jetties built at Ballona Creek	Leidersdorf, 1994
1900 (earliest)	Roadways constructed in wetlands	EPA, 2012
1904/1905	Venice Pier & Breakwater (breakwater remains)	Shaw, 1980, Tekmarine, 1985, and Leidersdorf, 1994
1905	Major coastal storm	Leidersdorf, 1994
1909	Old Ballona Creek Jetties (no longer exist)	Shaw, 1980 and Tekmarine, 1985
1909	Santa Monica Municipal Pier	Shaw, 1980, Tekmarine, 1985, and Leidersdorf, 1994
1912	Santa Monica Newcombe Pier	Leidersdorf, 1994
1915	Major coastal storm	Leidersdorf, 1994
1916	Flooding	Leidersdorf, 1994
1916-1930	Horseshoe Pier (Redondo Beach)	Leidersdorf, 1994
1923	Standard Oil Pier (El Segundo)	Leidersdorf, 1994
1923-1958	33 groins (Topanga Beach)	Leidersdorf, 1994
1926	Major coastal storm	Leidersdorf, 1994
1926-1937	Monstad Pier (Redondo Beach)	Leidersdorf, 1994
1928 (earliest)	20 groins Sunset Blvd to Santa Monica Pier (4 remain)	Shaw, 1980 and Tekmarine, 1985
1928	Open pile pier (Hermonsa Beach)	Leidersdorf, 1994
1929	Open pile pier (Manhattan Beach)	Leidersdorf, 1994
1930	Oil and gas exploration and production begins in wetlands	EPA, 2012
1931	Major coastal storm	Leidersdorf, 1994
1934	Santa Monica Breakwater	Shaw, 1980, Tekmarine, 1985, and Leidersdorf, 1994
1934	Rubble groin at Venice Beach	Leidersdorf, 1994
Pre-1935	Ocean Park Pier (no longer exists)	Shaw, 1980 and Tekmarine, 1985
1935	Ballona Creek flood control channels begin	SCCWRP, 2011
1937 – 1988	21 bridge crossings constructed over creek throughout watershed	National Bridge Inventory, 2012
1938	Severe flooding	Leidersdorf, 1994
1938 (earliest)	3 groins Santa Monica Pier to Venice Breakwater (2 groins remain)	Shaw, 1980 and Tekmarine, 1985
1938	1,800,000 cy fill from Hyperion facility to Dockweiler Beach	Leidersdorf, 1994
1938	Timber groin (El Segundo)	Leidersdorf, 1994
1938	Ballona Creek jetties	Leidersdorf, 1994
1939	Ballona Creek flood control channels completed	USACE, 1995
1939	Redondo Beach Breakwater	Shaw, 1980 and Tekmarine, 1985
1939	Tropical wave storm	Leidersdorf, 1994
1939	60,000 cy bypass from Santa Monica Breakwater to Santa Monica Beach	Leidersdorf, 1994
1939	North breakwater (King Harbor)	Leidersdorf, 1994
1941	Coastal storm	Leidersdorf, 1994
1945	150,000 cy from Hyperion to Venice Beach	Leidersdorf, 1994

Pre-1946 (earliest)	4-8 groins Ballona Creek to Redondo Beach (4 remain	Shaw, 1980 and Tekmarine, 1985
1946	South Jetty, Marina del Rey, Ballona Creek jetties extended	Shaw, 1980, Tekmarine, 1985, and Leidersdorf, 1994
1946-1948	13,900,000 cy fill from Hyperion to Venice and Dockweiler Beaches	Leidersdorf, 1994
1946-1948	Tombolo formed at Venice Beach after Hyperion fill	Leidersdorf, 1994
Post-1946	Venice Beach groin	Shaw, 1980 and Tekmarine, 1985
1947	3 groins built on Redondo Beach	Leidersdorf, 1994
1947	100,000 cy fill from onshore to Redondo Beach	Leidersdorf, 1994
1948	Groin at El Segundo	Leidersdorf, 1994
1949-1950	960,000 cy bypass from Santa Monica Breakwater	Leidersdorf, 1994
1950-1960	Sawtelle-Westwood system channels completed	USACE, 1995
1951	Two groins at Dockweiler Beach	Leidersdorf, 1994
1951	240,000 cy from Scattergood power plant to Dockweiler Beach	Noble, 2012
1952-1953	Coastal storm	Leidersdorf, 1994
1956	2,400,000 cy from Scattergood power plant to Dockweiler Beach	Leidersdorf, 1994
1957	Marina del Rey construction begins	LA County Department of Beaches and Harbors
1957-1958	780,000 cy bypass from Santa Monica Breakwater	Leidersdorf, 1994
1957-1958	Strong El Nino Winter	Leidersdorf, 1994
1958-1960	North breakwater extended (King Harbor)	Leidersdorf, 1994
1958-1964	South breakwater (King Harbor)	Leidersdorf, 1994
1959	Middle (extended) and North Jetties, Marina del Rey	USACE, 1995 and Leidersdorf, 1994
1960-1962	3,200,000 cy fill from Marina del Rey to Dockweiler	Leidersdorf, 1994
1962	Centinela Creek channel completed	USACE, 1995
1963	6,900,000 cy fill from Marina del Rey to Dockweiler	Leidersdorf, 1994
1963	Marina del Rey breakwater begins	Leidersdorf, 1994
1964	Benedict Canyon system channels completed	USACE, 1995
1965	Offshore breakwater, Marina del Rey completed; marina opened	USACE, 1995 and Leidersdorf, 1994
1968-1969	1,400,000 cy from offshore to Redondo Beach	Leidersdorf, 1994
1969	Flooding	Leidersdorf, 1994
1969	Dredging of Ballona Creek mouth	USACE, 2004
1969	389,000 cy bypass from Marina del Rey	Leidersdorf, 1994
1972-1973	Severe El Nino winter	Leidersdorf, 1994
1973	Dredging of Marina del Rey entrance	USACE, 2004
1973	17,000 cy backpass from Marina del Rey to Venice Beach	Leidersdorf, 1994
1975	10,000 cy bypass from Marina del Rey to Dockweiler Beach	Leidersdorf, 1994
1979-1980	Major coastal storm	Leidersdorf, 1994
1981	Dredging of Marina del Rey entrance and Ballona Creek mouth	USACE, 2004
1981	217,000 cy bypass from Marina del Rey to Dockweiler Beach	Leidersdorf, 1994
1982-1983	Severe El Nino winter, major coastal storms	Leidersdorf, 1994
1983-1984	Groin at El Segundo	Leidersdorf, 1994
1984	Groin at El Segundo	Leidersdorf, 1994
1984	620,000 cy from offshore to El Segundao	Leidersdorf, 1994
1987	Dredging of Marina del Rey entrance and Ballona Creek mouth	USACE, 2004

1987	35,000 bypass from Marina del Rey to Dockweiler Beach	Leidersdorf, 1994
1988	Coastal storm	Leidersdorf, 1994
1988	155,000 cy from Hyperion to Dockweiler	Leidersdorf, 1994
1988-1989	945,000 cy from Hyperion to El Segundo	Leidersdorf, 1994
1992	Dredging of Marina del Rey entrance	USACE, 2003
1994	Dredging of Marina del Rey entrance	USACE, 2003
1996	Dredging of Marina del Rey entrance	USACE, 2003
1996	240,000 cy from Marina del Rey to Dockweiler Beach	Kinnetic Laboratories, 2011
1998	Dredging of Marina del Rey entrance	USACE, 2004
1998	74,000 cy from Marina del Rey to Dockweiler Beach	Kinnetic Laboratories, 2011
1999	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
1999	282,000 cy from Marina del Rey to Redondo Beach	Kinnetic Laboratories, 2011
2004	State Coastal Conservancy funds Ballona Wetlands Restoration Project	State Coastal Conservancy
2007	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
2007	327,000 cy from Marina del Rey to Dockweiler Beach	Kinnetic Laboratories, 2011
2009	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
2009	4,700 cy from Marina del Rey to Dockweiler Breach	Kinnetic Laboratories, 2011
2012	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011

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Contents

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APPENDIX F2
Summary of Results from Sediment Sampling and Analysis in Area B – Ballona Marsh, Draft Technical Memorandum

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TECHNICAL MEMORANDUM – DRAFT

Date: July 22, 2006

To: Jeremy Lowe, PWA

From: David Pohl, PhD., P.E.
Cathy Hartman

Subject: Summary of Results from Sediment Sampling and Analysis in Area B – Ballona Marsh

Purpose of Sediment Investigation

The Draft Ballona Wetland Existing and Historical Conditions Report presented a summary of the available water and sediment quality data for the Project Area and also identified several data needs/gaps in Section 5. One of the unknown factors in the assessment was the sediment quality in the existing tidal marsh within Area B (Ballona Marsh). Although sediment quality results were available from the Ballona Creek estuary, a direct correlation to the current sediment characteristics in Area B could not made due to the significant difference in long-term loading history of these sediments. The sediments in the tidal marsh have experienced muted tidal flows and subsequent reduced constituent loadings while sediments in the Ballona Creek estuary have been subject to the full storm flows and constituent loadings from the entire Ballona Creek watershed. Sediment quality data from Area B is needed to characterize the current baseline condition and evaluate the long-term quality of sediments in the restoration areas and potential impacts to the wetland species.

Sample Location and Study Methods

Eight stations located within Area B were sampled by the City of Los Angeles Department of Sanitation for sediment quality on May 5, 2006 (Figure 1).

Sediments from Area B were analyzed for metals, PAHs, pesticides, PCBs, grain size, and toxicity. Most of the stations (BWS-3, 4, 5, 9, and 10) are within Area B's east channel between Ballona Creek and Culver Blvd. The east channel is connected to Ballona Creek by self-regulating tide gates which allow for muted tidal flow. One station, BWS-1, is located within the west channel, which is connected to Ballona Creek by a 36' pipe with a flap gate on the creek side which prevents tidal flows in while allowing drainage to occur. BWS-8 is located on the southeastern side of Culver Blvd., where it may be influenced by freshwater seeps. BWS-11 is located on the northwestern side of Culver Blvd. where it is likely influenced by storm water and urban runoff.

Figure 1. Sediment Quality Sampling Stations within Area B.

Currently, there are no universally accepted criteria for assessing contaminated sediments. However, the Effect Range Low (ERL) and Effect Range Median (ERM) values originally developed by Long and Morgan (1990) and subsequently revised and expanded upon by Long and MacDonald (1992) and Long et al. (1995) can be used to evaluate the potential for sediment to cause adverse biological effects (Table 1). These parameters were developed from a large data set where results of both sediment toxicity bioassays (e.g., amphipod tests) and chemical analyses were available for individual samples. The guidelines were intended to provide informal (non-regulatory) effects-based benchmarks of sediment chemistry data (Long et al. 1998). Two effects categories have been identified:

ERL – Effects Range Low: concentrations below which adverse biological effects are *rarely* observed and therefore provides a conservative benchmark; and

ERM – Effects Range Medium: concentrations above which adverse biological effects are more frequently, though not always observed.

Sediment chemistry data from samples collected in Area B were compared to the ERM and the more conservative ERL. In addition, for each sediment sample, ERM values were used to calculate a mean ERM quotient (ERM-Q). The concentration of constituents tested was divided by its ERM to produce a quotient, or proportion of the ERM equivalent to the magnitude by which the ERM value is exceeded or not exceeded. The mean ERM-Q for each sample was then calculated by summing the ERM-Qs for selected constituents, and then dividing by the total number of ERM-Qs assessed. ERM-Qs were not calculated for constituents below the detection limit and thus were not used in the generation of the mean ERM-Q. The mean ERM-Q thus represents an assessment for each sample of the cumulative sediment chemistry relative to the threshold values. In this way, the cumulative risks of effect to the benthic community can provide a mechanism to compare channels within the existing marsh to the creek. This method has been used and evaluated by several researchers (Hyland et al. 1999, Carr et al. 1996, Chapman 1996, and Long et al. 1995) throughout the country.

The aggregate approach using an ERM-Q is a more reliable predictor of potential toxicity but should not be used to infer causality of specific contaminants. ERL and ERM values were originally derived to be broadly applicable and they cannot account for site-specific features that may affect their applicability on a more local or regional level. Local differences in geomorphology can result in chemicals being more or less available and therefore more or less toxic than an ERL or ERM value might indicate. Additionally, some regions of the country are naturally enriched in certain metals and local organisms have become adapted.

Table 1. Sediment Effects Guideline Values.

Parameter	Effects Range-Low (ERL)	Effects Range-Median (ERM)
Metals (mg/Kg)		
Antimony	2.0	2.5
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Nickel	20.9	51.6
Zinc	150	410
Organics (µg/Kg)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1,100
Fluorene	19	540
Naphthalene	160	2,100
Phenanthrene	240	1,500
Low-molecular weight PAH	552	3,160
Benz(a)anthracene	261	1,600
Benzo(a)pyrene	430	1,600
Chrysene	384	2,800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5,100
Pyrene	665	2,600
High molecular weight PAH	1,700	9,600
Total PAH	4,022	44,792
Total PCBs	22.7	180

Source: Long et al. 1995
ERL = Concentration at lower tenth percentile at which adverse biological effects were observed or predicted.
ERM = Concentration at which adverse biological effects were observed or predicted in 50% of test organisms.
mg/Kg = milligrams per kilogram.
µg /Kg = micrograms per kilogram.

Summary of Analytical Results

Sediments from Ballona Marsh were analyzed for four groups of constituents: metals, PAHs, pesticides, and PCBs. The key question of this sampling effort was whether known impacted waters from Ballona Creek have also impaired the sediments in the tidal channels within Area B. Concentrations of chemical constituents were expected to be greater in the Ballona Creek estuary sediments compared to Area B, due to greater overall loading from the Ballona Creek watershed. Flow into the existing tidal marsh of Area B has been restricted by tidal gates, and is from the creek estuary where mixing of the fresh water creek flows with the salt water of Santa Monica Bay occurs. However, wetlands are known to act as a sink for lower mobility constituents such as heavy metals and semi-volatile compounds that include PAHs. Additional questions that were to be investigated were whether there was evidence of impacts from historical uses of portions of Area B for agricultural purposes (bean cultivation) and from urban runoff. Area B is subject to urban runoff flows from adjacent residential communities and transportation corridors (Culver Blvd.). Table 2 presents the results of the chemical analysis and toxicity testing.

Metals

The concentrations of metals detected in the sediments samples exceeded the ERM at two of the eleven stations. The concentrations of copper, lead and zinc in the sediment at Station BWS-11 located adjacent to Culver Boulevard were above the ERM indicating potential impact to the sediments. These three metals are typically found in urban runoff and are generally associated with automobile tires, brake pads and emissions. Although these metals are also found at concentrations above the water quality objectives in Ballona Creek, the location of this sample adjacent to Culver Boulevard suggests a direct impact from runoff from the roadway and from direct aerial deposition.

Table 2. Analytical Results for Ballona Marsh Sediments

Parameter	Units	MDL	ERL*	ERM*	BWS-1	BWS-3	BWS-4	BWS-5	BWS-8	BWS-9	BWS-10	BWS-11
Toxicity												
Mean *Eohaustorius estuarius* survival (relative to control)	%				94.79	98.96	91.67	**64.58**	96.88	**<u>34.38</u>**	**60.42**	**<u>9.38</u>**
Sediment Size and TOC												
Gravel	%				0	0	0	0	0	0	0	0
Sand	%				51.2	70.2	79.7	22.8	47.4	37	30.5	47.4
Silt	%				41.8	24	16.6	51.5	46.6	51.5	57.9	45.1
Clay	%				7.11	5.98	3.73	25.8	6	11.5	11.6	7.47
Median size	microns				66	250	360	13	56	40	28	56
Mean size	microns				110	470	470	5.9	140	60	55	55
Total Organic Carbon	%	0.001			0.919	0.777	0.372	0.597	1.15	1.04	0.41	4.64
Metals												
Arsenic	mg/kg	0.22	8.2	70	6.13	3.7	4.26	**12.4**	**10.3**	**8.45**	5.56	**14.6**
Cadmium	mg/kg	0.02	1.2	9.6	**2.39**	**2.12**	**1.83**	**4.5**	**4.66**	**3.67**	**3.32**	**6.16**
Chromium	mg/kg	0.1	81	370	29.2	21.9	18	70.2	52.1	35.4	33.4	64.3
Copper	mg/kg	0.18	34	270	**35.3**	30.6	17	**60.8**	**82.9**	**48.8**	**39.3**	**<u>440</u>**
Lead	mg/kg	0.15	46.7	218	46.6	26.9	20.8	**103**	**92.5**	**62.6**	24	**<u>248</u>**
Mercury	mg/kg	4E-04	0.15	0.71	0.122	0.065	0.041	**0.229**	**0.272**	0.143	0.0976	**0.29**
Nickel	mg/kg	0.2	20.9	51.6	16	13.4	9.2	**30.7**	**27.9**	20.5	**21.7**	**38.5**
Silver	mg/kg	0.02	1	3.7	**1**	0.43	0.27	**<u>3.77</u>**	**1.54**	**1.85**	0.43	0.46
Zinc	mg/kg	0.21	150	410	**155**	109	54.9	**190**	**330**	**192**	124	**<u>1770</u>**
Selenium	mg/kg	0.35			0.48	0.56	0.55	<0.35	1.61	<0.35	0.42	0.55

Parameter	Units	MDL	ERL*	ERM*	BWS-1	BWS-3	BWS-4	BWS-5	BWS-8	BWS-9	BWS-10	BWS-11
PAHs												
Total detectable PAHs	mg/kg		4.022	44.79	0	0	0	0	0	0	0	1.5
Pesticides & PCBs												
Total detectable DDT	ug/kg		1.58	46.1	**3.6**	**17.1**	0	1.2	**7.3**	**5.6**	1	**9.6**
Total detectable chlordane	ug/kg		0.5	6	**4.5**	**51.4**	0	**1.2**	**2.4**	**2.7**	**1.2**	**6.7**
OP Pesticides												
Azinphosmethyl (Guthion)	ug/kg	13.8			<13.8	<13.8	<13.8	<13.8	<13.8	<13.8	<13.8	<13.8
Bolstar	ug/kg	1.5			<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Chlorpyrifos (Dursban)	ug/kg	1.6			<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
Coumaphos	ug/kg	13.5			<13.5	<13.5	<13.5	<13.5	<13.5	<13.5	<13.5	<13.5
Def	ug/kg	3.5			<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5
Demeton (Total)	ug/kg	2.5			<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Diazinon	ug/kg	2			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Dichlorvos	ug/kg	3.3			<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Dimethoate	ug/kg	4.91			<4.91	<4.91	<4.91	<4.91	<4.91	<4.91	<4.91	<4.91
Disulfoton	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
EPN	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Ethion	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Ethoprop	ug/kg	1.4			<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4
Fensulfothion	ug/kg	18.7			<18.7	<18.7	<18.7	<18.7	<18.7	<18.7	<18.7	<18.7
Fenthion	ug/kg	2.7			<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7
Malathion	ug/kg	0.6			<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Merphos	ug/kg	4.5			<4.5	<4.5	<4.5	<4.5	<4.5	<4.5	<4.5	<4.5
Mevinphos	ug/kg	5.2			<5.2	<5.2	<5.2	<5.2	<5.2	<5.2	<5.2	<5.2
Naled	ug/kg	17			<17	<17	<17	<17	<17	<17	<17	<17
Parathion, ethyl	ug/kg	2.75			<2.75	<2.75	<2.75	<2.75	<2.75	<2.75	<2.75	<2.75
Parathion, methyl	ug/kg	3.4			<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4
Phorate	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Prowl (Pendimethalin)	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	300
Ronnel	ug/kg	1.4			<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4
Stirophos	ug/kg	6.2			<6.2	<6.2	<6.2	<6.2	<6.2	<6.2	<6.2	<6.2
Sulfotep	ug/kg	1.14			<1.14	<1.14	<1.14	<1.14	<1.14	<1.14	<1.14	<1.14
Tokuthion	ug/kg	1.8			<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Trichloronate	ug/kg	1.3			<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3
Trifluralin	ug/kg	4.4			<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4
Pyrethroids												
Bifenthrin	ug/kg				ND	ND	ND	ND	ND	ND	ND	34J
Cyfluthrin	ug/kg				ND	ND	ND	ND	ND	ND	ND	ND
Cypermethrin	ug/kg				ND	ND	ND	ND	ND	ND	ND	ND
Esfenvalerate/Fenvalerate	ug/kg				ND	ND	ND	ND	ND	ND	ND	ND
Lambda cyhalothrin	ug/kg				ND	ND	ND	ND	ND	ND	ND	ND
Permethrin	ug/kg				ND	ND	ND	ND	ND	ND	ND	ND
PCBs												
Total detectable PCBs	ug/kg		22.7	180	16	**25**	0	0	0	**36**	0	**24**
Mean ERM quotient					0.22	0.80	0.07	0.32	0.32	0.26	0.15	0.84

MDL = Method Detection Limit is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as defined in 40 CFR Part 136 Appendix B.

* Effects Range-Low and Effects Range-Median (Long et al. 1995)

Toxicity results in **bold** = moderately toxic (per Bight criteria)

Toxicity results in **bold** = highly toxic (per Bight criteria)

Chemistry results in **bold** = exceeds ERL

Chemistry results in **bold** = exceeds ERM

J - Estimated value

The other sediment sample that was observed to exceed the ERM was at BWS-5 for silver. The more conservative ERL benchmark was exceeded at numerous locations as shown on Table 2. The greatest number of exceedances is observed at Stations BWS-5, -8, -9 and -11. A summary of the results are presented below.

- *Arsenic* concentrations were above the more conservative ERL benchmark of 8.2 mg/kg at four stations; BWS-5, BWS-8, BWS-9, and BWS-11. Values ranged from 8.45 to 14.6 mg/kg at BWS-11. However, none approached the 70 mg/kg ERM.

- *Cadmium* concentrations were above the more conservative ERL of 1.2 mg/kg at all stations sampled. Values ranged from 1.83 mg/kg at BWS-4 to 6.16 mg/kg at BWS-11. However, none exceeded the ERM value of 9.6 mg/kg.

- *Copper* concentrations were above the ERL benchmark of 34 mg/kg at six out of eight stations. The concentrations at these stations ranged from just above the ERL at BWS-1 to 83 mg/kg at BWS-8. The concentrations were above the ERM of 270 mg/kg at BWS-11 with a detected value of 440 mg/kg.

- *Lead* concentrations were above the more conservative ERL of 46.7 mg/kg at four stations that included BWS-5, -8, -9 and -11. However, there the ERM of 218 mg/kg was exceeded at only at BWS-11 (248 mg/kg).

- *Mercury* concentrations were above the ERL of 0.15 mg/kg at three stations but had no exceedances of the ERM of 0.71 mg/kg. Exceedances at stations BWS-5, -8, and -11 ranged from 0.229 to 0.29 mg/kg.

- *Nickel* concentrations were above the more conservative ERL of 20.9 mg/kg at four stations. Exceedances at stations BWS-5, -8, -10, and -11 ranged from a low of 21.7 mg/kg at BWS-10 to a high of 38.5 mg/kg at BWS-11. The 20.5 mg/kg detected at BWS-9 fell just below the ERL. Nickel was not detected at any stations at levels above the ERM.

- *Silver* was detected at levels above the more conservative ERL of 1 mg/kg at four stations, including one exceedance of the ERM of 3.7 mg/kg. Stations BWS-1, -8, and -9 were each detected at concentrations between 1 and 1.85 mg/kg. The single exceedance of the ERM was at BWS-5, at which a concentration of 3.77 mg/kg was detected.

- *Zinc* exceeded the ERL of 155 mg/kg at five stations, including one exceedance of the ERM of 410 mg/kg. Samples collected from stations BWS-1, -5, -8, and -9 were each found to have concentrations between 155 mg/kg at BWS-1 and 330 mg/kg at BWS-8. The single exceedance of the ERM was at BWS-11, where a concentration of 1,770 mg/kg was detected.

PAHs

Total detectable PAHs were only detected at BWS-11 with a value of 1.5 mg/kg, below the ERL of 4.02 mg/kg. The results indicate no impact to the sediments of Area B from PAHs.

Pesticides

The concentration of organochlorine pesticides (OP pesticides) in the sediment samples in Area B exceeded the ERM at two (BWS-3 and -11) of the eleven locations for total detectable chlordane. Station BWS-3 is located adjacent to the tide gate in the main channel. Due to the location of this sample, the results indicate a potential impact from waters of Ballona Creek on the sediment near the tide gates with regard to chlordane. There were no other exceedances of the ERM in the main channel, and the concentrations of chlordane deceased in the main channel with greater distance from the tidal gate. The exceedances at BWS-11 of the ERM may be the result of impact from urban runoff at this location adjacent to Culvert Blvd. There were no other detections of pesticides above the ERM.

Other organochlorine pesticides detected, for which there are no current ERL/ERM guidelines, include nonachlors, enfosulfans, and oxychlordane. Cis-nonachlor was detected at station BWS-3, at a concentration of 5.4 µg/kg and at BWS-11 at a concentration of 2.9 µg/kg. Trans-nonachlor was detected at six of the eight stations at values ranging from a low of 0.4 µg/kg at BWS-5 to a high of 16.6 µg/kg at BWS-3. No nonachlors were detected at BWS-4 or BWS-8. Endosulfan I was detected at BWS-1 at a concentration of 0.6 µg/kg. Oxychlordane was detected at BWS-11 at a concentration of 1.3 µg/kg. OP pesticides and pyrethroids were also detected at BWS-11.

Total detectable DDT exceeded the ERL at five stations, BWS-1, -3, -8, -9, and -11, with values ranging from 3.6 µg/kg at BWS-1 to 17.1 µg/kg at BWS-3. Total detectable DDT was below the ERL value at BWS-5 and BWS-10 and was not detected at BWS-4. No levels were detected above the ERM of 46.1 µg/kg.

Total detectable chlordane exceeded the ERL of 0.5 µg/kg at seven out of eight sampled stations and the ERM of 6 µg/kg at two stations. No chlordanes were detected at BWS-4. The ERM was exceeded at BWS-3 and BWS-11, with respective values of 51.4 µg/kg and 6.7 µg/kg.

Dieldrin was detected in three of the eight stations sampled. Values above the ERL of 0.02 µg/kg ranged from 1 µg/kg at BWS-9 to 1.3 µg/kg at BWS-1 to 2.4 µg/kg at BWS-3. The remaining five stations were non-detect, however, the method detection limit for this constituent was 0.8 µg/kg, a higher value then the ERL. These five stations may in fact have exceeded the ERL if they were between 0.02 and 0.8 µg/kg. No samples exceeded the ERM of 8 µg/kg.

One OP pesticide and one pyrethroid were detected at levels above their method detection limits at BWS-11. Prowl (pendimethalin) was detected at concentrations of 300 µg/kg and bifenthrin at an estimated value of 34 µg/kg. These analytes are emerging contaminants of concern and do not have established ERLs or ERMs. Pendimethalin is an OP pesticide known as Prowl that is used as an herbicide and is considered of low acute toxicity (http://www.epa.gov/epaoswer/hazwaste/minimize/factshts/pendmeth.pdf). Bifenthrin is a pyrethroid insecticide and miticide classified as "Restricted Use" due to toxicity to fish and aquatic organisms; its use is prohibited in areas where it may result in exposure of endangered species (http://www.fs.fed.us/foresthealth/pesticide/bifenthr.html). That these two pesticides were found only at BWS-11, where the primary influence is stormwater runoff and urban flows, may indicate that those flows are a transport mechanism. These constituents were not analyzed in sediments collected from the Ballona Creek estuary in 2003.

PCBs

There were no detections of PCBs in the sediment samples above the ERM. Total detectable PCBs exceeded the ERL of 22.7 µg/kg at three stations, BWS-3, BWS-9, and BWS-11. The exceedances ranged from 24 and 25 µg/kg at BWS-11 and BWS-3 to 36 µg/kg at BWS-9.

ERM –Q Results

ERM-Q values were above the threshold of 0.10 at seven of the eight stations monitored in Area B. Only BWS-4 had a mean ERM-Q value below 0.10, with a value of 0.07. The highest ERM-Q was calculated for the sediment samples from BWS-3 and BWS-11. As discussed above, the ERM-Q represents an assessment of the cumulative sediment chemistry relative to the threshold values. The high ERM-Q for BWS-3 is driven by the higher chlordane concentration. This sample is located the closest to the tide gates to Ballona Creek and therefore indicates a potential impact from tidal flows into the main channel from the creek. The ERM-Q for sample BWS-11 is driven by both metals and pesticide concentrations. BWS-11 is located adjacent to Culver Blvd and appears to be impacted by urban runoff. ERM-Q values for the samples between BWS-11 and BWS-3 along the main channel decease with distance from the tide gates (0.26, 0.15 and 0.07) indicating decreasing impact from Ballona Creek, and localized impact from urban runoff.

<u>Summary of Acute Testing Results</u>

The mean percent survival of the test organism, *E. estuarius,* exposed to Ballona Marsh sediments ranged from 9 to 99%. Percent survival was the lowest at stations BWS-9 and BWS-11, with values of 34% and 9%, respectively. Station BWS-9 is the second sampling location from the tide gates to Ballona Creek. The concentrations of metals, pesticides and PCBs in BWS-9 were not significantly greater than the other samples located in the main channel, and the ERM-Q of this sample was 0.26, compare to the ERM-Q of 0.80 at BWS-3 located closest to the tide gate. These results for BWS-9 suggest a possible constituent or physical condition that is resulting in toxic response as opposed to from the concentration of the constituents analyzed for this program. Further testing may be needed to determine the cause of the toxicity response.

The toxic response observed for BWS-11 corresponds to detected higher concentrations of metals and several pesticides in this sample. The toxicity results also correspond to the ERM-Q value for this sample, which is the highest of the eleven samples. The results for BWS-11, which is located in a tributary channel adjacent to Culver Blvd., indicate a potential impact from urban runoff that is resulting in toxic response to aquatic organisms.

The mean percent survival of *E. estuarius* at BWS-5 and BWS-10 were 65% and 61%, suggesting that the sediments in these areas were moderately toxic to the test organisms. The remaining stations had a mean percent survival range between 92 and 99%, which suggests that the sediments in this area did not demonstrate an acute toxic response.

Summary of Geotechnical Testing Results

Sand, silt, and clay were the dominant sediment constituents at the stations monitored in the Ballona Marsh. Sand dominated the sediment composition at five stations, BWS-1, -3, -4, -8, and -11, followed by silt. Silt was the dominant constituent at BWS-5, followed by clay, and at BWS-9 and -10, followed by sand. Median grain size ranged from 13 to 360 microns. TOC content ranged from 0.37 to 4.64%. Station BWS-4 had the largest median grain size and the lowest TOC content.

Conclusions

The key question of this sampling effort was:

Have known impacted waters from Ballona Creek also impaired the sediments in the tidal channels within Area B?

Concentrations of chemical constituents were expected to be greater in the Ballona Creek estuary sediments compared to Area B, due to greater overall loading from the Ballona Creek watershed. The results of this sediment sampling and testing program in Area B indicate that the sediment close to the tide gate is potentially impacted by pesticides, specifically chlordane and DDT from Ballona Creek. Concentrations of chlordane and DDT decrease in concentration with distance from the tide gates. The impact from Ballona Creek on the sediments in Area B with regard to metals is not conclusive, and the results indicate other sources of metals. The physical characteristics of the sediment also influence the concentration of metals detected. Sediment with higher fraction of clay (BWS-5) exhibit will exhibit a greater adsorption capacity for metals.

Additional questions that were to be investigated were whether there was evidence of impacts from historical uses of portions of Area B for agricultural purposes (bean cultivation) and from urban runoff. Area B is subject to urban runoff flows from adjacent residential communities and transportation corridors (Culver Blvd.). The following results of this investigation indicated a strong connection to exceedances of sediment guidelines and toxicity response to potential impacts from urban runoff:

- The concentrations of copper, lead and zinc in the sediment at Station BWS-11 located adjacent to Culver Boulevard were above the ERM indicating potential impact to the sediments. These three metals are typically found in urban runoff and are generally associated with automobile tires, brake pads and emissions. Although these metals are also found at concentrations above the water quality objectives in Ballona Creek, the location of this sample adjacent to Culver Boulevard suggests a direct impact from runoff from the roadway and from direct aerial deposition.

- The concentration of organochlorine pesticides (OP pesticides) in the sediment samples in Area B exceeded the ERM at two (BWS-3 and -11). The exceedances at BWS-11 of the ERM may be the result of impact from urban runoff at this location adjacent to Culvert Blvd.

These conclusions are further supported from the calculated ERM-Q. The highest ERM-Q was calculated for the sediment samples from BWS-3 and BWS-11. The ERM-Q represents an assessment of the cumulative sediment chemistry relative to the threshold values. The high ERM-Q for BWS-3 is driven by the higher chlordane concentration. This sample is located the closest to the tide gates to Ballona Creek and therefore indicates a potential impact from tidal flows into the main channel from the creek. The ERM-Q for sample BWS-11 is driven by both metals and pesticide concentrations. BWS-11 is located adjacent to Culver Blvd and appears to be impacted by urban runoff. ERM-Q values for the samples between BWS-11 and BWS-3 along the main channel decease with distance from the tide gates (0.26, 0.15 and 0.07) indicating decreasing impact from Ballona Creek, and localized impact from urban runoff.

The results of the toxicity testing indicate the percent survival was the lowest at stations BWS-9 and BWS-11, with values of 34% and 9%, respectively. Station BWS-9 is the second sampling location from the tide gates to Ballona Creek. The concentrations of metals, pesticides and PCBs in BWS-9 were not significantly greater than the other samples located in the main channel, and the ERM-Q of this sample was 0.26, compare to the ERM-Q of 0.80 at BWS-3 located closest to the tide gate. These results for BWS-9 suggest a possible synergistic effect of the constituents that were detected (many above the ERL as discussed below), or from another possible constituent or physical condition that was not tested or specifically identified as part of this project. Further testing may be needed to determine the cause of the toxicity response.

The toxic response observed for BWS-11 corresponds to detected higher concentrations of metals and several pesticides in this sample. The toxicity results also correspond to the ERM-Q value for this sample, which is the highest of the eleven samples. The results for BWS-11, which is located in a tributary channel adjacent to Culver Blvd., indicate a potential impact from urban runoff that is resulting in toxic response to aquatic organisms.

Comparisons to the more conservative ERL guidelines indicated the greatest number of exceedances observed at Stations BWS-5, -8, -9 and -11. The higher number of exceedances at BWS-11 corresponds to the highest ERM-Q and toxicity response of the sediment samples. As stated above, these results indicated potential impact from urban runoff as this sample is located adjacent to Culver Blvd and is subject to runoff from this roadway. The higher number of exceedances of the conservative ERL at the other locations may be a function of higher clay fraction in the case of BWS-5, and urban runoff/fresh water input at BWS-8. The higher number of exceedances observed at BWS-9, located in the main channel further inland from BWS-3 and the tide gates to the Creek may be due to possible impacts from Ballona Creek. However, a defined concentration gradient for metals is not evident. Furthermore, although a toxic response was observed for the BWS-9 sample, a defined correlations to the constituent concentrations detected is not well evident when compared to the concentrations of these constituents in samples that did not show a toxic response. Further investigation of these results is recommended.

The existing marsh is also not open to full tidal flow, but muted flow controlled by the tide gates. Sediment quality data collected from the Ballona Creek estuary during the 2003 Bight program also shows metals exceedances of copper, lead, and zinc. Higher concentrations than the Ballona Creek sediment samples are observed in sample BWS-11 as presented in Table 3. This samples is likely impacted by urban runoff from Culver Blvd. Higher concentrations were also observed in samples BWS-3, -5, -8 and -9. Cadmium exceeded the ERL at each station sampled within Area B, but did not exceed criteria within Ballona Creek sediments sampled during the 2003 Bight program. It was reported to have exceeded the ERL in Ballona Creek sediments in the draft Total Maximum Daily Load report for Toxic Pollutants in Ballona Creek Estuary (CRWQCB & US EPA, Region IX, 2005). Cadmium has not been found to exceed water quality criteria within Ballona Creek.

Table 3. Range of Values for Constituents Found to Exceed within Ballona Marsh and Ballona Creek Estuary Sediments

	Ballona Marsh		Ballona Creek
	Range	Max	Estuary Range
Metals (mg/kg)			
Arsenic	3.7 – 14.6	BWS-11	2.37 – 4.01
Cadmium	1.83 – 6.16	BWS-11	0.13 – 0.96
Chromium	18 – 70.2	BWS-5	10.6 – 21.9
Copper	17 – 440	BWS-11	10.6 – 36.4
Lead	20.8 – 248	BWS-11	12.7 – 111
Mercury	0.041 – 0.29	BWS-11	0.03 – 0.11
Nickel	9.2 – 38.5	BWS-11	7.6 – 13.3
Selenium	<0.35 – 1.61	BWS-8	NA
Silver	0.27 – 3.77	BWS-5	0.36 – 0.87
Zinc	54.9 – 1770	BWS-11	73.5 – 202
PAHs (mg/kg)			
Total detectable PAHs	0 – 1.5	BWS-11	0.069 – 1.93
Pesticides and PCBs (ug/kg)			
Total detectable DDT	0 – 17.1	BWS-3	0 – 17.3
Total detectable chlordane	0 – 51.4	BWS-3	0 – 21.6
Prowl (Pendimethalin)	<1.8 – 300	BWS-11	NA
Bifenthrin	ND – 34J	BWS-11	NA
Total detectable PCBs	0 – 36	BWS-9	0 – 8

This comparison to the Ballona Creek sediments indicates the following:

- Most of the exceedances of the sediment guidelines within Area B were found in tributaries of the main channel both near the tidal inflow from the creek and at locations that are subject to urban runoff and fresh water flows from groundwater seeps.

- Area B may be acting as a sink for these metals that migrate to Area B in suspended sediment from Ballona Creek. Concentrations are in some locations greater in Area B possibly due to the control of tidal flows that limits the level of circulation and flushing that is observed in the Ballona Creek estuary, even through the creek estuary is subject to greater constituent loading.

- Urban Runoff and aerial deposition from Culvert Blvd. is impacting the sediments in the existing channels adjacent to the primary transportation corridor for Playa del Rey. As presented in Table 3, the majority of the highest concentrations of metals were detected in the sediment at BSW-11 located adjacent to Culver Blvd.

- Urban Runoff from adjacent communities and from portions of Area B that have been filled and subject to agricultural and oil/gas extraction may be contributing to metals concentrations in the channel sediments subject to these flows.

- It appears that metals from Ballona Creek could be accumulating in marsh sediments due to lack of tidal flushing, or there may be a source of metals other than Ballona Creek, such as urban runoff and stormwater flows from Culver Blvd. For constituents such as copper and zinc, where the highest values found in the marsh exceed those found in the creek by up to 10 times, a secondary source seems likely.

Steps Forward

Based on the results and conclusion of this sediment investigation of Area B, the following steps forward are recommended:

1. The benthic data that has been collected by the City of Los Angeles Department of Sanitation should be obtained and compared to the analytical and toxicity testing results from this study in order to determine if there is a correlation between higher constituent concentrations and/or toxicity response to the health of the benthic community. These data provide an additional set of results that will allow for further conclusions on the potential impact of sediments on the restored habitat. Evidence of benthic community impact will confirm results showing exceedances of sediment guidelines and/or toxic responses. These data may also indicate that there is little impact to the benthic community and therefore the chemistry and toxicity data do not provide the full picture with regard to the bioavailability of the constituents detected.

2. Results from Bight03 for other coastal wetlands should be compared to the results from this study to determine the level of impact compared to other wetlands in the region.

3. In order to better assess the potential impact of constituents detected in sediments and on the marsh habitat, tissue sampling and analysis of target species is recommended. Tissue sampling and analysis will provide data on the bioavailability and bioaccumulation of the constituents in the environment. Although several constituents were detected above the sediment guidelines, the actual impact to the species in the marsh needs to be assessed.

4. The alternative development for Area B should consider the evidence of impact from urban runoff and evaluate options to divert and treat these flows prior to their discharge into Area B.

5. Further evaluation of the future contribution/loads of legacy pesticides (chlordane and DDT) in the Ballona Creek estuary and potentially into Area B under muted tidal and full tidal flows should be performed to determine potential long-term impacts to the restored tidal wetlands.

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APPENDIX F3

Final Report – Ballona Wetland Preserve – Area A Preliminary Geotechnical Investigation and Beneficial Use Assessment

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Ballona Wetland Preserve - Area A Preliminary Geotechnical Investigation And Beneficial Use Assessment

Final Report

Prepared For:

Port of Los Angeles
Environmental Division
425 South Palos Verdes Street
San Pedro, CA 90731

April 2009

Ballona Wetland Preserve - Area A
Preliminary Geotechnical Investigation
and
Beneficial Use Assessment

Final Report

Prepared For:

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April 2009

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1.0 INTRODUCTION

1.1 Site Background

The Ballona wetland Preserve Area A is a 139 acre portion of the Ballona Wetlands Ecological Reserve, an area currently under evaluation for restoration as part of the Ballona Wetlands Restoration Project (Restoration Project). The Restoration Project is led by the California Coastal Conservancy (CCC) and the current owner, California Department of Fish and Game (CDFG). A feasibility analysis of several restoration alternatives is currently underway. These alternatives include a range of options from enhancement of existing upland habitats to restoration of full tidal flow and establishment of a diverse community of sub-tidal, tidal, and upland habitats. The Port of Los Angeles (POLA) is currently evaluating the potential of Area A as a possible wetland mitigation site, pending the analysis of the full tidal alternative costs and potential credits.

Historical uses of Area A have changed the topography from a tidal wetland to disturbed upland habitat. The construction of railroads in the 1900s placed fill in the southeast corner to elevate the tracks above tidal elevation. Parts of Area A were also filled in the 1920s when gas and oil production began in the area. Platforms to protect the oil and gas facilities from high tides were constructed and connected by a series of access roads, which were also elevated on fill. Area A was altered during the channelization of Ballona Creek in the 1930s and during the excavation of Marina del Rey Harbor in the 1960s when the site received a large volume of dredge material. Appendix A provides historical photographs of the study area showing these changes.

The site is currently fenced off and undeveloped except for a paved parking area along the western boundary. Figure 1-1 presents a current aerial view of Area A. Fiji Ditch, a tidal channel connected to Basin H of Marina del Rey Harbor, starts in the middle of the northern edge of the site and runs east and west. A great blue heron rookery exists on the western edge of the site. Sempra Utilities monitoring wells are located just south of the rookery. Unauthorized use of the site is extensive. Construction of earthen jumps for off-road vehicle use has created many shallow depressions throughout the area, which compacts soil and collects water. It was estimated that 200–300 individuals were encamped within Area A in May 2006.

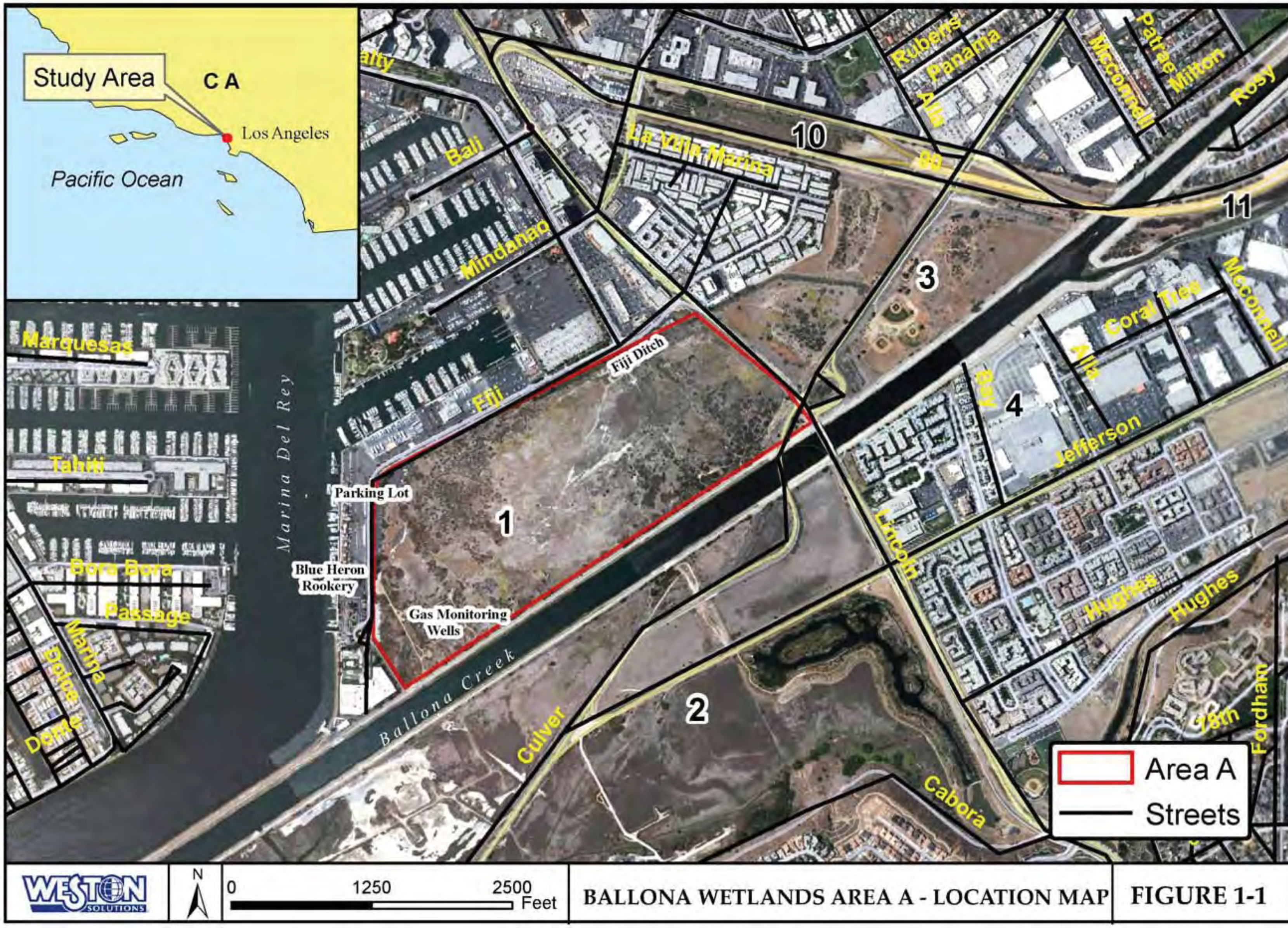

Figure 1-1. Ballona Wetland Preserve – Area A Location Map

In order to evaluate the potential of Area A as a possible wetland mitigation site, several alternatives were being assessed by CDFG and CCC. The United States Fish and Wildlife Service (USFWS) introduced Alternative 4, which was determined by POLA to provide the best opportunity for mitigation credits and a high-end estimate of mitigation costs.

A total of five distinct alternatives were being assessed for the Restoration Project. Each of the five alternatives were developed based on original conceptual designs that considered tidal sources, water quality, and developing sustainable habitats with sufficient transition zones to accommodate soil settlement and sea level rise. It was determined during this process that the open water channels needed to be located on one side of the site in order to establish sufficient transitional zones on the opposite side due to the 20–30 foot elevation differences from the open water to the upland areas. Each of these alternatives includes two inlets in order to provide sufficient tidal flow and circulation within the restored tidal marsh. The conceptual location of the inlet from the main channel of Marina del Rey can be relocated based on the proposed development in this area. Influent water from the main channel is preferred to the back basins and from Ballona Creek due to the water quality issues associated with these water sources.

Figure 1-2 presents Alternative 4, which is being evaluated as part of the Restoration Project. A corresponding cross section describing the depth of excavation and habitat elevation grade is provided on Figure 1-3. In order to begin evaluating the feasibility of using Area A as wetland mitigation site, POLA has contracted Weston Solutions, Inc. (WESTON) to conduct a Preliminary Geotechnical Investigation and Beneficial Use Assessment (Preliminary Area A Study) of the existing dredged material in Area A.

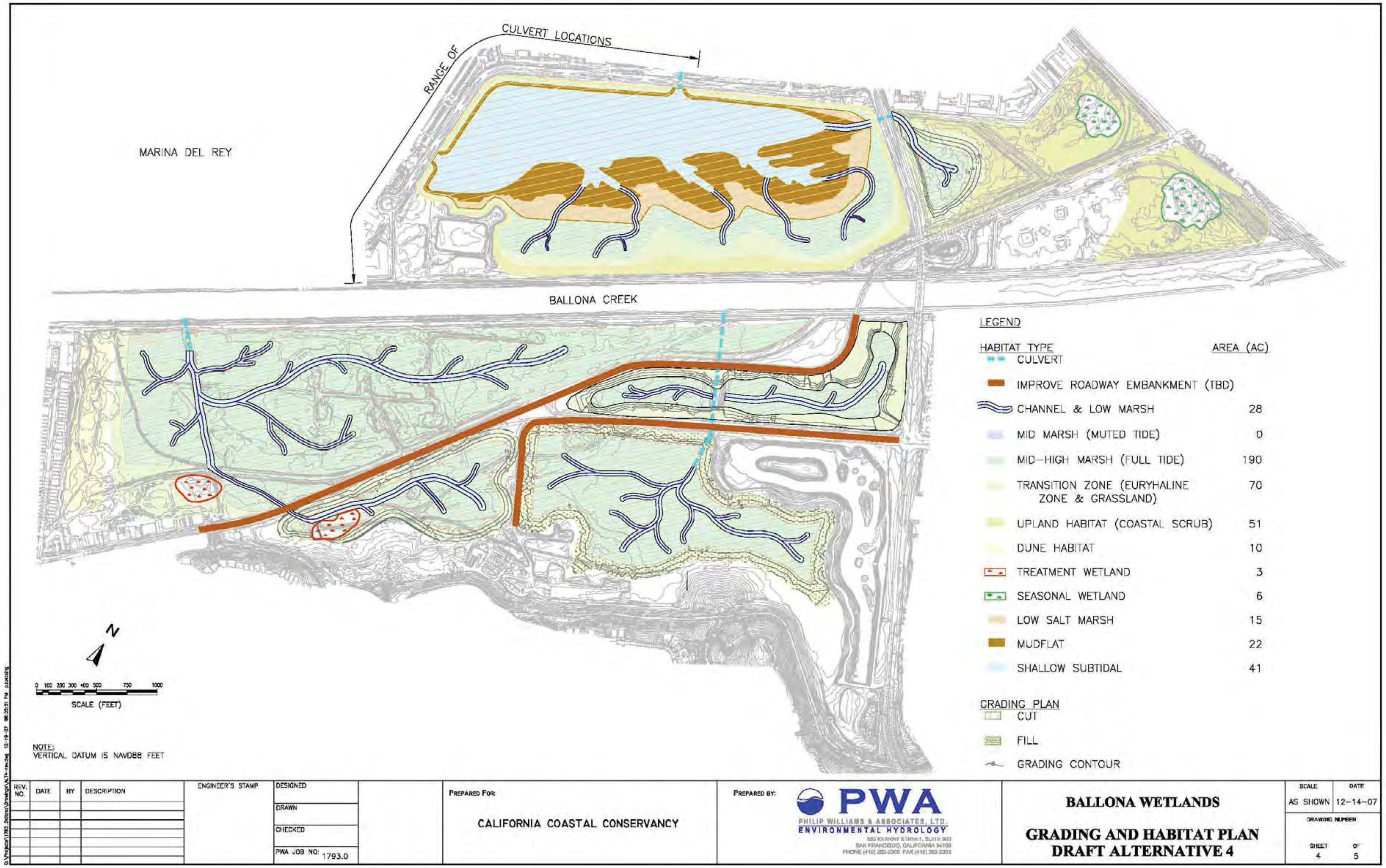

Figure 1-2. Ballona Wetland Restoration Project - Alternative 4

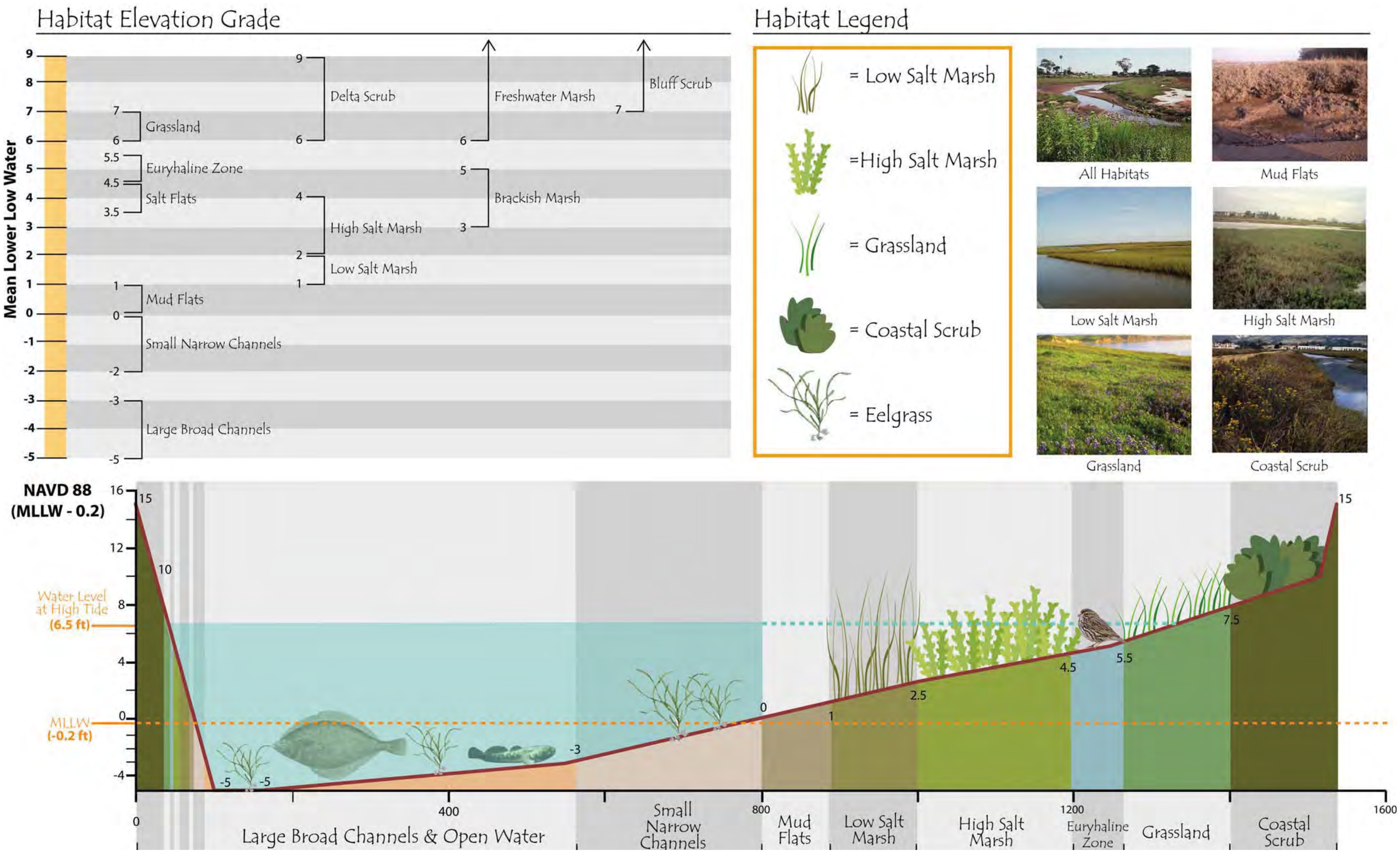

Figure 1-3. Cross Section of the Potential Tidal Restoration – Alternative 4

1.2 Scope of Work

The objectives of the Preliminary Area A Study were to identify the geotechnical, chemical, and physical characteristics of the soil and existing dredged material, determine the potential uses of the dredged material, and assess the cost associated with excavating and transporting the material. This screening level assessment will be used to guide a future, regulatory-compliant beneficial use assessment or dredge material evaluation for ocean disposal. The goal of this project was to answer the following study questions and provide recommendations to POLA.

Questions:

1. What are the chemical characteristics of the soil in Area A that are important to determine the required handling and use of the dredged material if removed to establish tidal flow?
2. Does the dredge material contain constituents of concern (COCs) at concentrations which require special handling or disposal due to historical gas extraction, or does it contain constituents, such as legacy pesticides, that may have existed in the dredged material prior to placement in Area A?
3. Will leachate from the dredge material contain COCs?
4. Are there chemical constituents in the soil that will remain a potential long-term risk to the ecosystem of the restored wetland?
5. What are the potential beneficial use and disposal options of the dredged material?
6. What are the geotechnical characteristics of the dredge material, including grain size distribution, that are key in determining potential beneficial uses of excavated material and the use of the dredge material for restoration?
7. Can the excavated dredge material be used for upland habitat in Area A?
8. What is the variability of grain size across Area A, with depth across the site, which may require segregation of materials for specific uses?
9. What is the volume of dredge material on site, and what level of assessment is necessary to attain regulatory compliance for beneficial uses?

Due to the unknown characteristics of the existing materials, a phased approach was recommended to address the questions listed above. This Preliminary Area A Study represents an initial assessment of the existing dredged material with regard to handling, placement, and potential beneficial uses. The Preliminary Area A Study consisted of three phases as presented on Figure 1-4.

- **Phase I** - included the analysis of existing geotechnical and groundwater data, review of historical and current topographical maps, completion of a field reconnaissance to identify possible sample location logistical and access issues, and preparation of a Study Work Plan. The Preliminary Area A Study Work Plan was prepared prior to permitting and field activities in order to identify the sampling locations and methods for the field and laboratory activities. The draft Study Work Plan was submitted to POLA for review. Comments from POLA were incorporated, and a draft final Study Work Plan was prepared and sent to CCC and CDFG for comment. Comments from these agencies were then incorporated, and the Final Study Work Plan was completed and submitted to POLA on December 12, 2007. Phase I also included completion of required access permit documents and access requests to the site for the geotechnical borings. WESTON worked with CDFG in the location of boreholes and drill rig access routes to avoid sensitive vegetation/habitat. Permits for site access were granted on October 26, 2007 (Appendix B).

- **Phase II**: included completion of the geotechnical borings and soil sampling within Area A in accordance with the approved Study Work Plan. Field activities began on February 5, 2008 and were completed on February 8, 2008. Phase II also included the site selection, drilling, soil sampling, and laboratory analysis of the soil samples for geotechnical and chemical characterization.

- **Phase III:** included quality assurance/quality control (QA/QC) of the laboratory data, compilation of the geotechnical and chemical results, assessment of the results, and preparation of this report. The report describes the field and laboratory activities performed, results of the sample testing, and findings from these results. Results from this investigation were used to address the study questions developed in the scope of work.

First, this report provides a summary of the methods used for the field and laboratory program (Section 2). Section 3 provides the data interpretation and analysis of the findings with regard to the key project questions. Section 4 presents the updated cost estimate for the proposed Alternative 4 based on the findings of the Preliminary Area A Study. Finally, recommendations for the future regulatory-compliant assessment of the beneficial uses are included in Section 5.

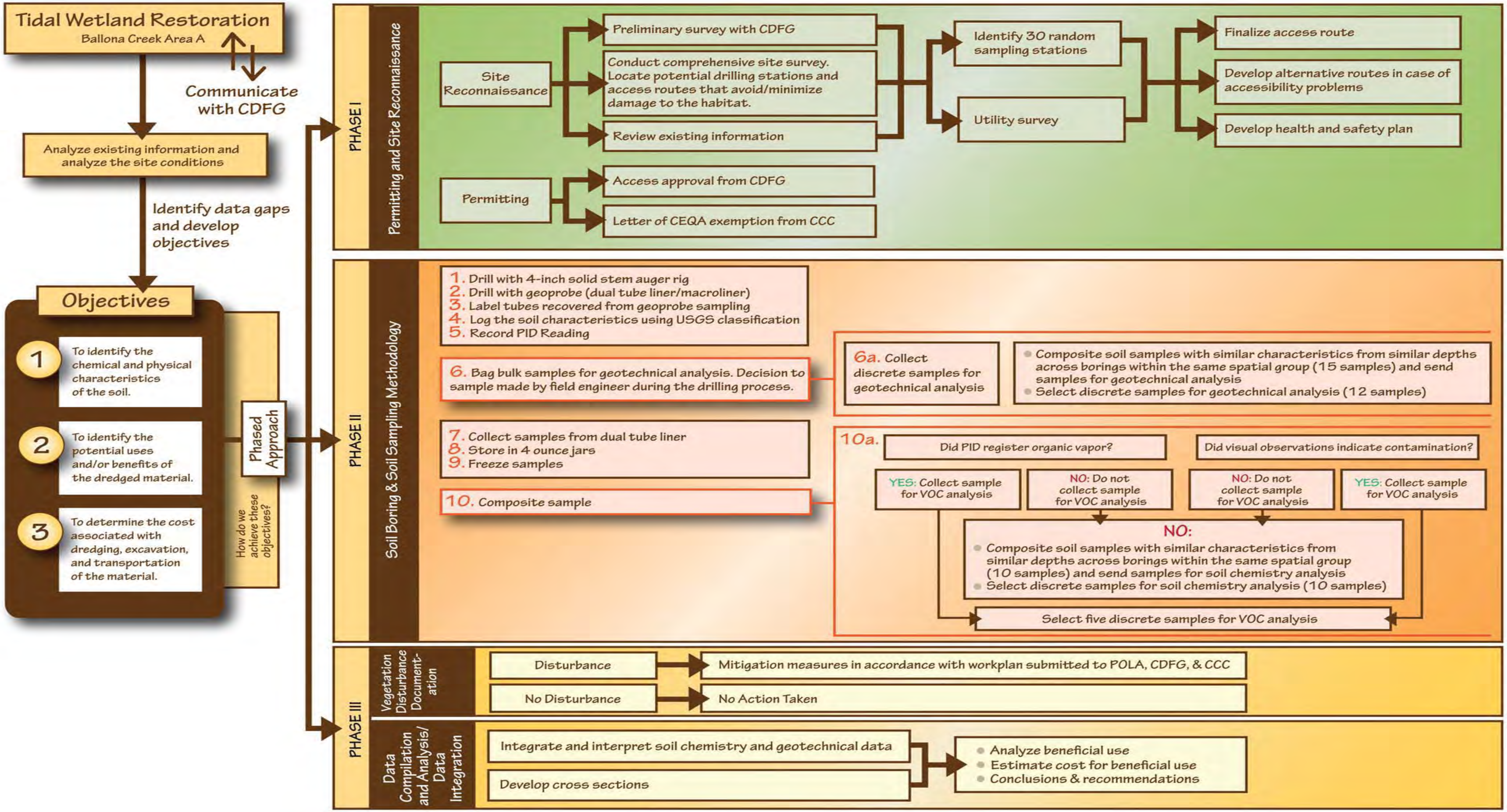

Figure 1-4. Schematic Representation of the Strategic Approach to Conduct Preliminary Geotechnical Investigation

2.0 MATERIALS & METHODS

This section describes the field sampling and laboratory methods and procedure used to complete the Preliminary Area A Study. Sampling and laboratory analysis was conducted in accordance with the approved Study Work Plan (WESTON, 2007). This section summarizes the process for the selection of representative sampling locations, acquisition of access and drilling permits, and completion of the sampling and laboratory programs for the Preliminary Area A Study.

2.1 Sampling Locations

In accordance with the approved Study Work Plan (WESTON, 2007), a total of twenty soil borings were proposed for the Preliminary Area A study. The following process for site selection was completed to ensure equal sample distribution across the study site, accessibility for the drill rig, and minimization of damage to sensitive species.

Step 1 - A random draw of 30 sample locations within the study site was done using Geographic Information Systems (GIS).
Step 2 –The Area A site map was divided into three equal segments. These three segments were then subdivided by transecting the subareas into three groups. It was intended to have two to three sample locations within each group in order to provide quality spatial representation of the sampling locations.
Step 3 - Field reconnaissance was conducted in coordination with POLA, CDFG, and CCC to identify the final 30 locations.
Step 4 – Twenty final sample locations were decided on the day of drilling, incorporating the constraints of drill rig accessibility and habitat considerations.

Table 2-1 includes the final location selections, grouped into segments and groups. Figure 2-1 depicts the initial and final sample locations, overlaid with the section lines and transects.

Table 2-1. Randomized Sampling Locations, Groups, and Segments

Segment	Groups	Stations
Segment 1	Group 1	5 ,6, 7,8,9
	Group 2	4, 10
	Group 3	1, 2, 3
Segment 2	Group 4	12, 13, 14,16, 17, 18
	Group 5	11, 15, 28
	Group 6	27, 29, 30
Segment 3	Group 7	19, 20, 21, 25
	Group 8	22, 23, 24, 26

WESTON staff worked in close coordination with POLA, CDFG, and the CCC to ensure the sampling activities were conducted in a manner that was sensitive to the ecological reserve. Necessary steps were taken to avoid any disturbance to the existing vegetation. Further discussion of the vegetation mapping and modification of the sample site locations and access route is presented below.

WESTON met with representatives of CCC and CDFG to review the selected sample locations and likely access routes to these sampling sites. In addition, the local utilities were contacted to verify that no underground utilities were located near selected boring locations. WESTON met with representatives of Sempra Utilities, which has an operating natural gas well on the southwest corner of the site as well as gasoline product monitoring wells at multiple locations. These wells were verified, marked, and mapped using Global Positioning System (GPS) coordinates. These wells were avoided during soil sampling activities. Figure 2-1 presents the selected 30 potential soil boring locations in green and indicates the final 20 soil boring locations in red. Station 26 was the only location that was relocated eastward to avoid any potential impact from a known abandoned gas line. Relocation of this station did not result in change of spatial distribution of the sampling locations. During the field work, some of the sites were moved marginally to accommodate accessibility issues.

Figure 2-1. Potential and Selected Sampling Locations

2.2 Vegetation Survey and Habitat Protection during Sampling

In accordance with the conditions of CDFG permits (Appendix B) to access the site and conduct the proposed sampling, vegetation surveys were conducted in Area A before and after soil sampling occurred. The survey revealed that the altered elevation contours from the deposition of dredge material developed a variety of plant community types. For the purposes of this report, Area A is broken into six major communities: limited salt pan/mudflats, pickleweed salt marsh, transitional zone with largely exotic species, riparian scrub, *Baccharis* scrub, and coastal scrub (Appendix C). Groupings of plants or individual plants of concern were flagged, and a designated WESTON field biologist was on site during all sampling operations.

Prior to sampling activities, the sampling locations were identified, and routes to and from these sample sites were plotted. Routes were designed to maximize usage of existing access points and pathways and minimize impairment to native habitat. Routes were chosen such that they traversed the exotic transitional zone where iceplant, crown daisy, mustard, and exotic grasses were the dominant species. Potential sample collection sites, which could not be accessed without substantial native plant disturbance, were eliminated and alternative sites were chosen. Stations 15 and 24 were relocated approximately 30 feet from the original location to avoid disturbance of habitat. Relocation of these stations did not result in change of spatial distribution of the sampling locations. Patches of pickleweed, salt marsh, salt pan/mudflats, and coastal scrub along the routes were avoided to the greatest extent possible. The drill rig and the tending Bobcat were instructed to follow one another in a single path to minimize sensitive habitat impacts. Drill equipment operators were made familiar with plant species of concern, and the vehicles were escorted along a pre-scouted route to the station locations by a WESTON field biologist to ensure minimal habitat impact. The proposed access routes and final access routes are as shown on Figure 2-2 and Figure 2-3. The access routes were fairly similar to the proposed routes with only minor changes due to the sensitive habitat and the accessibility constraints of the rig.

Due to limited access at one location, the drill rig and Bobcat had to cross a designated saltpan area. The route selected to access Station 25 and Station 17 was, however, a historic utility dirt road that contained little vegetation due to the highly compacted soils from past and current use.

After sampling activities were completed, the WESTON field team walked the final access route used by equipment. Special attention was given to the salt flat areas. Areas impacted by equipment mobilization were raked and regraded. WESTON revisited the sampling locations and the access route on March 5, 2008, to confirm no sensitive habitat was adversely impacted.

Figure 2-2. Proposed Access Route

Figure 2-3. Final Access Route

2.3 Access and Permits

WESTON conducted field reconnaissance in accordance with the requirements of the access and sampling permit from CDFG. On October 26, 2007, WESTON obtained an access permit from CDFG to enter Area A in order to survey the site and propose access routes for the selected random sampling points (Appendix B). Field reconnaissance was conducted in the presence of a WESTON field biologist. Existing site conditions and flora was documented. Special vegetation avoidance measures were utilized while identifying the proposed route. Existing access points and pathways were utilized for travel within Area A to the maximum extent possible. Each of the randomized soil sampling locations were located using a portable GPS unit and marked with a painted stake.

After completing the field reconnaissance, WESTON obtained an access permit (dated 12/11/2007) from CDFG to conduct geotechnical and soil sampling in Area A (Appendix B). This permit required sampling to be restricted to the designated areas sample sites using the proposed access points/routes. WESTON also obtained a letter of California Environmental Quality Act (CEQA) exemption (dated 01/14/2008) from the CCC. This letter is included in Appendix B.

2.4 Sampling Methodology

2.4.1 Sample Collection

Soil borings were completed at each of the 20 sampling stations using an ATV-mounted direct push rig and a 4-inch diameter solid stem auger drill rig. This drilling technique was selected because of its smaller footprint and lighter weight which, therefore, minimized the potential impact to sensitive ecosystems present in Area A. Due to the potential presence of natural gas in this area, non-sparking tools were used. WESTON sub-contracted RSI Drilling to complete the soil borings in accordance with the approved Study.

The soil sampling approach for the Preliminary Area A Study is presented on Figure 2-4. The direct push coring technique (DPT) was used in collection of both discrete and composite soil chemistry samples. Discrete chemistry core samples are samples taken from a discrete boring depth interval from a single borehole. Composite chemistry core samples were taken from similar boring depths or similar soil types from different borings. The cores samples were combined and then homogenized into one sample. Soil chemistry core samples were collected by driving a dual-lined, 4-foot long, 1.5-inch diameter DPT soil core into the subsurface using hydraulic pressure. Upon retrieval of the 4 foot long core, visual observations were made by a field engineer. These observations led to the selection of discrete and composite soil samples for chemical analysis. These soil cores were also used to visually define any changes in soil texture, moisture, or evidence of contamination. Soil descriptions noted by the engineer are presented in the field boring logs provided in Appendix D. Drilling equipment was thoroughly decontaminated between each borehole to avoid cross-contamination.

Soil core samples were scanned with a Photo Ionization Detector (PID) to detect the presence of organic vapors potentially from volatile organic compounds (VOC). Soil samples were also visually inspected for evidence of contamination, such as soil staining or sheen on the pore fluid of the soil sample. Five discrete samples identified as potentially impacted based on the PID reading and/or visual evidence were sent to the CRG Marine Laboratories (CRG) for VOC analysis.

Samples for geotechnical analysis (grain size distribution, liquid and plastic limits, and hydrometer analysis) were collected using a 4-inch diameter solid stem auger rig. The solid stem auger was advanced at 5 foot intervals. The solid stem auger technique was used to collect bulk soil grab samples for geotechnical analysis because these analyses required greater sample volume. Both discrete and composite were collected from borehole cuttings for geotechnical analysis in accordance with the approved sampling strategy as outlined on Figure 2-4. Composite bulk geotechnical soil samples were taken from similar stratigraphic layers at different boring depths within a single boring. Composite samples were also taken from soil cuttings of similar soil type from 2-3 borings within the same sub area. The sampling depth interval from which the soil samples were collected was determined based on the measurement of the length of auger that had been advanced into the boring location.

The depth of the borings depended on the distance from the ground surface to native materials (i.e., marsh mat) and the depth of excavation expected during restoration. Auger samples were collected to average depths of 12–13 feet below grade surface (bgs) where groundwater was typically encountered. DPT core samples were collected to the depth of approximately 24 feet bgs. Table 2-2 lists the boring locations, GPS coordinates, surface elevations, final boring depth, and depth to water (dtw). Table 2-3 shows the sample number for each discrete soil chemistry sample and the bore depth at which the sample was collected.

Table 2-2. Surface Elevations and Final Boring Depths

Boring Location	Latitude	Longitude	Drilling			Surface Elevation (ft)	Final Boring Depth		Depth to Ground water (ft)
			Date	Start Time	End Time		Direct Push Technology (Dual Core Liner) (ft)	Solid Stem Auger Rig (Bulk Samples) (ft)	
Station 2	33.9734	-118.44451	2/5/2008	15:50	16:10	30	24	10	10
Station 3	33.97418694	-118.443475	2/8/2008	16:05	16:45	30	24	8	8
Station 4	33.97184333	-118.4447522	2/5/2008	13:30	13:55	30	24	16	16
Station 5	33.97051444	-118.4430675	2/6/2008	9:45	10:10	30	24	13	13
Station 6	33.96970806	-118.4432386	2/6/2008	7:45	8:10	20	24	13	13
Station 9	33.97168611	-118.4422205	2/6/2008	11:20	12:15	30	24	8	8
Station 10	33.97272	-118.46211	2/6/2008	13:40	14:10	30	24	5	5
Station 11	33.97410972	-118.4410092	2/7/2008	8:10	8:55	30	24	9	9
Station 15	33.97427444	-118.4401275	2/8/2008	15:05	15:35	30	24	4	4
Station 17	33.97600417	-118.4392794	2/8/2008	13:05	13:40	30	24	4.5	4.5
Station 18	33.97579	-118.4405436	2/8/2008	13:55	14:50	30	24	14	14
Station 21	33.97755694	-118.4365917	2/8/2008	9:50	10:50	30	24	18	18
Station 23	33.976865	-118.4345305	2/8/2008	8:35	9:30	30	24	12	12
Station 24	33.97556	-118.43605	2/8/2008	7:20	8:20	20	24	7	7
Station 25	33.97502917	-118.4378281	2/8/2008	11:15	12:50	20	24	6	6
Station 26	33.97504	-118.43637	2/7/2008	15:15	16:05	30	24	10	10
Station 27	33.97364	-118.63718	2/7/2008	14:05	15:05	30	24	12	12
Station 28	33.97469778	-118.4379058	2/7/2008	11:30	12:20	20	24	9	9
Station 29	33.97345389	-118.4386047	2/7/2008	10:30	11:15	30	24	9.5	9.5
Station 30	33.97252472	-118.4392269	2/7/2008	9:30	10:20	20	24	12	12

2.4.2 Sample Processing and Storage

The process for selecting soil samples for geotechnical and chemical analysis is outlined on Figure 2-4. Soil core and cuttings was bagged, labeled, and placed on ice. Once all drilling activities were complete, discrete samples (from a defined depth interval and single boring) were selected from the soil core and cuttings for geotechnical analysis in accordance with the selection process presented on Figure 2-4. Twelve discrete samples—samples from one soil horizon—were taken for geotechnical analysis, and 10 discrete samples were taken for chemical analysis. CRG was tasked to composite core samples from different soil horizons within one borehole or from across similar soil horizons from different boreholes. A total of 10 composite samples were analyzed for soil chemistry parameters. The various soil chemistry parameters that were analyzed have been tabulated in the following subsection. Table 2-3 shows boring locations and the corresponding depths at which the samples were collected for chemical analysis. Table 2-4 shows the individual samples used to create composite samples for chemical analysis. A total of 14 composite samples were combined from soil cuttings for geotechnical analysis. Table 2-5 shows boring locations and corresponding depths at which the samples were collected for geotechnical analysis. Table 2-5 also shows individual samples that were used to create 14 composite samples for geotechnical analysis.

Chain-of-custody procedures were followed in accordance with the approved Study Work Plan. Documentation of sample collection, transport, and list of analytes were recorded in the chain-of-custody. The chain-of-custodies are attached in Appendix E.

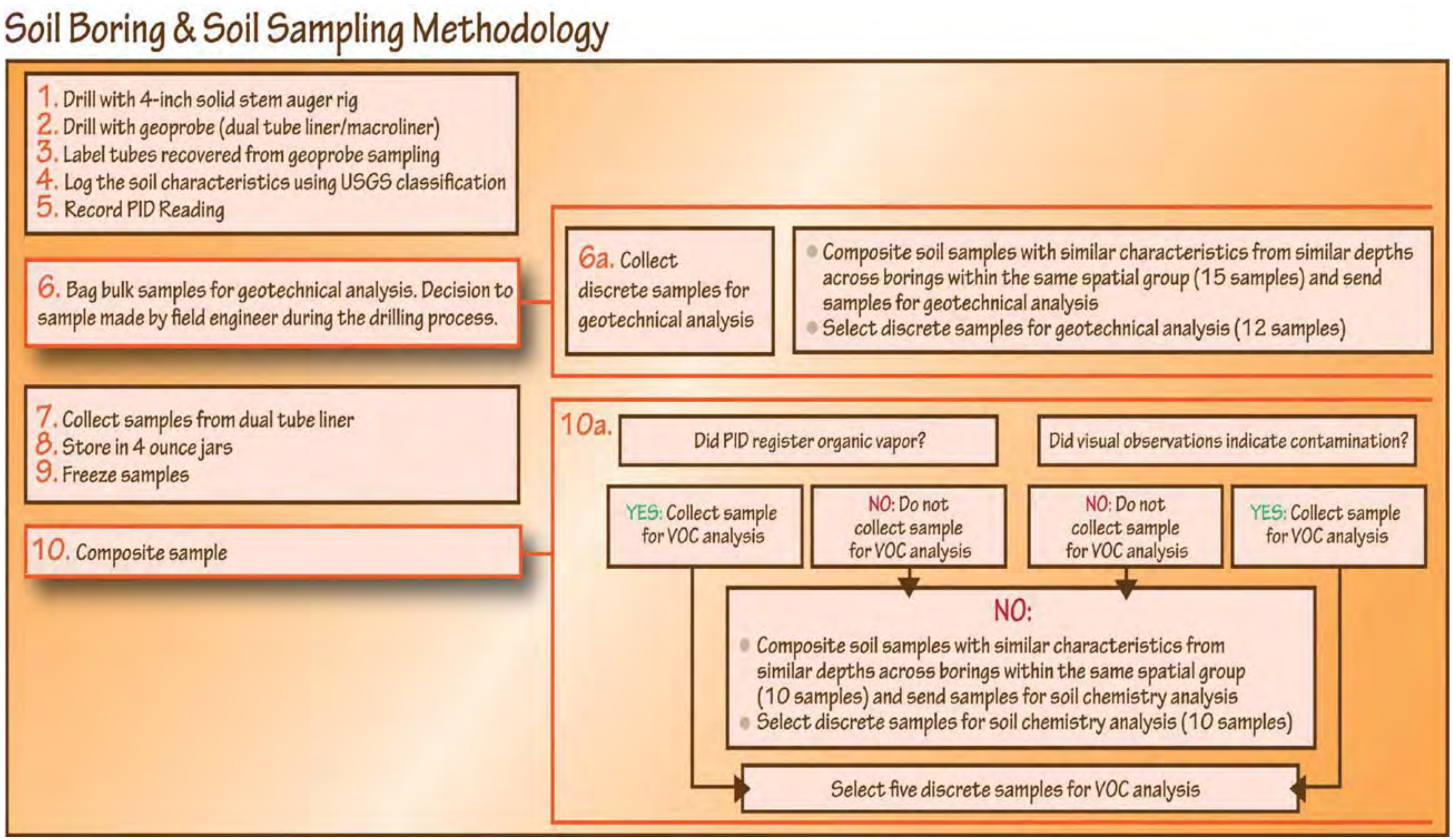

Figure 2-4. Soil Boring and Sampling Strategy

Table 2-3. Sample ID and Sampling Location Depth for Chemistry Analysis

Samples for Soil Chemistry Analysis	Station ID	Sample Depth (ft)
Discrete Samples		
S5-060208-15-16	Station 5	15-16
S9-060208-3-4	Station 9	3-4
S10-060208-6-7	Station 10	6-7
S18-060208-7-8	Station 18	7-8
S17-080208-10-11	Station 17	10-11
S15-080208-15-16	Station 15	15-16
S11-070208-14-15	Station 11	14-15
S29-070208-6-7	Station 29	6-7
S23-080208-12-13	Station 23	12-13
S21-080208-6-7	Station 21	6-7
Discrete Samples for VOC Analysis		
S18-080208-11-12	Station 18	11-12
S15-080208-11-12	Station 15	11-12
S23-080208-15-16	Station 23	15-16
S23-080208-12-13	Station 23	12-13
S21-080208-11-12	Station 21	11-12
Composite* Samples		
S5-S6-15-16	*	*
S5-S6-S9-3-4	*	*
S4-S10-5-7	*	*
S3-11-12-15-16	*	*
S17-S18-10-12	*	*
S15-S28-15-16	*	*
S11-S15-14-20	*	*
S27-S29-S30-6-8	*	*
S23-S24-S26-21-24	*	*
S21-S25-6-8	*	*

*see the Table 2-4 for component of composite samples

Table 2-4. Soil Compositing Information for Chemistry Analysis

Composite Sample ID	Discrete Samples*	Station Id	Sample Depth (ft)
S5-S6-15-16	S5-060208-15-16	Station 5	15-16
	S6-060208-15-16	Station 6	15-16
S5-S6-S9-3-4	S5-060208-3-4	Station 5	3-4
	S6-060208-3-4	Station 6	3-4
	S9-060208-3-4	Station 9	3-4
S4-S10-5-7	S4-050208-5-6	Station 4	5-6
	S10-060208-6-7	Station 10	6-7
S3-11-12-15-16	S3-080208-11-12	Station 3	11-12
	S3-080208-15-16	Station 3	15-16
S17-S18-10-12	S17-080208-10-11	Station 17	10-11
	S18-080208-11-12	Station 18	11-12
S15-S28-15-16	S15-080208-15-16	Station 15	15-16
	S28-070208-15-16	Station 28	15-16
S11-S15-14-20	S15-080208-17-18	Station 15	17-18
	S11-070208-14-15	Station 11	14-15
S27-S29-S30-6-8	S27-070208-7-8	Station 27	7-8
	S29-070208-6-7	Station 29	6-7
	S30-070208-7-8	Station 30	7-8
S23-S24-S26-21-24	S23-080208-23-24	Station 23	23-24
	S24-080208-21-22	Station 24	21-22
	S26-070208-22-23	Station 26	22-23
S21-S25-6-8	S21-080208-6-7	Station 21	6-7
	S25-080208-7-8	Station 25	7-8

* Samples were composited using equal amounts of the discrete samples.

Table 2-5. Sample ID and Sampling Location Depth for Geotechnical analysis

Samples for Soil Chemistry Analysis	Sample ID	Station ID	Sample Depth (ft)
Composite Samples			
G1-0-2	S6-060208-0-2	Station 6	0-2
	S5-060208-0-2	Station 5	0-2
	S9-060208-0-2	Station 9	0-2
G1-3-5	S5-060208-3-5	Station 5	3-5
	S9-060208-3-5	Station 9	3-5
	S6-060208-3-5	Station 6	3-5
G1-10-13	S6-060208-10-13	Station 6	10-13
	S5-060208-10-13	Station 5	10-13
G2-3-5	S4-050208-3-5	Station 4	3-5
	S10-060208-3-5	Station 10	3-5
G3-3-5	S2-080208-3-5	Station 2	3-5
	S3-080208-3-5	Station 3	3-5
G4-3-5	S18-050208-3-5	Station 18	3-5
	S17-080208-3-5	Station 17	3-5
G5-6-9	S11-070208-6-8	Station 11	6-8
	S28-070208-7-9	Station 28	7-9
G6-7-10	S29-070208-7-9	Station 29	7-9
	S27-070208-8-10	Station 27	8-10
	S30-070208-10-11	Station 30	10-11
G7-3-5	S21-080208-3-5	Station 21	3-5
	S25-080208-3-5	Station 25	3-5
G8-3-5	S26-070208-3-5	Station 26	3-5
	S23-080208-3-5	Station 23	3-5
	S24-080208-3-5	Station 24	3-5
G8-7-10	S26-070208-7-9	Station 26	7-9
	S23-080208-8-10	Station 23	8-10
	S24-080208-8-10	Station 24	8-10

Table 2-5. Sample ID and Sampling Location Depth for Geotechnical analysis

Samples for Soil Chemistry Analysis	Sample ID	Station ID	Sample Depth (ft)
Seg1-0-2	S2-050208-0-2	Station 2	0-2
	S3-080208-0-2	Station 3	0-2
	S10-060208-0-2	Station 10	0-2
Seg2-0-2	S15-080208-0-2	Station 15	0-2
	S28-070208-0-2	Station 28	0-2
	S18-080208-0-2	Station 18	0-2
	S11-070208-0-2	Station 11	0-2
	S29-070208-0-2	Station 29	0-2
	S30-070208-0-2	Station 30	0-2
	S17-080208-0-2	Station 17	0-2
	S27-070208-0-2	Station 27	0-2
Seg3-0-2	S21-080208-0-2	Station 21	0-2
	S25-080208-0-2	Station 25	0-2
	S23-080208-0-2	Station 23	0-2
	S24-080208-0-2	Station 24	0-2
Discrete Samples			
S6-060208-8-10		Station 6	8-10
S2-050208-8-10		Station 2	8-10
S21-080208-13-15		Station 21	13-15
S21-080208-8-10		Station 21	8-10
S18-080208-8-10		Station 18	8-10
S2 050108 13-15		Station 2	13-15
S25-080208-5-6		Station 25	5-6
S18-080208-12-14		Station 18	12-14
S30-070208-3-5		Station 30	3-5
S5-060208-8-10		Station 5	8-10
S4 050208 13-15		Station 4	13-15
S4-050208-8-10		Station 4	8-10

2.4.3 Geotechnical and Chemical Analysis

WESTON subcontracted the chemical analysis of the selected samples to CRG. G Force Companies (G Force) was sub-contracted for the geotechnical analysis of the selected soil samples. Geotechnical and geochemical analysis was conducted on 20 discrete and composited soil samples. Geotechnical analysis used American Society for Testing and Materials (ASTM) methods for grain size, liquid and plastic limits, and moisture content. Chemical analysis included general chemistry, metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, semi-volatile organic carbons (s-VOCs) and VOCs. These analyses were performed using the appropriate United States Environmental Protection Agency (USEPA) methods. Table 2-6 shows the chemical analyses for each discrete and composite soil samples. Table 2-7 shows the samples and corresponding analysis for the geotechnical parameters.

Table 2-6. List of Analytes and Samples analyzed for Soil Chemistry

Samples for Soil Chemistry Analysis	Station ID	Depth (ft)	Trace Metals	Trace Mercury	Organotins	Polynuclear Aromatic Hydrocarbons	Phthalates	Acid Extractable Compounds	Organochlorine Pesticides & PCBs	Toxicity Characteristic Leachate Procedure (TCLP)	Dissolved sulfides	Percent solids	pH	Salinity	TOC	Total Sulfides	TPH diesel	TPH gas	Volatile Organic Compounds inc. Acrolein & Acrylonitrile	Ammonia in Sediment Determination	TRPH in Sediment Determination
Method			USEPA 6020(m)	USEPA 245.7(m)	Krone et. Al., 1989	USEPA 8270C(m)	USEPA 8270C(m)	USEPA 8270C(m)	USEPA 8270C(m)		Plumb, 1981/TERL	USEPA 160.3	SM 4500 H+	SM 2510 B	USEPA 9060 A	Plumb, 1981/TERL	USEPA 8015m	USEPA 8015m	USEPA 8260B	USEPA 8270C(m)	USEPA 1664
Discrete Samples																					
S5-060208-15-16	Station 5	15-16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S9-060208-3-4	Station 9	3-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S10-060208-6-7	Station 10	6-7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S18-060208-7-8	Station 18	7-8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S17-080208-10-11	Station 17	10-11	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S15-080208-15-16	Station 15	15-16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S11-070208-14-15	Station 11	14-15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S29-070208-6-7	Station 29	6-7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S23-080208-12-13	Station 23	12-13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S21-080208-6-7	Station 21	6-7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Discrete Samples for VOC analysis																					
S18-080208-11-12	Station 18	11-12																	Yes		
S15-080208-11-12	Station 15	11-12																	Yes		
S23-080208-15-16	Station 23	15-16																	Yes		
S23-080208-12-13	Station 23	12-13																	Yes		
S21-080208-11-12	Station 21	11-12																	Yes		
Composite Samples																					
S5-S6-15-16	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S5-S6-S9-3-4	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S4-S10-5-7	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S3-11-12-15-16	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S17-S18-10-12	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S15-S28-15-16	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S11-S15-14-20	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S27-S29-S30-6-8	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S23-S24-S26-21-24	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
S21-S25-6-8	*	*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes

Table 2-7. List of Samples and Geotechnical Analysis

Samples for Soil Chemistry Analysis	Sample ID	Station ID	Depth (ft)	Grain Size Analysis with Hydrometer (ASTM D 422-63)	Atterberg Limits (ASTM D 4318)	Moisture Content (ASTM D-2216)
Composite Samples						
G1-0-2	S6-060208-0-2	Station 6	0-2	Yes		
	S5-060208-0-2	Station 5	0-2			
	S9-060208-0-2	Station 9	0-2			
G1-3-5	S5-060208-3-5	Station 5	3-5	Yes	Yes	
	S9-060208-3-5	Station 9	3-5			
	S6-060208-3-5	Station 6	3-5			
G1-10-13	S6-060208-10-13	Station 6	10-13	Yes	Yes	
	S5-060208-10-13	Station 5	10-13			
G2-3-5	S4-050208-3-5	Station 4	3-5	Yes	Yes	
	S10-060208-3-5	Station 10	3-5			
G3-3-5	S2-080208-3-5	Station 2	3-5	Yes	Yes	
	S3-080208-3-5	Station 3	3-5			
G4-3-5	S18-050208-3-5	Station 18	3-5	Yes	Yes	
	S17-080208-3-5	Station 17	3-5			
G5-6-9	S11-070208-6-8	Station 11	6-8	Yes	Yes	
	S28-070208-7-9	Station 28	7-9			
G6-7-10	S29-070208-7-9	Station 29	7-9	Yes	Yes	
	S27-070208-8-10	Station 27	8-10			
	S30-070208-10-11	Station 30	10-11			
G7-3-5	S21-080208-3-5	Station 21	3-5	Yes		
	S25-080208-3-5	Station 25	3-5			
G8-3-5	S26-070208-3-5	Station 26	3-5	Yes		
	S23-080208-3-5	Station 23	3-5			
	S24-080208-3-5	Station 24	3-5			
G8-7-10	S26-070208-7-9	Station 26	7-9	Yes	Yes	
	S23-080208-8-10	Station 23	8-10			
	S24-080208-8-10	Station 24	8-10			
Seg1-0-2	S2-050208-0-2	Station 2	0-2	Yes		
	S3-080208-0-2	Station 3	0-2			
	S10-060208-0-2	Station 10	0-2			
Seg2-0-2	S15-080208-0-2	Station 15	0-2	YES		
	S28-070208-0-2	Station 28	0-2			
	S18-080208-0-2	Station 18	0-2			
	S11-070208-0-2	Station 11	0-2			
	S29-070208-0-2	Station 29	0-2			

Table 2-7. List of Samples and Geotechnical Analysis

Samples for Soil Chemistry Analysis	Sample ID	Station ID	Depth (ft)	Grain Size Analysis with Hydrometer (ASTM D 422-63)	Atterberg Limits (ASTM D 4318)	Moisture Content (ASTM D-2216)
	S30-070208-0-2	Station 30	0-2	Yes		
	S17-080208-0-2	Station 17	0-2			
	S27-070208-0-2	Station 27	0-2			
Seg3-0-2	S21-080208-0-2	Station 21	0-2	Yes		
	S25-080208-0-2	Station 25	0-2			
	S23-080208-0-2	Station 23	0-2			
	S24-080208-0-2	Station 24	0-2			
Discrete Samples						
S6-060208-8-10	S6-060208-8-10	Station 6	8-10	Yes	Yes	Yes
S2-050208-8-10	S2-050208-8-10	Station 2	8-10	Yes	Yes	Yes
S21-080208-13-15	S21-080208-13-15	Station 21	13-15	Yes	Yes	Yes
S21-080208-8-10	S21-080208-8-10	Station 21	8-10	Yes	Yes	Yes
S18-080208-8-10	S18-080208-8-10	Station 18	8-10	Yes	Yes	Yes
S2-050108-13 15	S2-050108-13-15	Station 2	13-15	Yes	Yes	Yes
S25 080208-5-6	S25-080208-5-6	Station 25	5-6	Yes	Yes	Yes
S18-080208-12-14	S18-080208-12-14	Station 18	12-14	Yes	Yes	Yes
S30 070208-3-5	S30-070208-3-5	Station 30	3-5	Yes	Yes	Yes
S5-060208-8-10	S5-060208-8-10	Station 5	8-10	Yes	Yes	Yes
S4-050208-13 15	S4-050208-13-15	Station 4	13-15	Yes	Yes	Yes
S4-050208-8-10	S4-050208-8-10	Station 4	8-10	Yes	Yes	Yes

3.0 RESULTS AND FINDINGS

3.1 Geotechnical Results

Appendix D provides the soil boring logs for the 20 borings completed for the Preliminary Area A Study. The boring logs were developed from the field boring logs and the results of the geotechnical analysis of selected soil samples. The boring logs indicate that, in general, the dredged materials at the site do not greatly vary with depths or site location. The dredged materials are predominantly low plasticity clays, silty clays, and clayey silts. The exception is a gradual transition to soils with greater gravel and cobble content on the north eastern portion of the site adjacent to Lincoln Boulevard.

The results of the geotechnical analysis are provided in Appendix F and a summary of the geotechnical results is presented in Table 3-1. The results for the composite samples are shown for the depth interval from which the soil samples were taken. For example, composite sample G5-6-9 was composed of Station 11 discrete sample S11-070208-6-8 and Station 28 discrete sample S28-070208-7-9. The results of the geotechnical analysis for the individual Station 11 and Station 28 samples were then used to characterize the composite sample G5-6-9.

The results of the geotechnical analysis confirm the field observations which indicated the dredged materials within Area A do not vary greatly in grain size and soil classification. In fact, all the composite and discrete samples collected and analyzed for geotechnical properties were classified as low plasticity clays, silty clays, sandy clays or clayey silts (CL) per the Unified Soil Classification System (USCS). The only exception was the soil at Station 25 at a depth of 5-6 feet bgs. At this location, the soil is classified as high plasticity clay (CH). Historically, Area A was formed by filling the area with the dredge material that was excavated from Marina del Rey Harbor and Ballona Creek in the 1960s. These clayey soils are generally poor draining soils as evident by the seasonal ponding of precipitation during high rainfall years and the formation of salt pans and salt-marsh adapted vegetation on low lying areas of Area A. Due to the high clay content, these soils are generally not well suited for structural fill materials, but may be used for grading fill as part of the Restoration Project or other landscaped areas that are not subject to structural loading. Further discussion of potential beneficial uses of the dredged material is presented in Section 4. Beneficial uses will also depend on the chemical constituents present in the soil.

Table 3-1. Summary of Geotechnical Results by Depth and Sampling Locations

Depth	Station ID	Sample ID	Classification by Particle Size	Percent Retained															Atterberg Description	Atterberg Limits			USCS Classification
				Gravel								Sand						Clay/Silt					
				3"	2"	1.5"	1"	0.75"	0.5"	3/8"	Total Gravel #4	#10	#20	#40	#60	#100	Total Sand #200	Total Silt + Clay <#200		Liquid Limit	Plastic Limit	Plasticity	
0-2	Station 6	G1-0-2	Sandy Clay	0	0	0	0	0	0	0	1	3	5	7	9	14	32	68					
0-2	Station 5	G1-0-2	Sandy Clay	0	0	0	0	0	0	0	1	3	5	7	9	14	32	68					
0-2	Station 9	G1-0-2	Sandy Clay	0	0	0	0	0	0	0	1	3	5	7	9	14	32	68					
0-2	Station 2	Seg1-0-2	Clayey Sand	0	0	0	0	1	1	3	6	12	16	21	26	36	62	38					
0-2	Station 3	Seg1-0-2	Clayey Sand	0	0	0	0	1	1	3	6	12	16	21	26	36	62	38					
0-2	Station 10	Seg1-0-2	Clayey Sand	0	0	0	0	1	1	3	6	12	16	21	26	36	62	38					
0-2	Station 15	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 28	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 18	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 11	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 29	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 30	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 17	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 27	Seg2-0-2	Sandy Clay	0	0	0	0	0	0	1	3	8	12	17	21	28	44	56					
0-2	Station 21	Seg3-0-2	Sandy Clay	0	0	0	0	0	0	0	0	1	3	6	9	18	38	62					
0-2	Station 25	Seg3-0-2	Sandy Clay	0	0	0	0	0	0	0	0	1	3	6	9	18	38	62					
0-2	Station 23	Seg3-0-2	Sandy Clay	0	0	0	0	0	0	0	0	1	3	6	9	18	38	62					
0-2	Station 24	Seg3-0-2	Sandy Clay	0	0	0	0	0	0	0	0	1	3	6	9	18	38	62					
3-5	Station 4	G2-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	13	49	51	Lean Clay	29	21	8	CL
3-5	Station 10	G2-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	13	49	51	Lean Clay	29	21	8	CL
3-5	Station 5	G1-3-5	Clayey Sand	0	0	0	0	0	1	3	10	14	18	22	27	35	61	39					
3-5	Station 9	G1-3-5	Clayey Sand	0	0	0	0	0	1	3	10	14	18	22	27	35	61	39					
3-5	Station 6	G1-3-5	Clayey Sand	0	0	0	0	0	1	3	10	14	18	22	27	35	61	39					
3-5	Station 2	G3-3-5	Sandy Clay	0	0	0	0	0	0	1	2	5	7	10	14	24	46	54	Lean Clay	38	18	20	CL
3-5	Station 3	G3-3-5	Sandy Clay	0	0	0	0	0	0	1	2	5	7	10	14	24	46	54	Lean Clay	38	18	20	CL
3-5	Station 18	G4-3-5	Sandy Clay	0	0	0	0	0	0	1	2	7	11	14	17	21	33	67	Lean Clay	38	20	18	CL
3-5	Station 17	G4-3-5	Sandy Clay	0	0	0	0	0	0	1	2	7	11	14	17	21	33	67	Lean Clay	38	20	18	CL
3-5	Station 21	G7-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	2	5	8	18	42	58					
3-5	Station 25	G7-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	2	5	8	18	42	58					
3-5	Station 26	G8-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	10	24	76	Lean Clay	45	17	28	CL
3-5	Station 23	G8-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	10	24	76	Lean Clay	45	17	28	CL
3-5	Station 24	G8-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	10	24	76	Lean Clay	45	17	28	CL
3-5	Station 30	S30-070208-3-5	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	8	17	83	Lean Clay	48	20	28	CL
5-6	Station 25	S25-080208-5-6	Sandy Clay	0	0	0	0	0	0	0	0	0	0	1	2	8	22	78	Fat Clay	51	18	33	CH
6-8	Station 11	G5-6-9	Sandy Clay	0	0	0	0	0	0	0	0	0	1	1	2	10	30	70	Lean Clay	38	17	21	CL
7-9	Station 28	G5-6-9	Sandy Clay	0	0	0	0	0	0	0	0	0	1	1	2	10	30	70	Lean Clay	38	17	21	CL
7-9	Station 29	G6-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	3	7	12	21	79	Lean Clay	40	19	21	CL

Table 3-1. Summary of Geotechnical Results by Depth and Sampling Locations

				Percent Retained																			
				Gravel								Sand						Clay/Silt		Atterberg Limits			
Depth	Station ID	Sample ID	Classification by Particle Size	3"	2"	1.5"	1"	0.75"	0.5"	3/8"	Total Gravel #4	#10	#20	#40	#60	#100	Total Sand #200	Total Silt + Clay <#200	Atterberg Description	Liquid Limit	Plastic Limit	Plasticity	USCS Classification
7-9	Station 26	G8-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	9	21	79	Lean Clay	44	17	27	CL
8-10	Station 27	G6-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	3	7	12	21	79	Lean Clay	40	19	21	CL
8-10	Station 23	G8-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	9	21	79	Lean Clay	44	17	27	CL
8-10	Station 24	G8-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	2	4	9	21	79	Lean Clay	44	17	27	CL
8-10	Station 6	S6-060208-8-10	Sandy Clay	0	0	0	0	0	0	0	0	2	4	8	16	25	42	58	Lean Clay	37	16	21	CL
8-10	Station 2	S2-050208-8-10	Clayey Sand	0	0	0	0	0	0	1	3	7	13	23	33	44	60	40	Lean Clay	30	15	15	CL
8-10	Station 21	S21-080208-8-10	Sandy Clay	0	0	0	0	0	0	0	0	1	4	11	15	20	28	72	Lean Clay	46	18	28	CL
8-10	Station 18	S18-080208-8-10	Sandy Clay	0	0	0	0	0	0	1	5	10	16	22	27	32	38	62	Lean Clay	35	17	18	CL
8-10	Station 5	S5-060208-8-10	Clayey Sand	0	0	0	0	1	4	7	14	24	29	38	48	52	62	38	Lean Clay	35	16	19	CL
8-10	Station 4	S4-050208-8-10	Sandy Clay	0	0	0	0	0	0	0	1	3	6	9	13	20	47	53	Lean Clay	31	18	13	CL
10-11	Station 30	G6-7-10	Sandy Clay	0	0	0	0	0	0	0	0	0	1	3	7	12	21	79	Lean Clay	40	19	21	CL
10-13	Station 6	G1-10-13	Sandy Clay	0	0	0	0	0	0	0	1	2	4	6	10	15	30	70	Lean Clay	42	20	22	CL
10-13	Station 5	G1-10-13	Sandy Clay	0	0	0	0	0	0	0	1	2	4	6	10	15	30	70	Lean Clay	42	20	22	CL
12-14	Station 18	S18-080208-12-14	Sandy Clay	0	0	0	0	0	0	0	0	2	6	9	12	14	19	81	Lean Clay	43	19	24	CL
13-15	Station 21	S21-080208-13-15	Sandy Clay	0	0	0	0	0	0	0	0	1	3	8	14	21	29	71	Lean Clay	42	16	26	CL
13-15	Station 2	S2-050108-13-15	Clayey Sand	0	0	0	0	1	2	3	4	10	17	25	34	43	56	44	Lean Clay	33	16	17	CL
13-15	Station 4	S4-050208-13-15	Sandy Clay	0	0	0	0	0	0	0	1	2	5	12	22	28	46	54	Lean Clay	30	15	15	CL

USCS Definition:
CL- Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
CH- Inorganic clays of high plasticity, organic silts

3.2 Chemistry Results

3.2.1 Comparison to Relevant Criteria

Analytical results were compared to relevant soil screening levels, sediment quality guidelines, and hazardous waste criteria to determine suitability of material for specific beneficial uses or placement options. Relevant numeric standards for comparisons include:

- Hazardous Waste Criteria
  - Total Threshold Limit Concentration (TTLC) and Soluble Threshold Limit Concentration (STLC): TTLC and STLC are used to determine the hazardous waste characterization under California State regulations as outlined in Title 22 of the California Code of Regulations (CCR).Concentrations of contaminants in project soil were compared to TTLC and 10 times the STLC. If concentrations exceed 10 times the STLC, a Waste Extraction Test (WET) must be performed to estimate the contaminant leachate. If concentrations of contaminants in soil exceed the TTLC or leachate from the WET exceed the STLC, the material is classified as hazardous waste. If a waste is determined to be a hazardous waste, specific regulations and statutes regarding the management, storage, transportation and disposal must be met.
  - Toxicity Characteristic Leaching Procedure (TCLP): TCLP is the characterization for hazardous waste based on Federal guidelines. TCLP analysis was performed to provide an estimate of the soil contaminant leachate and to determine if this material is classified as hazardous waste or if it is considered suitable for upland placement. Analytes leaching from the soil were compared to USEPA Title 40 Code of Federal Regulations (CFR) Part 261 values (USEPA, 2006).

- Human Health Screening Levels
  - California Human Health Screening Levels (CHHSLs): Concentrations of 54 hazardous chemicals in soil that the California Environmental Protection Agency (Cal/EPA) considers to be below thresholds of concern for risks to human health based on ingestion, inhalation, and dermal absorption. The CHHSLs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) on behalf of Cal/EPA, and are contained in their report entitled “Human-Exposure-Based Screening Numbers are Developed to Aid Estimation of Cleanup Costs for Contaminated Soil”. Any exceedances of the CHHSLs do not indicate that the levels are of concern, but suggest that further evaluation of potential human health concerns may be considered. Residential CHHSLs are recommended for use by the California Department of Toxic Substances Control (DTSC) for human health screening evaluation described in the Preliminary Endangerment Assessment (PEA) Guidance Manual.
  - Preliminary Remediation Goals (PRGs): For contaminants that CHHSLs are not developed, the PRGs are used. The PRGs were developed by USEPA Region IX as a risk-based screening tool for evaluating and cleaning up contaminated sites. The Region IX PRGs were developed prior to the CHHSLs and are similar or slightly less stringent. The values are calculated from current human health toxicity values with standard exposure factors to estimate contaminant concentrations in environmental

media (soil, air, and water) that are considered by the Agency to be health protective of human exposures (including sensitive groups), over a lifetime. As with CHHSLs, exceedances do not indicate that the levels present are a human health concern, however, more evaluation may be required.

- Ecologically Relevant Screening Criteria
  - Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation and Upland Beneficial Reuse. These sediment screening criteria and testing requirements are for the beneficial reuse of dredged material such as wetlands creation and upland disposal. The criteria were developed by the California Regional Water Quality Control Board.
  - Effects Range-Low (ER-L) and Effects Range-Median (ER-M) Values: Effect range values are used in dredged material evaluations for ocean disposal. These values were developed by Long et al. (1995), and are helpful in assessing the potential significance of elevated sediment-associated COCs, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., toxicity tests, benthic community effects) and chemical analysis were available for individual samples. To derive these guidelines, the chemical values for paired data demonstrating benthic impairment were sorted in according to ascending chemical concentration. The ER-L was then calculated as the lower tenth percentile of the observed effects concentrations and the ER-M as the 50th percentile of the observed effects concentrations. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. For dredged material evaluations, the ER-L and ER-M sediment quality values are used in conjunction with bioassay testing and are included for comparative purposes only. For certain pesticide compounds (i.e., chlordane and dieldrin) the ER-L and ER-M levels are so low as to make it largely impractical to detect them in typical harbor sediments using routine analytical procedures. Accordingly, having non-detect results that were greater than the ER-L, ER-M, or method detection limits (MDLs) would not require re-analysis.

A summary of the measured chemical constituents and comparison to the most appropriate soil screening levels, sediment quality guidelines, and hazardous waste criteria are provided in the appendices. The complete chemical analysis results from CRG of the selected soil samples are provided in Appendix G1 - G5. A summary of elevated contaminants above soil screening criteria and sediment quality guidelines are discussed below and presented in Table 3-2 and Table 3-3, respectively.

3.2.1.1 Comparison to Hazardous Waste Criteria

No chemicals were detected at concentrations greater than the TTLC or at concentrations greater than 10 times the STLC value (Appendix G1). Results of TCLP analyses indicated no analytes above the toxicity characteristic standards USEPA 40 CFR Part 261 values (USEPA, 2006) (Appendix G2). Therefore, the material is not classified as a hazardous waste and is suitable for upland placement options.

3.2.1.2 Comparison to Human Health Criteria

The analyzed organic chemicals of concern were PAHs, PCBs and organochlorine pesticides. With the exception of one soil sample, none of the Area A samples contained concentrations of PAHs, PCBs, or pesticides above the CHHSLs and PRGs soil criteria (Appendix G3). The concentration of benzo [a] pyrene at Station 27 was 39.7 µg/kg dry weight and this exceeded the human health screening level (set at 38 µg/kg dry weight) for potential use at residential land use.

While most of the chemical screening values for are below levels of concern for human health, arsenic and iron have ambient concentrations greater than residential CHHSLs and PRGs (Appendix G3). These exceedances suggest the material could be an issue if the sediments are used where humans will have continual contact (e.g. residential property or recreational property). The concentrations of arsenic and iron found are consistent with natural concentrations in marine sediments. A summary of soil samples that exceeded soil criteria is shown in Table 3-2.

During the boring and sampling operations, PID readings were taken to identify potential “hot” zones which might contain elevated VOC concentrations. Soil samples from five stations showed elevated PID readings in the field and were subsequently selected for s-VOC and VOC analysis. The results of the laboratory analysis showed that none of the five samples exceeded CHHSLs or PRGs criteria for residential and commercial land use. Appendix G3 shows the results of all the s-VOC and VOC analysis from the discrete and composite station samples.

Due to the historic and current presence of gasoline production and transportation at Area A, the 20 soil stations were analyzed for total petroleum hydrocarbons (TPHg and TPHd) and benzene, ethylbenzene, toluene, and xylenes (BETX). None of the soil samples had concentrations of TPHg, TPHd or BETX above the CHHSLs and PRGs (Appendix G3). However, during drilling operations at Station 25 and 26, the field engineer noted evidence of soil staining throughout the soil core. These two stations are closest to the abandoned gasoline transportation line that runs north-to-south through Area A. Additional soil sampling may be necessary prior to any large-scale excavation of site.

3.2.1.3 Comparison to Ecologic Criteria

The results of the chemical analysis were also compared to soil clean-up standards which may be applied to the Area A soils since the dredged material has been dewatered. In addition, the soil below the water table may be considered sediment and may be subject to proposed sediment quality criteria if used for the Restoration Project. The Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation and Upland Beneficial Reuse, as established by the California Regional Water Quality Control Board, were used to determine if the Area A soil was suitable for wetland application (Appendix G4). The results of chemical analysis showed that all the analyzed chemical constituents were below the Interim Sediment Screening Criteria.

Concentrations of metals were also compared to ER-L and ER-M values (Appendix G5). Several metals slightly exceeded the corresponding ER-L values, including arsenic, cadmium, copper, lead, mercury, nickel, and silver (Table 3-3). No metals exceeded the corresponding ER-M values, indicating relatively low concentrations.

Concentrations of organics were also compared to ER-L and ER-M values (Appendix G5). The only organic to exceed the corresponding ER-L value was 4,4'-DDE in the composite sample from Stations 21 and 25 (Table 3-3). No organics exceeded the corresponding ER-M values, indicating relatively low concentrations.

CRG was not able to extract enough pore water from the soil samples for salinity and conductivity analysis. However, two soil samples were analyzed for salinity at the WESTON laboratory by using a refractometer. The dissolved salts were extracted from the soil samples by adding small quantities of deionized (DI) water and agitating the soil samples. The results indicate that the salt concentration of the soil is greater that 5 ppt. The soil at Area A is from marine sources such as Marina del Rey Harbor and Ballona creek. Currently there is existence of pickle weed which grows in soils with high salt content. Hence, it is inferred that the soil has a high salt content relative to that from a freshwater source. In addition, the soil pH indicates that it is basic in nature across Area A.

Table 3-2. Summary of Soil Samples with Analytes that Exceed California Human Health Screening Levels or Preliminary Remediation Goals

Group	Analyte	Units	RL	Residential Land Use		Commercial/Industrial Land Use Only		S10-060208-6-7	S11-070208-14-15	S11-S15-S28-14-20	S15-080208-15-16	S15-S28-15-16	S17-080208-10-11	S17-S18-10-12	S18-080208-7-8	S21-080208-6-7	S21-S25-6-8
				CHHSLs	PRG	CHHSLs	PRG	Discrete	Discrete	Composite	Discrete	Composite	Discrete	Composite	Discrete	Discrete	Composite
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Iron (Fe)	µg/dry g	5		23000		100000	15890	37840	41390	38250	32840	28970	37170	37940	30390	32920
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	<5	<5	<5	<5	<5	<5	<5	<5	7.3	6.8

Group	Analyte	Units	RL	Residential Land Use		Commercial/Industrial Land Use Only		S23-080208-12-13	S23-S24-S26-21-24	S27-S29-S30-6-8	S29-070208-6-7	S3-11-12 15-16	S4-S10-5 7	S5-060208-15-16	S5-S6-15 16	S5-S6-S9-3-4	S9-060208-3-4
				CHHSLs	PRG	CHHSLs	PRG	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Iron (Fe)	µg/dry g	5		23000		100000	27480	36000	31170	26180	34330	18770	35380	26340	20140	14270
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	3.4 J	<5	39.7	<5	6.1	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
Yellow - Concentration exceeds respective soil screening criteria.

Table 3-3. Summary of Soil Samples with Analytes that Exceed Effects Range-Low or Effects Range-Median Values

Group	Analyte	Units	RL	Disposal Option Sediment Screening Criteria		S10-060208-6-7	S11-070208-14-15	S11-S15-S28-14-20	S15-080208-15-16	S15-S28-15-16	S17-080208-10-11	S17-S18-10-12	S18-080208-7-8	S21-080208-6-7	S21-S25-6-8
				ER-L	ER-M	Discrete	Discrete	Composite	Discrete	Composite	Discrete	Composite	Discrete	Discrete	Composite
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.262	0.201	1.243	0.836	0.684	0.089	0.595	0.307	0.614	0.57
	Copper (Cu)	µg/dry g	0.05	34	270	11.15	33.62	22.17	39.25	28.84	18.03	28.89	28.99	31.63	35.6
	Lead (Pb)	µg/dry g	0.05	46.7	218	4.742	7.802	4.583	7.924	6.104	3.783	5.758	6.194	24.94	50.72
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.043	0.053	0.055	0.068	0.052	0.041	0.049	0.06	0.303	0.215
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	14.69	27.15	21.2	25.37	21.42	17.05	24.09	23.61	22.55	23.94
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.04 J	0.035 J	0.072	0.038 J	0.113	0.042 J	0.173	0.052	1.079	1.027
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	11.6

Group	Analyte	Units	RL	Disposal Option Sediment Screening Criteria		S23-080208-12-13	S23-S24-S26-21-24	S27-S29-S30-6-8	S29-070208-6-7	S3-11-12-15-16	S4-S10-5-7	S5-060208-15-16	S5-S6-15-16	S5-S6 S9-3-4	S9-060208-3-4
				ER-L	ER-M	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.67	0.482	0.63	0.257	0.499	0.199	0.175	0.147	0.255	0.208
	Copper (Cu)	µg/dry g	0.05	34	270	25.64	30.61	37.79	20.12	28.08	14.52	27.21	21.25	12.81	9.257
	Lead (Pb)	µg/dry g	0.05	46.7	218	5.361	7.187	31.96	8.573	19.58	4.625	4.742	3.514	6.364	3.383
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.028	0.083	0.189	0.077	0.089	0.065	0.067	0.058	0.046	0.053
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	26.33	25.27	25.6	19.71	26.05	15.74	20.98	16.44	15.2	13.25
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.105	0.221	0.224	0.129	0.174	0.096	<0.05	0.258	0.138	0.04 J
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
Yellow - Concentration exceeds respective sediment screening criteria.

3.3 Soil Cross Sections

Soil cross sections were developed from boring logs (Appendix D) and geotechnical laboratory results. Figure 3-1 shows the location of the cross sections in the study site. Figure 3-2 shows the cross section A-A' and Figure 3-3 shows the cross section B-B'. For the purpose of development of cross sections, it was assumed that the area is topographically flat in elevation. The cross sections indicate that soil within the site could be characterized as having limited stratification and is spatially similar in nature. The cross sections show that the water table is tidally influenced. The water table indicated is representative of the water table at the specific time the water table was recorded or the sampling was conducted (Refer to Appendix D for borelogs and sampling times)

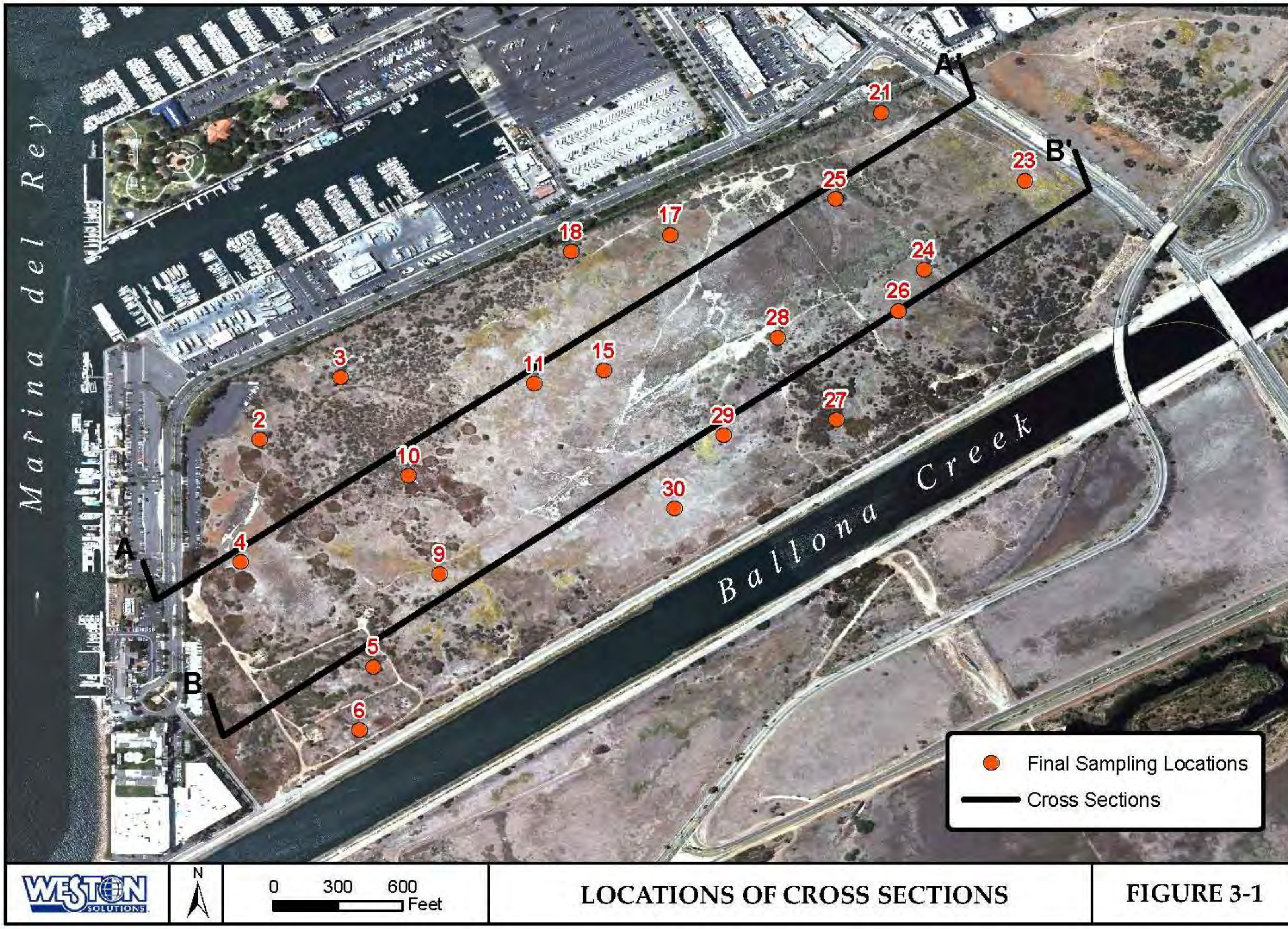

Figure 3-1. Location of Cross Sections

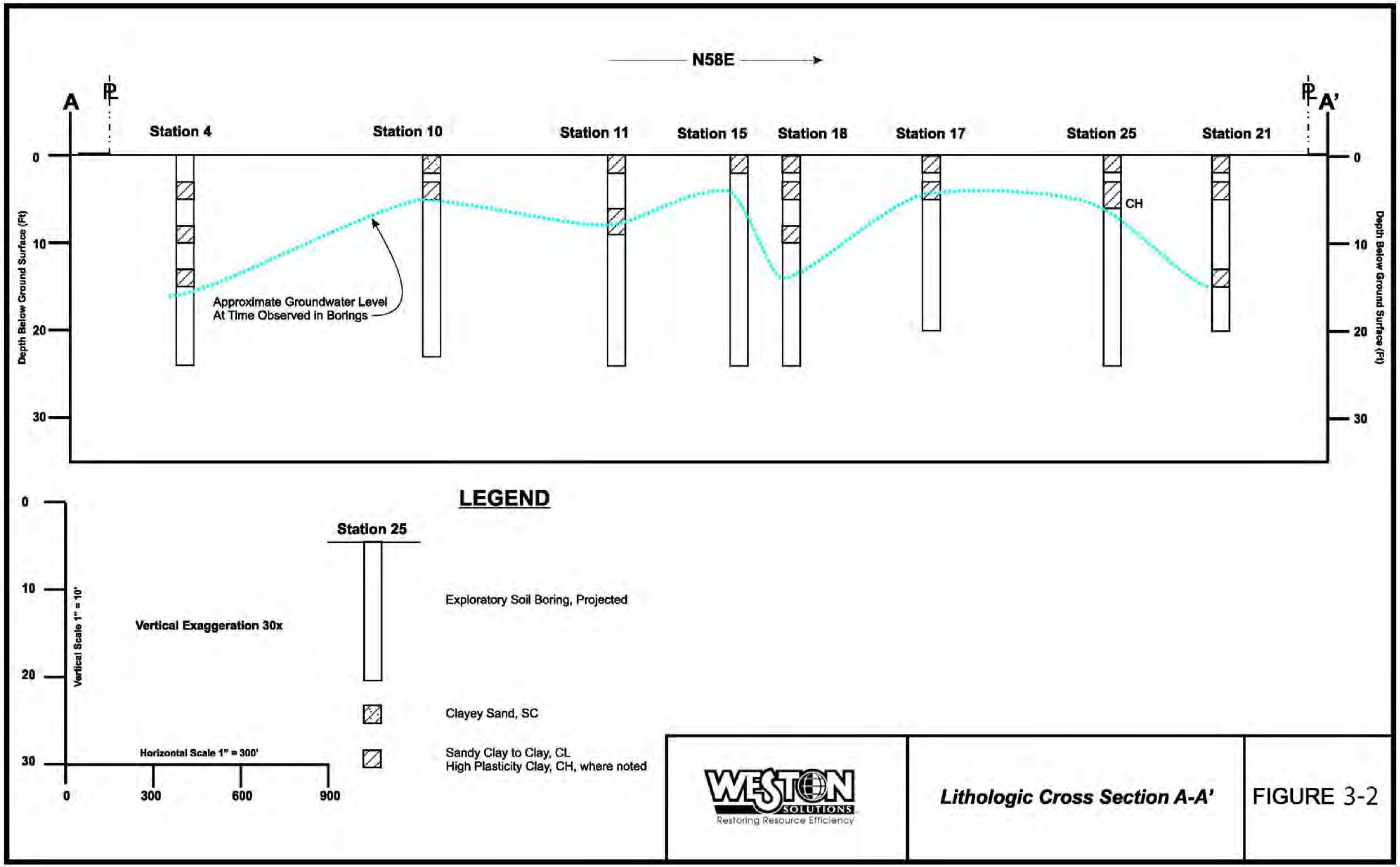

Figure 3-2. Cross Section A-A'

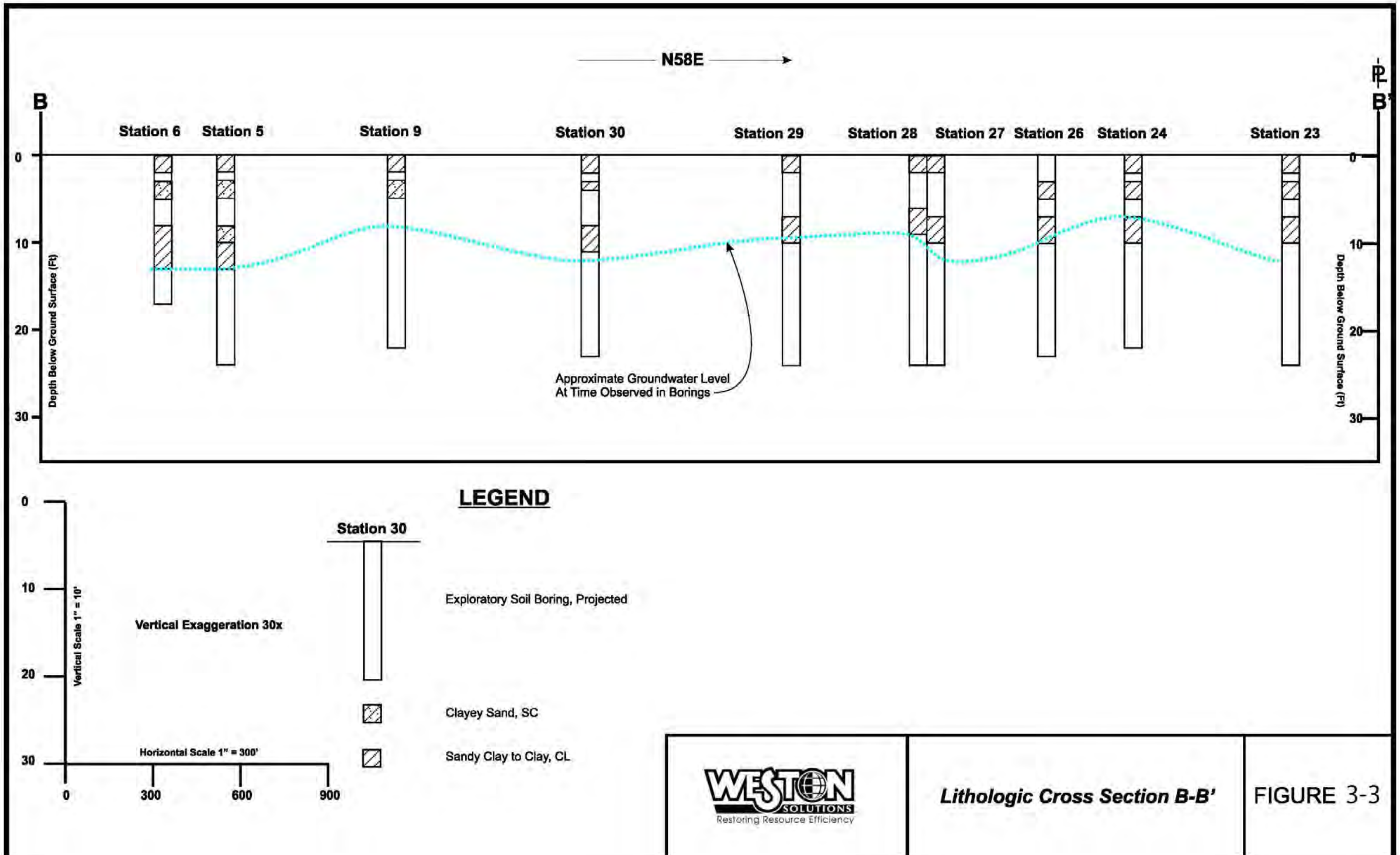

Figure 3-3. Cross Section B-B'

4.0 DISPOSAL OPTIONS

There are a number of environmental, economic and aesthetic beneficial uses for the soil at Area A. Five relevant general categories include: habitat restoration/enhancement, landscaping, beach nourishment, landfill development, and construction activities (i.e., road works/fill). The general criteria used to determine the feasibility of these beneficial uses is summarized in Table 4-1. The primary focus of this section was on potential beneficial uses; however, open water ocean disposal is also presented.

4.1 Habitat Restoration/Enhancement

Dredged material may be used beneficially as substrate for the restoration and enhancement of various wildlife habitats. Habitat restoration is defined as the return of a habitat to a close approximation of its condition prior to disturbance and habitat enhancement is the modification of specific structural features to increase one or more functions based on management objectives (USEPA, 2005). There are four general habitats suitable for the beneficial use of dredged material: wetland, upland, aquatic, and island habitats. The contamination levels compared to the California Regional Water Quality sediment screening criteria and the geotechnical characteristics of the material found in Area A would probably best be utilized for beneficial uses related to habitat development. The most cost effective solution would be to apply as much of the dewatered sediment onsite. The marine dredged material is completely dewatered; therefore, recommendations for material are most likely suitable for wetland and upland placement in coastal zones to support salt tolerant species. However, the saturated zones may be used for upland placement. These saturated soils may also be compared against the sediment criteria developed wetland restoration for San Francisco Bay region by the State of California.

The process steps for wetland restoration or upland habitat creation utilizing dewatered dredged material are as follows:

- Study and design (reconnaissance, feasibility study, design, permitting, easements);
- Perform tiered biological/chemical investigations regarding the effects of the material on plants and animals;
- Excavation of dewatered material from a confined disposal facility (CDF);
- Load, transport, and offload material from truck;
- Natural revegetation of the site or management of site to attract desired wildlife communities;
- Placement of temporary or permanent containment (plants or protective structure);
- Development of success criteria; and
- Ongoing monitoring.

Table 4-1. General Beneficial Use Evaluation Criteria

Beneficial Use	Type of Use	Soil Evaluation Criteria (USCS classification)	pH	Organics	Other Criteria	Area A Soil	Is this a potential Beneficial Use option ?	Comments
Habitat Restoration/ Enhancement	Upland	Upland: plant preferences	6-7.5	> 1.5%	Few pollutants; Salts < 500 ppm	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays and Fat clay (CL/CH) Very small pockets of Clayey sand Liquid limit ranges from 20 to 48 Plastic limit ranges from 15 to 20 Plasticity index ranges from 13 to 33 Low permeability. Low concentrations of pollutants (meets soil quality criteria in accordance with California code of regulations) Soil is non hazardous pH ranges from 8.5 to 9.5 Low to medium organic content	Yes	Salts may prevent beneficial use in the sediments below 5.5 mean lower low water (MLLW), where salt water intrusion may be occurring.
	Wetlands	Wetlands: fine grained; Upland: plant preferences	6-7.5	> 1.5%	Few pollutants; Salts < 500 ppm		Yes	Salts may prevent beneficial use in the sediments below 5.5 MLLW, where salt water intrusion may be occurring.
Landscape/ Vegetative Cover		sandy loam; silt loam	6-7.5	> 1.5%	Few pollutants, Low fines; Salts < 500 ppm; Possible to combine sands with loams (LL<50)		No	High salt content for typical landscape
Beach Nourishment		sands (typed to beach)	-	-	Little/No pollutants (compare against background levels)		No	Grain size: Area A sediments are too fine
Solid Waste Management: Landfill	Cap	CL, CH	-	Medium/ Low	Low permeability		Yes	
	Cover	sandy clay, clayey sand (ideal: 5-10% sand, 5% fines)	-	Medium/ Low	Few pollutants; Low permeability		Yes	
	Liner/Barrier	CL, CH	-	Medium/ Low	Few pollutants; Low permeability		Yes	
	Base	gravels (G-)	-	Low	PI < 1 (where PI=LL-PL)		Yes	
Solid Waste Management: Confined Aquatic Disposal Cap	Cap	CL, CH	-	Medium/ Low	Low permeability		Yes	
Construction Activities	Road fill subbase	gravels (G-)	-	Low	PI < 1 (where PI=LL-PL); if CL or CH, treat with lime/install enhancement fabric		No	Roadwork and other construction applications would likely require the excavated material to be gravels or coarse grained sand with low organic concentrations (to reduce swelling). As such, it is unlikely that the Area A material could be utilized in this manner.
	Road fill subgrade	-	-	-	PI < 12 (where PI=LL-PL)		No	
	General - Fill		-	Low	Little/No Pollutants		Yes	
	Pier A west - Backfill		6-9	Low	Little/No Pollutants Low to medium plasticity Salts < 500 ppm; Possible to combine sands with loams		Yes	

PI = Plasticity Index No
LL = Liquid Limit
PL = Plastic Limit

4.1.1 Wetland Habitat Restoration/Enhancement

Dredged material may be beneficially used to restore or enhance wetland habitats. A wetland habitat is a low-lying area characterized by vegetation that is subject to periodic inundations. Wetland restoration may be used to enhance or reclaim wetlands that have been lost to open water as the result of erosion, subsidence, sea-level rise, and other factors. Wetland enhancement entails the manipulation of the physical, chemical, or biological characteristics of a wetland site, often by modifying the site elevation or hydrology in order to improve a specific function, such as water quality or wildlife habitat. These improvements may provide protected areas free from human, feral, or non-indigenous species impacts, and enhance colonization by desirable organisms including threatened and endangered species. In addition, wetlands provide natural protection from coastal erosion, flooding and storm surge.

Wetland restoration and enhancement is a viable beneficial use option for consolidated clay and silt/soft clay as surface material, with the possibility for using coarser or contaminated sediment as foundational material. Restoration and enhancement is accomplished by either applying thin layers of dredged material to bring a degraded wetland up to an intertidal elevation, or by creating erosion barriers using dewatered dredge material to allow the natural revegetation of a degraded or impacted wetland. Restoration/enhancement of existing wetlands is generally more successful than the creation of a new wetland where none previously existed.

Advantages of wetland restoration and enhancement include:

- High public appeal;
- Enhancement of desirable biological communities, including threatened or endangered species;
- Barrier creation for protection from coastal erosion and storm-related flooding;
- Sequestration of certain contaminants in less bioavailable forms or locations; and
- Typically a lower-cost beneficial use option especially if proximate to dredging location.

Area A contains clayey soils and material is suitable as surface material. The soil chemistry was compared to CHHSLs and PRGs to assess the risk to human health and it was found that the soil is free of chemicals of concern except for increased concentrations for arsenic, iron and benzo[a]pyrene (at one station). The soil chemistry at Area A was also compared to the Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation sediment screening criteria. The data showed that the concentrations of chemical constituents are lower than the prescribed standards and the soil at Area A is probably suitable for wetland habitat restoration/enhancement.

4.1.2 Upland Habitat Creation

An upland habitat is one in which the vegetation is not normally subjected to inundations. Upland habitats provide refuge for a broad category of terrestrial communities and range from bare ground to mature forest. Dredged material may be used to create upland habitat either through relocation of dewatered material to the proposed upland site. Upland habitat creation is a viable beneficial use option for virtually all sediments: rock, gravel and sand, consolidated clay, silt/soft clay, and sediment mixtures. Soil amendments, such as lime and organic matter, may be required to provide a suitable medium for the growth of upland plant species. The relatively high salt concentrations may only allow for salt tolerant upland species (halophytes, e.g., mulefat, saltgrass, statice, sea-blite)

Advantages of upland habitat creation include:

- High public appeal;
- Minimal site management;
- Creation of desirable biological communities; and
- Typically a lower-cost beneficial use option especially if proximate to dredging location

Area A contains predominantly clayey soils. The soil chemistry at Area A was compared to the Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation sediment screening criteria and it was found that the concentration of chemical constituents are lower than the prescribed standards and the soil at Area A is probably suitable for upland habitat creation. The saturated sediments from this region are also potentially viable for upland placement for habitat creation. The saturated sediment may be considered for placement in the upland region within the tidal restoration work at Area A.

4.2 Landscape/Vegetative Cover for Parks

Landscaping refers to the beneficial application of soil for landscaping, agriculture, residential and commercial horticulture, sod farming, and even livestock pastures. Depending on the contaminant levels of the excavated material, it could be applied directly or mixed with rich soils to create an amended mixture. The salt content in Area A limits the suitability of the sediments for typical landscaping.

4.3 Beach Nourishment

Beach nourishment refers to the strategic placement of large quantities of beach quality sand on an existing beach to provide a source of nourishment for littoral movement or restoration of a recreational beach. Generally, beach nourishment projects are carried out along a beach where a moderate and persistent erosion trend exists. Sediment with physical characteristics similar to the native beach material used is used. Material at Area A is predominantly fine-grained; therefore, it is not suitable for beach nourishment on adjacent beaches.

4.4 Solid Waste Management: Landfill Cover and Capping

Solid waste in sanitary landfills is covered everyday with a minimum quantity of site soil to prevent infiltration, control vectors, improve aesthetics, and prevent fires. Liners and barriers are used to prevent the lateral and vertical migration of pollutants. Once landfills reach capacity, a relatively impermeable cap in needed to close the system. Caps are usually covered with sandy and vegetated layers and include vents/drains to allow gases to dissipate into the atmosphere (United States Army Corps of Engineers [USACE], 1987; Great Lakes Commission, 2004).

Dewatered dredged material may be used beneficially at landfills as daily or final cover and as capping material for abandoned contaminated industrial sites known as "brownfields." Solid waste landfills require a minimum of 6 inches cover daily to prevent unsightly appearance, pest control, odor control, and to prevent surface water infiltration. In addition, the closure of a landfill or brownfield requires a cap of clean material to isolate the solid waste from the surrounding environment. Landfill cover is a viable beneficial use for consolidated clay and silt/clay. Final cover and capping is applicable for virtually all sediment types, although amendments to the material may be required to achieve the required physical properties for the intended end use.

The process steps for landside solid waste management utilizing dewatered dredged material are as follows:

- Study and Design (Reconnaissance, Feasibility Study, Design, Permitting);
- Excavation of dewatered material from CDF;
- Load, transport and offload material from trucks and stockpile at construction site;
- Blend dredged material with amendments in pug mill (due to the unconsolidated nature of the material);
- Place and spread material with bulldozers; and
- Monitoring.

A confined aquatic disposal (CAD) facility is a location where dredged material is disposed at the bottom of a body of water, usually within a depression constructed specifically for the disposal, or within a depression created during sand mining. Often, material placed in a CAD has elevated contaminants or physical characteristics that are not suitable for standard ocean disposal. Material contained in a CAD is confined to the designated area to prevent lateral or vertical movement. If material is elevated in contaminants, a clean layer of suitable clean sediment is required to minimize exposure to marine organisms.

The process steps for utilizing dewatered dredged material for cover at a CAD facility are as follows:

- Study and design (reconnaissance, feasibility study, design, permitting, easements);
- Perform tiered biological/chemical investigations regarding the effects of the material on plants and animals;
- Excavation of dewatered material from CDF;
- Load and transport by truck to barge loading site, then offload;
- Placement of cap; and
- Operation, maintenance, and monitoring of cap.

Advantages of using dewatered dredged material as daily of final landfill cover or for capping include:

- Accommodates relatively large quantities of dredged material compared to other beneficial uses;
- Dredged material typically possesses important cover material characteristics such as workability, moderate cohesion, and low permeability;
- Dredged material provides a cover that retards the infiltration of water and the diffusion of air to the waste, thus reducing infiltration of leachate into surface water and groundwater;

- Provides foundation for post-closure redevelopment such as parks, golf courses, parking lots, or light industrial use; and
- Material originated from the marine environment, therefore it is consistent with physical properties that are advantageous to placement back into the marine environment

Disadvantages of using dredged material as landfill cover include:

- Lack of availability of appropriate sites within reasonable distance of source

Area A contains fine grained clayey soils. The soil chemistry was compared to CHHSLs and PRGs to assess the risk to human health and it was found that the soil quality is acceptable for use as a landfill cover. The soil chemistry at Area A was also compared to the Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation sediment screening criteria and it was found that the concentrations of chemicals of concern are lower than the prescribed standards. Thus, the soil at Area A is suitable for landfill cover and confined aquatic disposal. However, once the specific facility is identified, the soil quality needs to comply with the soil screening criteria set forth for the specific landfill/CAD.

4.5 Construction Activities: Roads and Fill

The use of dewatered dredged material as construction fill for roads, construction projects, dikes, levees or CDF expansion is a practical beneficial use. The use of dewatered dredged material for material transfer is a viable beneficial use for sands/gravel, consolidated clay, and silt/clay, although fine-grained dredged material may require amendment to provide the physical properties required for light load engineering uses. Road work includes the beneficial use of material for fill layers (base or subbase) for roads, foundations or small structures and grading. The beneficial application of soil for road construction in California is regulated by Caltrans while its application for other constructions is regulated by the California Building Code and local building regulations. The material must have a strong bearing strength and therefore, must consist of gravel with few organics or fines (Caltrans 2006; Port of Long Beach, 2000).

Material may be amended by the addition of crushed glass, lime, cement, and fly ash. The type, combination, and amount of amendment material depends on the moisture content, the amount of fines (clays and silts), and organic content of the dredged material. Greater amounts of amendments are typically required if the dredged material has a high clay and/or organic content. The amount and type of amendment will also be dictated by the required physical properties of the finished product. Such amendments can also be used to stabilize contaminants, making this a potential use for contaminated dredged material. Proven methods have been developed for land improvement by filling the site with sand or fine sediments, such as consolidated clay and silt/clay.

Advantages of utilizing dewatered dredged material for the beneficial use of material transfer for fill include the following:

- Provides a recycled material source to replace standard construction fill materials beneficial from both a cost and resource management perspective;
- Some large public projects require large quantities of fill material and could accommodate large quantities of dredged material;

- Use in CDF expansion creates additional capacity for future maintenance dredging needs;
- Favorable to the public and local officials due to economic benefits to the public and commercial communities that industrial development in port areas can create; and
- Use of dewatered dredge material from a nearby storage facility can offset the increased transportation costs associated with hauling material from a conventional source.

The disadvantages of utilizing dewatered dredged material for the beneficial use of material transfer for fill include the following:

- Availability of this beneficial use option depends upon need and timing of development projects with dredged material;
- Bearing capacity of unamended dredged material will not meet requirements of the proposed development and amendment of dredged material adds to project costs; and
- Rehandling and movement of dredged material over long distances could make use of dredged material impractical for some projects.

Area A has inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays and fat clay with very small pockets of clayey sand. The soil is characterized by low permeability. The soil chemistry was compared to CHHSLs and PRGs to assess the risk to human health and it was found that the soil quality is acceptable for use at both residential land uses and industrial/commercial land uses. The material at Area A is suitable for construction activities. Determination of final acceptance for a construction project will depend on the specific criteria for the specific construction activity.

4.6 Open Water Disposal

Open water disposal refers to the discharge of dredged material in oceans, rivers, lakes, or estuaries by means of a pipeline or release from a hopper dredge or barge. For the purpose of this project, dredged material would be discharged from a barge into the ocean at the USEPA designated LA-3 Ocean Disposal Site. This site is located approximately 31 nautical miles from the project site. Prior to disposal, dredged material from Area A must be evaluated for suitability in accordance with *Evaluation of Dredged Material Proposed for Ocean Disposal* (USEPA/USACE, 1991). This evaluation includes solid phase (SP), suspended particulate phase (SPP), and bioaccumulation potential (BP) tests. SP tests are performed to estimate the potential impact on of dredged material on benthic organisms that attempt to re-colonize the area. SPP tests are performed to estimate the potential impact of dredged material on organisms that live in the water column. BP tests are performed to estimate the potential uptake of dredged material contaminants by organisms.

Open-water placement must comply with applicable state and federal regulations. Such regulations include, but are not limited to the Marine Protection, Research, and Sanctuaries Act (MPRSA); Clean Water Act (CWA), Section 404 (in-harbor placement) and the National Environmental Policy Act (NEPA). In all instances, applicable state and federal regulations must be followed and appropriate permits must be obtained.

Advantages of ocean disposal include the following:

- Accommodates large quantities of dredged material compared to beneficial uses;

- More economical than most beneficial uses;
- Logistically easier than most beneficial uses.

Ocean disposal is more economical than most beneficial uses due to rehandling costs. Rehandling is the process of loading, transporting, and offloading dredged material. Rehandling is often the most important factor in determining the economic feasibility of a dredging project since costs increase with the number of times dredged material is re-handled. For disposal at the LA-3 Ocean Disposal Site, dredged material would be transported by barge. For beneficial use alternatives, material would be transported by truck. Truck haul begins to lose economic efficiency as the transport distance and/or dredged material volume increases.

Based on this screening level assessment, concentrations of contaminants in Area A are relatively low (< ER-M values), indicating the dredged material is potentially suitable for ocean disposal pending a full dredged material evaluation.

4.7 Cost Estimation

The cost estimate for beneficial use of excavated material was developed based on the tidal restoration Alternative 4, proposed by USFWS, that was included in alternatives being analyzed by CDFG and CCC. The purpose of this alternative was to establish tidal and sub-tidal habitat consistent with the tidal habitat that existed in this area before it was filled with dredge material from Marina del Rey Harbor and Ballona Creek. Alternative 4, which is currently under consideration, is shown in Figure 1-2. This concept design was used to estimate the excavation volume which in turn was used to estimate screening level costs. The calculation excavation volume for Alternative 4 is 2,379,000 cubic yards. Figure 1-3 shows the expected cross section after the proposed wetland restoration is completed.

The estimated costs to beneficially use excavated material as landfill cover and/or capping material at a brownfield are provided in Appendix H. The total cost including permitting, design, site preparation and development, excavation, transport, and placement is approximately $59 per cubic yard. This cost estimate is a screening level estimate only and assumes 6% to 8 % escalation of costs per year. If the dredged/excavated material is used for landfill, it is assumed to be transported and used as daily cover for sites within 125 mile radius of the Ballona wetlands.

5.0 CONCLUSIONS

The Ballona Wetlands Area A was a former wetland that was used in the early to mid 1900s as a depository for dredge material removed during construction activities in the Marina del Ray Harbor and Ballona Creek. Approximately 4.5 million cubic yards (mcy) of dredge material was placed on the wetlands and the material is now being considered for removal in support of wetland restoration activities. Before the dredge material can be transported for potential beneficial use or ocean disposal, a geotechnical and chemical study was needed to identify any special handling or disposal restrictions that may be required. The Ballona Wetlands Area A preliminary geotechnical investigation and beneficial use/ocean disposal analyses was performed to characterized the dredge material in terms of general USCS classification, chemical constituents, potential health and environment hazards associated with the dredge material, and potential beneficial uses or disposal options for the material after excavation from the former wetlands.

The geotechnical characteristics of the dredge material that are key to determining potential beneficial uses of the excavated soil and the use of the soil for restoration are 1) grain size distribution, 2) plastic limit, 3) liquid limit and 4) moisture content. The lithology of Area A is similar across the site and is classified as mixtures of clay. According to USCS classification, the soil is classified as inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays and lean clays. The northwest portion of the study site close to Lincoln Boulevard has cobbles and coarse gravel in the top few feet of soil. This subarea might need segregation and separate stockpiling during excavation since its beneficial use is different from the rest of the site.

Soil samples from 20 site locations were analyzed for a suite of organic constituents and metals to determine the potential human health risks associated with exposure to excavated dredge material. In addition, a leaching study was performed to determine potential environmental exposure to toxic metals. The key metrics for screening the Area A soils for beneficial use or ocean disposal was the ability to demonstrate that the soils did not contain chemicals of concern at concentrations exceeding TTCL, STLC, CHHSL, PRGs, Interim Sediment Screening Criteria, and ER-L and ER-M values. The leaching study performed on the soil samples successfully demonstrated that the soil was non hazardous and does not pose an environmental risk due to toxic levels of leachable metals. In addition the soil is suitable for a variety of beneficial uses due to concentrations of PAHs, PCBs, pesticide, s-VOCs, or VOCs that are below the regulated human exposure limits or interim sediment quality criteria. Several soil samples did exceed PRGs (residential use) for arsenic and lead and one sample exceeded the PRG (residential use) for benzo (a) pyrene. Soil samples that contained exceedances in arsenic were found in the eastern third of the site and in the general location where field engineers had noted discoloration and streaking of the soil during core sampling. This area is also the location of an abandoned underground fuel transportation line. Several metals and one organic exceeded the corresponding ER-L values; however, no analytes exceeded the corresponding ER-M values. This indicates relatively low concentrations of contaminants. The dredged material may potentially be suitable for ocean disposal pending a full dredged material evaluation.

The preliminary beneficial use analysis identified the following potential options:

a. Habitat Restoration/ Enhancement

b. Landscape/ Vegetative Cover
c. Beach Nourishment
d. Solid Waste Management: Landfill
e. Solid Waste Management: Confined Aquatic Disposal Cap
f. Construction Activities

The geotechnical characterization of the Area A soil showed that it is a mixture of fine-grained materials. Because the soil is predominately low plasticity clays, silty clays, sandy clays or clayey silts (CL), the dredged material is most suitable for landfill activities and habitat restoration activities. Soil amendments, such as lime and organic matter, may be required to provide a suitable medium for the growth of upland plant species. The salinity of the soil may only allow for salt tolerant upland species (halophytes such as mulefat, saltgrass, statice and sea-blite). In addition, the soil could be used for general fill if the top 3 or 4 feet of fill material consisted of soil with a higher organic content.

The volume of excavated material that would be generated under the Alternative 4 Restoration Project is estimated to be approximately 2.5 to 3 million cubic yards. The estimation is based on the concept design introduced by USFWS that is being evaluated by CDFG and CCC. A summary of the approximate volume potentially suitable for each beneficial use and placement alternative is presented in Table 5-1.

Table 5-1. Summary of Beneficial Use and Disposal Options and Approximate Volume Potentially Suitable for Each Alternative

Beneficial Use or Disposal Option	Type of Use	Approximate Volume Suitable	Comments
Habitat Restoration/ Enhancement	Upland	800,000 cy plus, dependent on salt content and end use.	Salts may prevent beneficial use in the sediments below 5.5 MLLW, where salt water intrusion may be occurring.
	Wetlands	800,000 cy plus, dependent on salt content and end use.	Salts may prevent beneficial use in the sediments below 5.5 MLLW, where salt water intrusion may be occurring.
Solid Waste Management: Landfill	Cap	2.4 mcy	
	Cover	2.4 mcy	
	Liner/Barrier	2.4 mcy	
	Base	2.4 mcy	
Solid Waste Management: Confined Aquatic Disposal Cap	Cap	2.4 mcy	Dependent on compatibility of material with area surrounding the Confined Aquatic Disposal facility.
Construction Activities	General - Fill	2.4 mcy	
	Pier A west - Backfill	2.4 mcy	
Ocean Disposal	N/A	1.5 mcy	Pending a full dredged material evaluation.

Although the preliminary chemical assessment demonstrated that the majority of the Area A soil is within regulatory limits for use as landfill material and restoration activities, the screening criteria cannot be applied without consideration of site specific factors. This is a screening level assessment and more analysis would be required before a disposal option is selected and/or implemented.

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APPENDIX F4
Sediment Characteristics Sampling and Analysis Plan (SAP) for Ballona Wetlands

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SEDIMENT CHARACTERISTICS SAMPLING AND ANALYSIS PLAN – BALLONA WETLAND

Final

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1.0 INTRODUCTION

Weston Solutions, Inc. (Weston) under contract with ESA-PWA has prepared this work plan for sample collection and analysis to characterize soils and sediments within Areas A, B and C for beneficial use within the proposed Ballona Wetland Restoration Project, located in Los Angeles, California.

1.1 Purpose

The purpose of this work plan is to outline the sampling and analytical methods and procedures to characterize the chemical nature of the sediments within Areas A, B and C in order to determine their suitability for use as upland and/or wetland material within the Ballona Wetland Restoration Project. This Work Plan for chemical characterization of sediments is to be coordinated with the geotechnical investigation planned as part of the current design efforts. Samples for chemical and bioassay analysis as defined in this Work Plan will be collected during the geotechnical investigation completed by Group Delta Consultants, Inc. (GDC). Weston has coordinated through ESA-PWA with GDC on the development of this Work Plan to provide a cost effective approach to characterize the sediments for re-use on-site. This Work Plan also provides the proposed screening tools and guidelines that will be used to assess the on-site sediments for use in the Ballona Wetland Restoration Project.

1.2 Site Description

Areas A, B, and C are 139, 398, and 66 acres, respectively, portions of the Ballona Wetlands Ecological Reserve, an area currently proposed for restoration as part of the Ballona Wetlands Restoration Project (Restoration Project). The Restoration Project is led by the California Coastal Conservancy (CCC) and the current owner, California Department of Fish and Game (CDFG).

Area A is bound by Marina del Rey channel on the west, Ballona Creek on the south, Fiji Way to the north and Lincoln Boulevard to the east. Area A was altered during the channelization of Ballona Creek in the 1930s and during the excavation of Marina del Rey Harbor in the 1960s, when the site received a large volume of dredge material. Approximately 15 to 25 feet of dredged and fill material has been placed on Area A during the excavation of Ballona Creek and Marina del Rey.

The site is currently fenced off and undeveloped except for a paved parking area along the western boundary. See Figure 1-1 for a current aerial view of Areas A, B and C.

Above: View of Area A from Marina Ditch culvert facing south. Black mustard, the yellow flowering plant predominant in this photo, is a non-native invasive species.

Fiji Ditch, a tidal channel connected to Basin H of Marina del Rey Harbor, starts in the middle of the northern edge of the site and runs east and west.

Area C is bound on the north by residential area, on the south by Ballona Creek, and lies west of Highway 90 and east of Lincoln Boulevard. Culver Boulevard currently transects the site. One of the largest changes to the area came in the early 1960's with the excavation of Marina Del Rey and the disposal of dredge fill from that project on the remaining wetlands north of Ballona Creek. The land surface was raised 12 to 15 ft above MSL, raising the land surface above tidal inundation and burying the existing marsh surface and drainage channels. (Draft Ballona Wetland Existing Conditions Report 2nd Revision, version 4, Philip Williams and Associates, March 2006).

Above: Looking northwest across Area C from Culver Boulevard

Area B covers an area of 398 acres, bound on the north by the Ballona Creek Channel, on the south by the Del Rey Bluffs, and lies west of Lincoln Boulevard and Playa del Rey. Site elevations range between approximately 2 and 5 ft in the lower flat portions, and up to 50 ft MSL below Del Rey Bluff. It is surrounded by residential development on the east, west, and southern sides, and Ballona Creek on the north. Area A is directly north of Area B on the other side of Ballona Creek. Culver Boulevard dissects the site in a southwest to northeast manner. West Jefferson Boulevard also runs in this manner in the eastern portion of the site, merging with Culver Boulevard approximately mid way through the site.

Above: Looking south over a tidal channel in Area B

Figure 1-1. Aerial Photograph of Areas A, B and C

1.3 Project Description

The Ballona Wetlands restoration includes the reintroduction and revival of critical wetland habitat, including target animal and plant species, and the creation of a natural open space for the public benefit. The restoration plan will include the following (shown in Figure 1-2):

Ballona Creek Channel Restoration

- Removal (breaches) of the existing north and south levees in 4 locations, and the lowering and realignment of the channel for the creation of a natural meandering channel.

Area A

- Mass grading, soil excavation and removal, and hauling of previously placed dredged materials.
- Construction of flood protection levees along the north perimeter of the site using the excavated soils.
- Maintain Fiji Channel in current configuration

Area B

- Construction of flood protection levees along the north side of Culver Boulevard, and the west portion of the area
- Realignment of Ballona Creek by excavating of existing levee and lowering of existing higher elevation areas to between elevation 4.0 ft. and 6.0 ft. NAVD.
- Restoration of wetlands between the new levees and the realigned Ballona Channel, and managed restoration of the wetlands area located south of the new levees (construction of buried culverts).
- Fill placement in a stockpile area bordered by Culver Boulevard, Jefferson Boulevard, and Lincoln Boulevard.

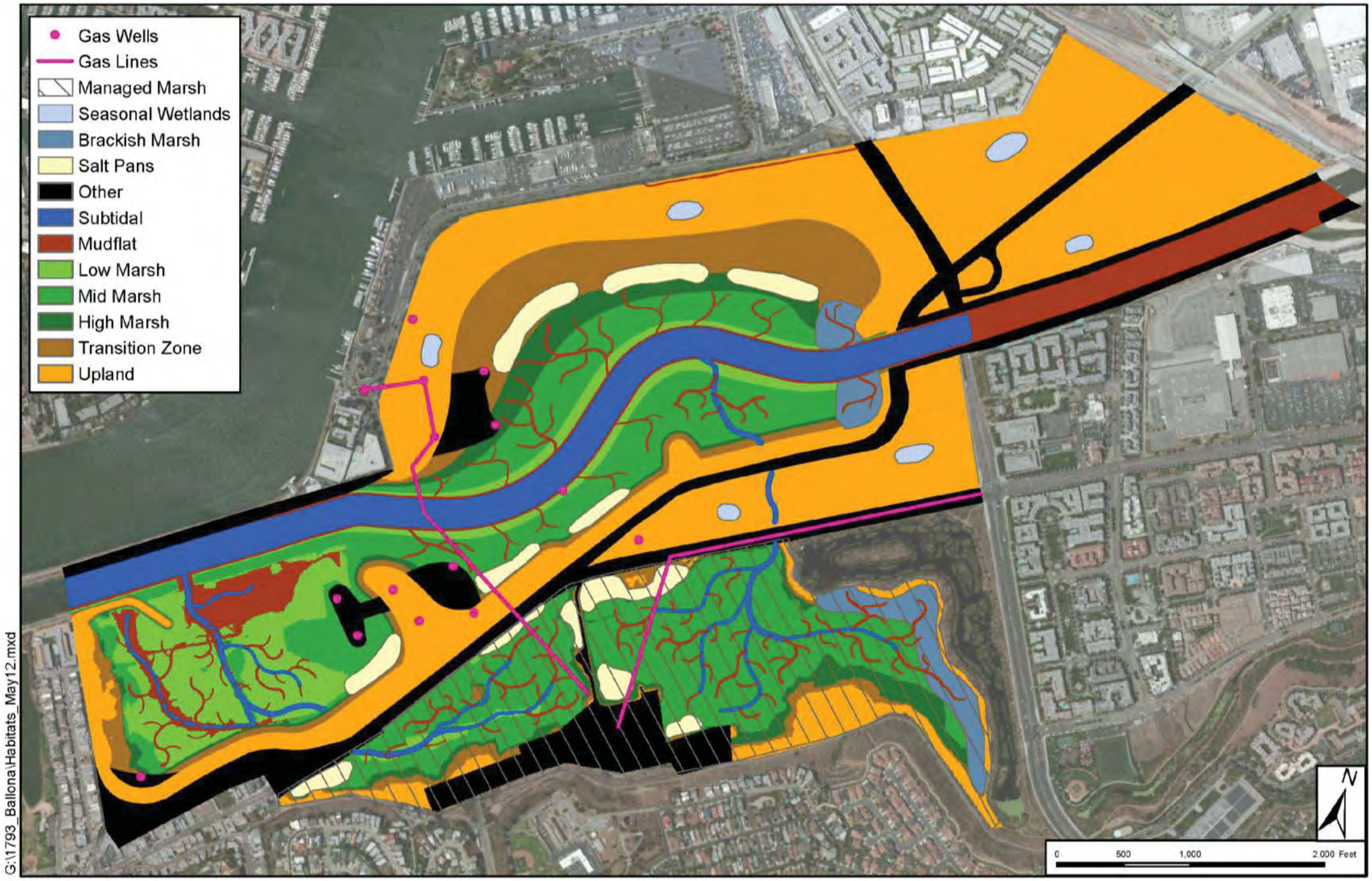
Area C

- Fill placement in stockpile areas in locations on the north and south sides of Culver Boulevard.

Other Areas

- Construction of a pedestrian and bicycle bridge spanning the Ballona Creek Channel near Culver Boulevard, and an at-grade bicycle roadway along the new levee in Area B.

The implementation of the restoration plan will require a technical analysis and review, and approval by the U.S. Army Corps of Engineers (USACE) along with a Section 408 permit.



NOTES: Tidal channel, salt pan, brackish marsh, and seasonal wetland habitats are shown schematically. Upland sub-habitat types are not shown. Planning and design of these and other habitats will be refined.

ESA PWA

Ballona Wetlands Restoration

Figure 1

Restored Habitat Zones Post-Restoration

Figure 1-2. Ballona Wetland Restoration Plan

1.4 Results of Previous Geotechnical Investigation in Area A

A preliminary geotechnical investigation was completed by Weston under contract from the Port of Los Angeles in 2008. The primary objective of the Preliminary Study was to provide geotechnical and chemical data to characterize approximately 4.5 million cubic yards (cy) of dredge material which has been placed on Area A over the years and which is being considered for removal in support of the Restoration Project. This study was used to determine potential beneficial uses of the dredge material; to identify any special handling or disposal restrictions that may be required, based on sediment and leachate chemistry; and to guide any further assessment deemed necessary. This program included the collection of sediment samples from direct push cores for chemical and geotechnical analysis. The location of the completed borings for the Preliminary Study is shown on Figure 1-3. The complete results are presented in the Final Report – Ballona Wetland Preserve – Area A Preliminary Geotechnical Investigation and Beneficial Use Assessment (Weston, 2009).

This screening level assessment was used to guide a future, regulatory-compliant beneficial use assessment or dredge material evaluation for on-site beneficial use, off-site use and potential ocean disposal that would be needed for various restoration alternatives that were being evaluated at that time. The following subsections first present the screening criteria that were used to access the results of the Preliminary Investigation, and secondly, a summary of the results of chemical testing compared to these criteria. The results of the Preliminary Investigation were used to scope the sediment characterization sampling and analysis program presented in this Work Plan.

1.4.1 Relevant Screening Criteria for Area A Sediments

Analytical results will be compared to relevant soil screening levels, sediment quality guidelines, and hazardous waste criteria to determine suitability of material for specific beneficial uses or placement options. Relevant numeric standards for comparisons include:

- <u>**Hazardous Waste Criteria**</u>
    - **Total Threshold Limit Concentration (TTLC) and Soluble Threshold Limit Concentration (STLC)**: TTLC and STLC are used to determine the hazardous waste characterization under California State regulations as outlined in Title 22 of the California Code of Regulations (CCR).Concentrations of contaminants in project soil were compared to TTLC and 10 times the STLC. If concentrations exceed 10 times the STLC, a Waste Extraction Test (WET) must be performed to estimate the contaminant leachate. If concentrations of contaminants in soil exceed the TTLC or leachate from the WET exceed the STLC, the material is classified as hazardous waste. If a waste is determined to be a hazardous waste, specific regulations and statutes regarding the management, storage, transportation and disposal must be met.
    - **Toxicity Characteristic Leaching Procedure (TCLP):** TCLP is the characterization for hazardous waste based on Federal guidelines. TCLP analysis was performed to provide an estimate of the soil contaminant leachate and to determine if this material is classified as hazardous waste or if it is considered suitable for upland placement. Analytes leaching from the soil were compared to USEPA Title 40 Code of Federal Regulations (CFR) Part 261 values (USEPA, 2006).

Figure 1-3. Preliminary Geotechnical Investigation Boring Location Plan

- <u>**Human Health Screening Levels**</u>
  - **California Human Health Screening Levels (CHHSLs)**: Concentrations of 54 hazardous chemicals in soil that the California Environmental Protection Agency (Cal/EPA) considers to be below thresholds of concern for risks to human health based on ingestion, inhalation, and dermal absorption. The CHHSLs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) on behalf of Cal/EPA, and are contained in their report entitled "Human-Exposure-Based Screening Numbers are Developed to Aid Estimation of Cleanup Costs for Contaminated Soil". Any exceedances of the CHHSLs do not indicate that the levels are of concern, but suggest that further evaluation of potential human health concerns may be considered. Residential CHHSLs are recommended for use by the California Department of Toxic Substances Control (DTSC) for human health screening evaluation described in the Preliminary Endangerment Assessment (PEA) Guidance Manual.
  - **Preliminary Remediation Goals (PRGs)**: For contaminants that CHHSLs are not developed, the PRGs are used. The PRGs were developed by USEPA Region IX as a risk-based screening tool for evaluating and cleaning up contaminated sites. The Region IX PRGs were developed prior to the CHHSLs and are similar or slightly less stringent. The values are calculated from current human health toxicity values with standard exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that are considered by the Agency to be health protective of human exposures (including sensitive groups), over a lifetime. As with CHHSLs, exceedances do not indicate that the levels present are a human health concern, however, more evaluation may be required.

- <u>**Ecologically Relevant Screening Criteria**</u>
  - **Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation and Upland Beneficial Reuse**. These sediment screening criteria and testing requirements are for the beneficial reuse of dredged material such as wetlands creation and upland disposal. The criteria were developed by the California Regional Water Quality Control Board. (This sediment screening criteria and testing requirements are for the beneficial reuse of dredged material such as wetlands creation and upland disposal. The report document was created by the California Regional Water Quality Control Board for the San Francisco Bay Region.) The criterion for wetland surface material is based on ambient values within San Francisco Bay and therefore may not be applicable for Ballona Wetland. Other criterion that may be used includes Effects Range-Low value as discussed in the following bullet and ambient concentration in Area B. Ambient values are used because attaining lower values may not be possible if constituent inputs to existing wetlands continue after restoration. Sediment ambient values are available for Area B for comparison.
  - **Effects Range-Low (ER-L) and Effects Range-Median (ER-M) Values**: Effect range values are used in dredged material evaluations for ocean disposal. These values were developed by Long et al. (1995), and are helpful in assessing the potential significance of elevated sediment-associated COCs, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., toxicity tests, benthic community

effects) and chemical analysis were available for individual samples. To derive these guidelines, the chemical values for paired data demonstrating benthic impairment were sorted in according to ascending chemical concentration. The ER-L was then calculated as the lower tenth percentile of the observed effects concentrations and the ER-M as the 50^{th} percentile of the observed effects concentrations. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. For dredged material evaluations, the ER-L and ER-M sediment quality values are used in conjunction with bioassay testing and are included for comparative purposes only. For certain pesticide compounds (i.e., chlordane and dieldrin) the ER-L and ER-M levels are so low as to make it largely impractical to detect them in typical harbor sediments using routine analytical procedures. Accordingly, having non-detect results that were greater than the ER-L, ER-M, or method detection limits (MDLs) would not require re-analysis. The use of ER-L and ER-M for use as screening criteria for sediments in Area A is appropriate when used as a tiered approach that includes using bioassay results to determine actual toxic effects to the benthic community.

- **Sediment Quality Objectives (SQOs)** - California's SQOs are described in the *Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality* (SWRCB and CA EPA, 2009). The goals of the SQOs are to determine whether pollutants in sediments are present in quantities that are toxic to benthic organisms and/or will bioaccumulate in marine organisms to levels that may be harmful to humans. The SQOs are based on a multiple lines of evidence (MLOE) approach in which sediment toxicity, sediment chemistry, and benthic community condition are the lines of evidence (LOE). The MLOE approach evaluates the severity of biological effects and the potential for chemically mediated effects to provide a final station level assessment. The use of SQOs require that the site be fully submerged under tidal conditions and assumes establishment of a benthic community. These conditions will not exist until after the restoration in Area A, therefore the use of the SQOs is not applicable. The SQOs ratings cannot be applied without the use of benthic data, and therefore are not applicable at this time to assess Area A sediments. However, in the absence of clearly defined criteria for evaluating use of sediment in Area A for wetland surface material, chemical and bioassay methods and screening used for SQOs may be used for planning purposes and establishing baseline data as part of multiple screening criteria.

1.4.2 Summary of Results from Previous Investigation of Area A Sediment Using Relevant Screening Criteria

A summary of the measured chemical constituents and comparison to the most appropriate soil screening levels, sediment quality guidelines, and hazardous waste criteria was conducted on samples collected from the Preliminary Geotechnical Investigation and Beneficial Use Assessment of Area A (Weston, 2009). A summary of constituents above soil screening criteria and sediment quality guidelines are discussed below and presented in Table 1-1 and Table 1-2, respectively.

Comparison to Hazardous Waste Criteria

No chemicals were detected at concentrations greater than the TTLC or at concentrations greater than 10 times the STLC value. Results of TCLP analyses indicated no analytes above the toxicity characteristic standards USEPA 40 CFR Part 261 values (USEPA, 2006). Therefore, the material is not classified as a hazardous waste and is suitable for upland placement options.

Comparison to Human Health Criteria

The analyzed organic chemicals of concern were PAHs, PCBs and organochlorine pesticides. With the exception of one soil sample, none of the Area A samples contained concentrations of PAHs, PCBs, or pesticides above the CHHSLs and PRGs soil criteria. The concentration of benzo [a] pyrene at Station 27 was 39.7 µg/kg dry weight and this exceeded the human health screening level (set at 38 µg/kg dry weight) for potential residential land use.

While most of the chemical screening values are below levels of concern for human health, arsenic and iron were measured at ambient concentrations greater than residential CHHSLs and PRGs. The concentrations of arsenic and iron found are consistent with natural concentrations in marine sediments. A summary of soil samples that exceeded soil criteria is shown in Table 1-1.

During the boring and sampling operations, PID readings were taken to identify potential "hot" zones which might contain elevated VOC concentrations. Soil samples from five stations showed elevated PID readings in the field and were subsequently selected for s-VOC and VOC analysis. The results of the laboratory analysis showed that none of the five samples exceeded CHHSLs or PRGs criteria for residential and commercial land use.

Due to the historic and current presence of gasoline production and transportation at Area A, the 20 soil stations were analyzed for total petroleum hydrocarbons (TPHg and TPHd) and benzene, ethylbenzene, toluene, and xylenes (BETX). None of the soil samples had concentrations of TPHg, TPHd or BETX above the CHHSLs and PRGs. However, during drilling operations at Station 25 and 26, the field engineer noted evidence of soil staining throughout the soil core. These two stations are closest to the compressed natural gas line that runs north-to-south through Area A.

Comparison to Ecologic Criteria

The results of the chemical analysis were also compared to soil clean-up standards which may be applied to the Area A soils since the dredged material has been dewatered. In addition, the soil below the water table may be considered sediment and may be subject to proposed sediment quality criteria if used for the Restoration Project. The Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation and Upland Beneficial Reuse, as established by the California Regional Water Quality Control Board for San Francisco Bay use ambient values to assess suitability for surface wetland materials, and ER-M values for wetland foundation material (material is covered and not exposed). Comparisons to the ambient criteria were not performed as these values apply to San Francisco Bay.

Concentrations of metals were compared to ER-L and ER-M values. Several metals slightly exceeded the corresponding ER-L values, including arsenic, cadmium, copper, lead, mercury, nickel, and silver (Table 1-2). No metals exceeded the corresponding ER-M values, indicating relatively low concentrations.

Concentrations of organics were also compared to ER-L and ER-M values. The only organic to exceed the corresponding ER-L value was 4,4'-DDE in the composite sample from Stations 21 and 25 (Table 1-2). No organics exceeded the corresponding ER-M values, indicating relatively low concentrations.

Table 1-1. Summary of Soil Samples with Analytes that Exceed California Human Health Screening Levels or Preliminary Remediation Goals

Group	Analyte	Units	RL	Residential Land Use		Commercial/Industrial Land Use Only		S10 060208-6-7	S11 070208-14-15	S11 S15 S28-14-20	S15 080208-15-16	S15 S28 15-16	S17 080208-10-11	S17 S18 10-12	S18 080208-7-8	S21 080208-6-7	S21-S25 6-8
				CHHSLs	PRG	CHHSLs	PRG	Discrete	Discrete	Composite	Discrete	Composite	Discrete	Composite	Discrete	Discrete	Composite
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Iron (Fe)	µg/dry g	5		23000		100000	15890	37840	41390	38250	32840	28970	37170	37940	30390	32920
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	<5	<5	<5	<5	<5	<5	<5	<5	7.3	6.8

Group	Analyte	Units	RL	Residential Land Use		Commercial/Industrial Land Use Only		S23 080208-12-13	S23 S24 S26-21-24	S27 S29 S30 6-8	S29 070208-6-7	S3-11-12 15-16	S4-S10-5 7	S5 060208 15-16	S5-S6 15 16	S5-S6 S9-3 4	S9 060208 3-4
				CHHSLs	PRG	CHHSLs	PRG	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Iron (Fe)	µg/dry g	5		23000		100000	27480	36000	31170	26180	34330	18770	35380	26340	20140	14270
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	3.4 J	<5	39.7	<5	6.1	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
Yellow - Concentration exceeds respective soil screening criteria.

Table 1-2. Summary of Soil Samples with Analytes that Exceed Effects Range-Low or Effects Range-Median Values

Group	Analyte	Units	RL	Disposal Option Sediment Screening Criteria		S10 060208 6-7	S11 070208 14-15	S11-S15 S28 14-20	S15 080208 15-16	S15 S28 15-16	S17 080208 10-11	S17-S18 10-12	S18 080208 7-8	S21 080208 6-7	S21-S25 6-8
				ER-L	ER M	Discrete	Discrete	Composite	Discrete	Composite	Discrete	Composite	Discrete	Discrete	Composite
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.262	0.201	1.243	0.836	0.684	0.089	0.595	0.307	0.614	0.57
	Copper (Cu)	µg/dry g	0.05	34	270	11.15	33.62	22.17	39.25	28.84	18.03	28.89	28.99	31.63	35.6
	Lead (Pb)	µg/dry g	0.05	46.7	218	4.742	7.802	4.583	7.924	6.104	3.783	5.758	6.194	24.94	50.72
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.043	0.053	0.055	0.068	0.052	0.041	0.049	0.06	0.303	0.215
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	14.69	27.15	21.2	25.37	21.42	17.05	24.09	23.61	22.55	23.94
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.04 J	0.035 J	0.072	0.038 J	0.113	0.042 J	0.173	0.052	1.079	1.027
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	11.6

Group	Analyte	Units	RL	Disposal Option Sediment Screening Criteria		S23 080208 12-13	S23 S24 S26 21 24	S27-S29 S30 6-8	S29 070208 6-7	S3 11-12-15-16	S4-S10 5-7	S5 060208-15-16	S5-S6 15-16	S5-S6 S9-3-4	S9 060208-3-4
				ER-L	ER M	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.67	0.482	0.63	0.257	0.499	0.199	0.175	0.147	0.255	0.208
	Copper (Cu)	µg/dry g	0.05	34	270	25.64	30.61	37.79	20.12	28.08	14.52	27.21	21.25	12.81	9.257
	Lead (Pb)	µg/dry g	0.05	46.7	218	5.361	7.187	31.96	8.573	19.58	4.625	4.742	3.514	6.364	3.383
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.028	0.083	0.189	0.077	0.089	0.065	0.067	0.058	0.046	0.053
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	26.33	25.27	25.6	19.71	26.05	15.74	20.98	16.44	15.2	13.25
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.105	0.221	0.224	0.129	0.174	0.096	<0.05	0.258	0.138	0.04 J
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
Yellow - Concentration exceeds respective sediment screening criteria.

2.0 SCOPE OF WORK

This Work Plan presents the proposed Sediment Characteristic Sampling and Analysis program for Areas A, B and C in order to determine the suitability of existing sediment/soils within these areas for use as upland and/or wetland material within the Ballona Wetland Restoration Project. Because Area C will not be excavated and will receive greater than three feet of fill material, no sampling and analysis of existing soils are planned in Area C under this Work Plan. Proposed sampling and analysis for sediment characterization are therefore focused on Areas A and B where excavation of existing materials is anticipated. The scope of work includes the chemical characterization and toxicity analysis of sediment samples that will be collected for the geotechnical investigation planned as part of the current design efforts. Samples for chemical and bioassay analysis as defined in this Work Plan will be collected during the geotechnical investigation completed by Group Delta Consultants, Inc. (GDC). This Work Plan also provides the proposed screening tools and guidelines that will be used to assess the on-site sediments for use in the Ballona Wetland Restoration Project. The Scope of Work includes preparation of a summary report of the chemical and bioassay analysis, and the assessment of the results using the proposed screening tools and guidelines outlines in this Work Plan.

2.1 Sample Collection

Samples for chemical characterization and bioassay will be collected from selected geotechnical borings. Figure 2-1 presents the proposed geotechnical boring locations that are planned for the Geotechnical Investigation. The drilling methods and procedures for the Geotechnical Investigation are defined in the Work Plan for Geotechnical Investigation Ballona Wetland Restoration (Group Delta, 2012). Based on these proposed drilling methods, sediment samples will be collected from either spilt spoon samplers advanced ahead of hollow stem or rotary wash drilling methods. Sediment samples for chemical and bioassay analysis shall include both discrete and composite samples. Discrete samples shall be collected using split spoon or direct push sampling methods. The spilt spoon sampler shall collect sediment cores of five foot lengths in advance of the hollow stem and rotary wash techniques to minimize sample disturbance and avoid potential down-hole contamination from materials above the spilt spoon samples. Where additional sample volume is needed for bioassay testing, samples may be collected over a 10 foot interval or two five foot cores. Split spoon sampler shall be decontaminated in accordance with the protocols outlined in this Work Plan to avoid cross contamination of samples.

Direct push core sampling techniques are also proposed adjacent to the proposed boring locations to collect sediment samples for chemical and bioassay analysis. This option has been provided to potentially address both the need to thoroughly decontaminate the split spoons and augers and the sample volume requirements for chemical and bioassay sampling. In addition, the cone penetrometer (CPT) technique that will be used at several geotechnical boreholes does not have the ability to collect physical samples. Direct push technology (DPT) refers to tools used to perform subsurface investigations by pushing hollow steel rods into the ground. This method provides a low impact drilling technique should adjacent borings be needed. The direct push boreholes are significantly smaller and the rigs can be mounted on vehicles such as ATVs which are small and highly maneuverable.

Due to the potential presence of natural gas in this area, non-sparking tools will be used.

The driller will perform a thorough decontamination between each borehole to avoid cross-contamination. Decontamination procedures are outlined in this section.

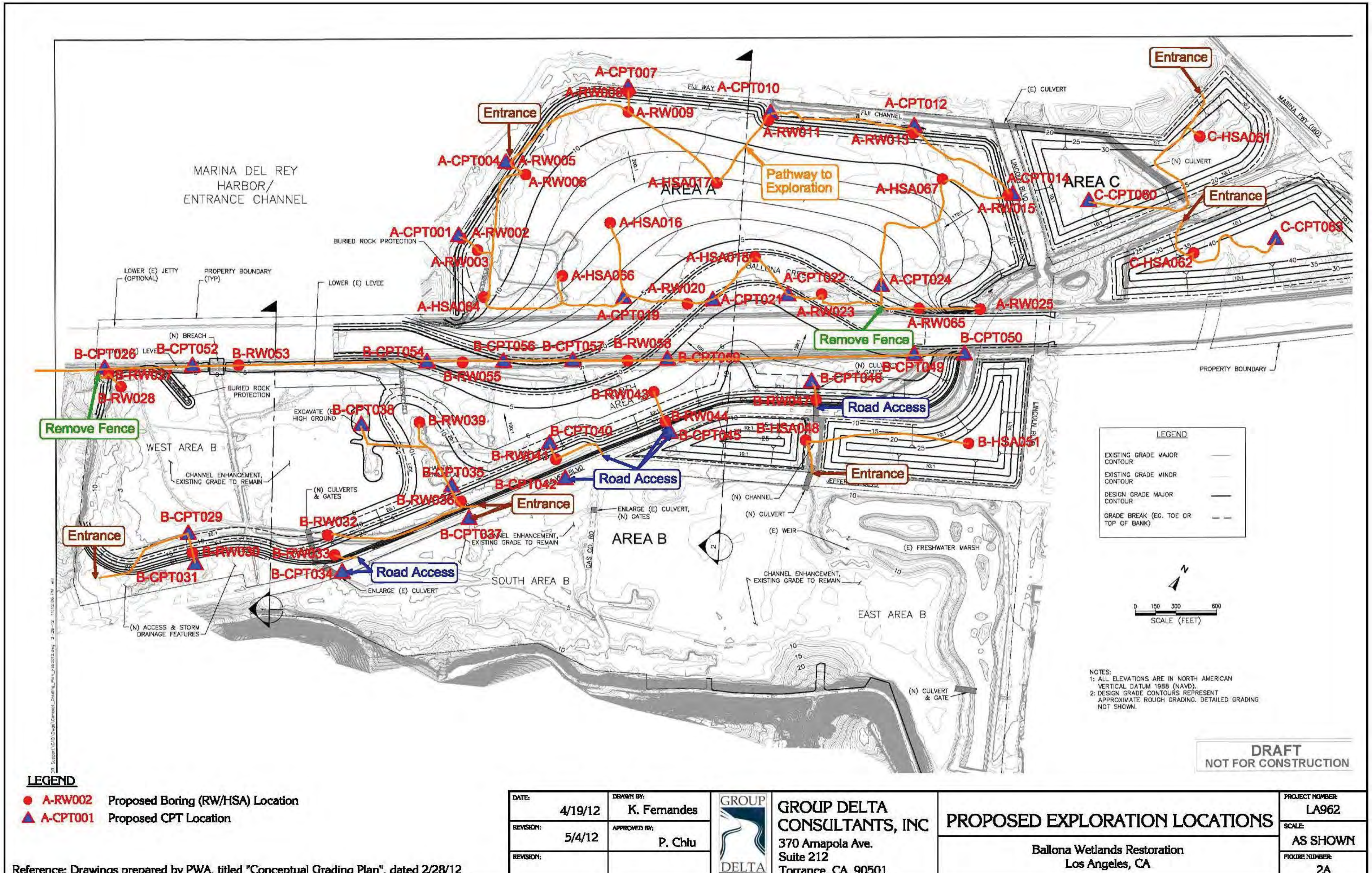


Figure 2-1. Proposed Geotechnical Investigation Boring Location Plan (Group Delta)

Based on these proposed drilling methods, sediment samples will be collected from selected Geotechnical Investigation borehole sites using either split spoon or DPT cores. Sediment samples for chemical and bioassay analysis shall include both discrete and composite samples. Discrete samples shall be collected from specific depths and material types. Composite samples shall be collected from multiple core samples within an interval of material.

Discrete Samples

Discrete samples are samples collected from one soil horizon and a specific elevation, and help to ensure accurate representation of the sediment by depth, soil type, and spatially. Discrete samples will be collected at proposed depths of excavation that will be exposed for restoration, and need to be assessed for suitability as tidal wetland or transition zone habitat. Multiple discrete samples may be needed at these proposed elevations should different materials be encountered. Discrete samples shall be collected from split spoon or DTP cores at the elevations and interval specified. Sufficient sample volume shall be collected to complete the chemical and bioassay testing specific in this Work Plan. For discrete sampling that requires sufficient volume for both chemical and bioassay testing to determine the suitability for wetland surface materials, samples may be collected from two consecutive five foot cores that equally straddle the proposed final elevation of the Restoration Project. If a different stratum is encountered within this 10 foot interval, such as the original marsh materials, separate chemical samples shall be collected from the different stratum, and similar materials above the different stratum shall be used for the bioassay and chemical samples for wetland surface suitability testing.

Composite Sampling

Composite samples are samples collected from different soil horizons within one borehole. Composites can be an efficient way to categorize larger volumes of sediment with a smaller number of samples. A qualified geologist or geotechnical engineer will base the selection of composite samples on the bore logs to ensure representative samples. Composite samples will be collected from spilt spoon or DTP cores over a 10-foot interval or greater. Composite samples will be mixed in the field. Each section to be composited will be homogenized in a stainless steel bowl with stainless steel utensils. Disposable mixing bowls and utensils may also be used, but shall be disposed of after use at each borehole location. The final composite will use a consistent sample volume from each section to be combined to ensure a representative sample. Separate composite samples will be taken from intervals above and below the water table in selected boreholes to characterize these materials suitability for use as upland materials.

Sediment samples shall be collected in accordance with the following four types of boreholes sites to address specific sediment characterization questions:

1. Area A and B Boreholes that are located in or near the proposed new Ballona Creek Channel alignment.
2. Area A and B Boreholes located within proposed Marsh Habitat and Transition Zone Habitat.
3. Area A Boreholes located in proposed Upland Areas.
4. Area A and B Boreholes near and within the Existing Gas Wells and subject to regrading.

Each of these sets of proposed boreholes and sediment samples address specific sampling objectives and therefore will have specific sampling requirements. These objectives consist of determining the suitability of existing materials for use in restored tidal wetland or upland habitat soils, and if contamination exists that require special material handling. The overall approach to the Sediment Characterization Program and chemical and bioassay analysis of selected sediment samples is presented in Table 2-1. Appendix A provides the coordinates for each of the proposed boring locations and the existing and proposed final grades at these sample locations. The depth of proposed sampling will be based on the sampling approach presented in Table 2-1 and the existing and proposed grades provided in Appendix A.

Table 2-1. Sediment Characterization Program – Chemical and Bioassay Analysis of Selected Sediment Samples

Borehole Sites	Sample ID	Sampling Objective	Sample Selection Process	Sample Type	Sampling Method	Estimated Depth	Chemical Analysis	Bioassay Analysis	Sample Volume Needed
1. Area A and B Boreholes in/near Proposed Channel **A-RW020** **A-HSA018** **B-RW055**	A-RW020-D-1 A-HSA018-D-1 B-RW055-D-1	Wetland Surface Suitability	Proposed Channel Elev.	Discrete	Split Spoon or Direct Push Core	Depth of Proposed Channel – Sample Interval 5 ft.	General Chemistry, Organics, Inorganics (See Table 2-3)	Acute, 2 Species Amphipod and Polychaete after sample acclimation	2 – 16 oz. sample jars (total 32 oz.) and 10 Liter Sample in Sediment Bag
	A-RW020-D-2 A-HSA018-D-2 B-RW055-D-2	Wetland Surface Suitability	Change in Material +/-5 ft. within Prop. Channel Elev. (e.g. old marsh mat'l) – if no change –collect 2.5 to 10 ft. below Channel Elev.	Discrete	Split Spoon or Direct Push Core	Within 10 foot interval of Proposed Channel Depth	General Chemistry, Organics, Inorganics (See Table 2-3)	No bioassay	2 – 16 oz. sample jars (total 32 oz.)
	A-RW020-C-3 A-HSA018-C-3 B-RW055-C-3	Use of Material for Upland Placement	Material above the water table – 10 ft interval of similar sediment	Composite	Split Spoon or Direct Push Core	Composite from two consecutive 5 ft. cores	General Chemistry, Organics, Inorganics (See Table 2-3)	No bioassay	2 – 16 oz. sample jars (total 32 oz.)
2.Area A and B Boreholes – Located in Proposed Marsh Habitat & Transition Zone **A-HSA016** **B-RW043**	A-HSA016-D-1 B-RW043-D-1	Wetland Surface Suitability	Proposed Wetland Restoration Elev.	Discrete	Split Spoon or Direct Push Core	Depth of Proposed Excavation – Sample Interval 5 ft.	General Chemistry, Organics, Inorganics (See Table 2-3)	Acute, 2 Species Amphipod and Polychaete after sample acclimation	2 – 16 oz. sample jars (total 32 oz.) and 10 Liter Sample in Sediment Bag
	A-HSA016-C-2 B-RW043-C-2	Use of Material for Upland Placement	Material above the water table – 10 ft interval of similar sediment	Composite	Split Spoon or Direct Push Core	Composite from two consecutive 5 ft. cores	General Chemistry, Organics, Inorganics (See Table 2-3)	No bioassay planned	2 – 16 oz. sample jars (total 32 oz.)
	A-HSA016-C-3 B-RW043-C-3	Use of Material for On-site Grading – Upland or Wetland	Material below the water table – 10 ft interval of similar sediment	Composite	Split Spoon or Direct Push Core	Composite from two consecutive 5 ft. cores	General Chemistry, Organics, Inorganics (See Table 2-3)	No bioassay planned	2 – 16 oz. sample jars (total 32 oz.)
3.Areas A Boreholes – Located in Upland Areas **A-HSA067**	A-HSA067-C-1	Use of Material for Upland Placement	Material above the water table – 10 ft interval to straddle proposed excavation depth	Composite	Split Spoon or Direct Push Core	Composite from two consecutive 5 ft. cores	General Chemistry, Organics, Inorganics (See Table 2-3)	No bioassay planned	2 – 16 oz. sample jars (total 32 oz.)/sample site
	A-HSA067-C-2	Use of Material for On-site Grading – Upland	Material below the water table – 10 ft interval of similar sediment	Composite	Split Spoon or Direct Push Core	Composite from two consecutive 5 ft. cores	General Chemistry, Organics, Inorganics (Table2-3)	No bioassay planned	2 – 16 oz. sample jars (total 32 oz.)/sample site
4.Area A and B Boreholes near Existing Gas Wells **A-HSA066 (DR 13)** **Del Rey 16 (Area A)** **B-HSA064 (DR 12)**	A-HSA066-S-1 DR-16-S-1 B-HSA064-S-1 Additional samples TBD based on site head space screening for VOCs and evidence of surface soil staining/stressed vegetation	Determine within area to be regraded if contains impacted surface soils from Gas Wells	Areas subject to regrading within gas well area and evidence of surface soil staining. No sampling planned at existing gas wells that are to be extended and filled over, unless site screening using head space analysis for VOC or evidence of surface soil staining is observed that indicate potential contamination	Discrete Surface Sample	Dedicated scoops or shovel	0 to 1 ft.	TRPH, TPH, PAHs (See Table 2-3)	No bioassay planned	1 – 16 oz. sample jar/sample site

A total of approximately 17 sediment samples and approximately 3 surface soil samples will be collected and analyzed at the borehole locations listed in Table 2-1. Table 2-1 outlines for each of the four site types, the corresponding Geotechnical Investigation boreholes, sampling objective, sample type, sampling methods, estimated depth and proposed laboratory analyses. Samples include both discrete and composite samples. Sample identification have also been assigned using the proposed Geotechnical Investigation designation and sample type (D for discrete and C for composite).

Sediment samples collected at or next to borehole locations that are in or adjacent to the proposed Ballona Creek channel realignment in Areas A and B (A-RW020, A-HSA018, and B-RW055) will include discrete samples at the proposed elevation of the new channel bottom and at designated intervals above and below the channel elevation. If different materials that include the original marsh materials are encountered within these intervals, discrete samples shall be collected of the marsh material and the fill material above. If no change in materials is observed within 5 feet of the proposed channel elevation, then a discrete sample shall be taken within 2.5 ft. and 10 ft. below the channel elevation. Because the proposed channel elevation is close to the original tidal marsh elevation, these discrete materials are anticipated to be encountered within this interval.

Because the sediments within five feet of the proposed channel elevation will establish the new tidal wetland materials, both chemical and bioassay testing is proposed. In order to obtain sufficient material volume for both chemical and bioassay testing, samples may be collected over a 10 foot interval of similar materials within five feet above and below the proposed channel elevation.

Composite samples shall be collected within 10 foot intervals or greater of materials above the water table at these borehole locations to assess the suitability of these materials for use in upland habitat. These soils will be removed for restoration and relocated to Areas C and B for uplands. Samples shall be collected for chemical analysis.

Sediment samples within boreholes in Areas A and B located within proposed marsh habitat and transitional zone habitat (A-HSA016 and B-RW043) will include both discrete and composite sampling similar to the approach for the channel boreholes. Discrete samples shall be collected within the 10 foot interval that straddles/intersects the proposed exaction elevation (five feet above and below the final elevation) of the restore wetlands. In order to assess the suitability of these materials for wetland habitat, both chemical and bioassay analysis is proposed. Composite samples shall be collected within 10 foot intervals or greater of materials above and below the water table at these borehole locations to assess the suitability of these materials for use in upland habitat. These soils will be removed for restoration and relocated to Areas C and B for uplands. Samples shall be collected for chemical analysis.

The third type of sample is located in proposed upland habitat areas within Area A (A-HSA067). Composite samples shall be collected within a 10 foot interval or greater of materials above the proposed depth of excavation and above the water table at this borehole location to assess the suitability of these materials for use in upland habitat.

Finally, the fourth type of samples includes surface soil samples collected near existing gas wells in Areas A and B where excavation and regrading is anticipated. Surface soil samples (0-1ft.) shall be collected using dedicated scoops/shovels near the existing gas wells and within areas that are proposed for regrading (A-HSA066-Del Rey 13, A-HSA064-Del Rey 12 and Del Rey 16). No sampling is planned at existing gas wells that are to be extended and filled over, unless there is evidence of contamination (surface staining, stressed vegetation, head space analysis using a photoionization detector (PID)) based on site screening. These surface soil samples will be analyzed for a select list of constituents including TRPH, TPH and PAHs as presented in Table 2-3.

Sample laboratory analyses required are described in this section.

2.2 Core Sample Description and Screening

Each five foot core will be logged and described by a qualified geologist or geotechnical engineer prior to sample collection for chemical and bioassay testing. For DPT borings, each core will be extracted using an acetate layer. Upon extraction, the acetate core will be labeled to indicate orientation to surface and split open for sampling. Upon opening, the core will immediately be scanned with an organic vapor monitor (OVM) or PID to assess if organic compounds are present and visually observed for evidence of contamination such as soil staining, impacted vegetation, or sheen. Based on the results of the organic vapor screening for the Preliminary Geotechnical Investigation, presence of volatile organic compounds is not anticipated, and therefore no VOC analysis is planned. Semi-volatile organic compounds may be present and will be screened for using head space analysis. This procedure will be conducted on cores where visual evidence of contamination is observed. Head space analysis shall also be conducted in samples collected near the gas wells. Head space analysis is conducted by collecting a soil sample and placing it into a sealed plastic bag. The sample is set in the sun or a warm place to promote volatilization of constituents in the sample for approximately 5-10 minutes. The PID is then used to insert the probe into a small opening in the sealed bag to measure any organic vapors. Observed measurements shall be recorded.

Sample processing will continue with geotechnical classification and additional sampling from the cores.

Geotechnical Description

Each 5´ core will be examined by a qualified geologist or geotechnical engineer and photographed. The geotechnical description of each core will include the texture, odor, color, length, approximate grain size distribution, plasticity characteristics of the fine-grained fraction, Unified Soils Classification System (USCS) designation, and any evident stratification of the sediment.

Geotechnical Samples

Geotechnical analysis will be performed on both discrete and composite samples. The analysis of sampled for geotechnical testing shall be coordinated with the proposed sampling for the Geotechnical Investigation to avoid duplication. If geotechnical analysis is already planned for the interval and location of the chemical analysis, then no additional geotechnical analysis is required. No geotechnical analysis is required for the nine shallow samples within the existing gas well areas within Area A and B. Geotechnical analysis shall include grain size, liquid and plastic limits, and moisture content by the methods described in Table 2-2. The final sample total will be based on coordination with the Geotechnical Investigation.

Table 2-2. Geotechnical Analysis

Parameter	Method
Grain Size Distribution	ASTM D-422
Hydrometer Analysis	ASTM D-422-63
Liquid and Plastic Limits	ASTM D-4318
Moisture Content	ASTM D-2216

2.3 Decontamination Procedures

Split spoon sampler: Split spoon samplers used to collect sediment/soil samples for chemical and bioassay testing shall be decontaminated after all samples have been containerized and before using the sampler again by first scrubbing the samplers with a brush and an industrial detergent (Alconox) and potable water followed by a double rinse (2 separate buckets) of potable water. The driller shall containerize the decontamination fluids for characterization and disposal under an approved industrial discharge permit to the sanitary sewer or other approved treatment/disposal facility.

Hollow Stem Augers: Hollow stem augers shall be decontaminated between boreholes to avoid cross contamination. Auger flights shall be steam cleaned and fluid collected and containerized for containerization and proper disposal under an approved permit. Drillers shall provide the equipment to conduct the decontamination and collection of rinse waters. The drillers shall provide for the testing of the containerized fluids and proper off-site disposal. Driller may also bring sufficient augers to the site to cover expected drilling for that day and perform decontamination at their off-site facility that has been permitted to contain and disposed of these fluids through an industrial discharge permit.

Direct Push Sampling: Acetate liners shall be used within the hollow drive core for sediment/soil sampling. Acetate liners are to be disposed after use and therefore do not require decontamination. The drive core shall be decontaminated between boreholes to avoid cross contamination. Drive cores shall be shall be decontaminated by first scrubbing the core with a brush and an industrial detergent (Alconox) and potable water followed by a double rinse in buckets of potable water. The driller shall containerize the decontamination fluids for characterization and disposal under an approved discharge permit to the sanitary sewer or other approved treatment/disposal facility.

2.4 Selection, Preparation and Shipment of Samples for Chemical Analysis and Bioassay Testing

Sampling Procedures, Processing, and Storage

Once the five foot cores from each borehole are logged and screened, each core will be either sampled for discrete or composite samples as outlined in Table 2-1. Sample containers shall be properly labeled with project name, date, station identification, sampling time, segment depth, and orientation to the surface; placed on ice; and shielded from light. Sediment samples for chemical and agronomy analysis shall be placed in two 16 oz. glass containers (total 32 oz.) provided by the laboratory and sealed with a Teflon-lined lid. Sediment samples for bioassay analysis shall consist of 10 liter plastic sampling bags that will be provided by the laboratory. Bioassay samples shall be stored at $\leq 4^{o}$C until test initiation. All samples will be handled appropriately as detailed in Table 2-3 and labeled with project name, date, station identification, sampling time, segment depth, and orientation to the surface.

Table 2-3. Sample Preservation and Holding Times

Parameter	Sample Container	Preservation	Holding Time
Geotechnical			
Grain size distribution	Ziploc™ bag	Not applicable	Not applicable
Hydrometer analysis	Ziploc™ bag	Not applicable	Not applicable
Liquid and plastic limits	Ziploc™ bag	Not applicable	Not applicable
Moisture content	Ziploc™ bag	Store Cool at <4°C	Not applicable
General Chemistry and Agronomy			
Total solids	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	
Salinity	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	
pH	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	
TOC	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	28 Days
Total ammonia	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	28 Days
Total sulfides	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	7 Days
Soluble sulfides	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	
Agronomy Analysis			
Sodium and the five soluble and exchangeable major nutrients, , boron, USDA texture, organic matter content, and micronutrients, and the neutralization/ acid generation potential (N/AGP)	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	
Organics			
TRPH	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	14 Days
TPH (as diesel or gasoline)	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	14 Days
Organotins	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	6 Months
Pesticides (DDT, DDE & Chlordane) & PCBs (Aroclors)	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	40 Days
PAHs, Phenols, & Phthalates	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	40 Days
PAHs, Phenols, & Phthalates (individually)	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	40 Days
Inorganics			
Metals (As, Cd, Cu, Cr, Pb, Hg, Ni, Ag, Se, Zn) plus Boron	Glass jar w/ Teflon-lined lid*	Store Cool at <4°C	6 Months
Bioassay			
Acute – 2 species	Sediment Bag (20 liters)	Store Cool at <4°C	14 days (recommended; must not exceed 6 weeks)

*Combine General Chemistry and Inorganics into one 16 oz. container and then fill a second 16 oz. container for the Organic analysis.

2.5 Analytical Methods and Requirements

Chemistry Samples

General chemistry, organic and metals analysis will be performed on both discrete and composite samples. Up to 17 discrete and composited samples will be collected and analyzed for the chemical analyses listed in Table 2-4. The three surface samples collected near the existing gas wells will be analyzed for organic compounds as listed in Table 2-4. It is anticipated that 8 discrete, 9 composite and three surface samples will be sent for chemical analysis.

Table 2-4. General Chemistry, Organic and Inorganic Analyses

Parameter	Method	MDL	# of samples
General Chemistry			
Total solids	EPA 160.3	0.1	17
TOC	EPA 9060	0.01	17
Total Ammonia	EPA 350.2M	0.01 mg/dry kg	17
Total Sulfides	EPA 376.2M	0.05 mg/dry kg	17
Soluble Sulfides	EPA 376.2M	0.002mg/dry kg	17
Salinity			17
pH			17
Organics			
TRPH	EPA 418.1	0.01 mg/dry kg	20
TPH (as diesel, gasoline, or motor oil)	EPA 8015M	0.25 mg/dry kg	20
Pesticides (DDT, DDE. Chlordane) & PCBs (Aroclors)	EPA 8081A/8082	1-10 µg/dry kg	17
Organotins	Krone et al., 1989	1-10 µg/dry kg	17
PAHs, Phenols, & Phthalates	EPA 8270C	1-100 µg/dry kg	20
Inorganics			
Metals (As,Cd,Cu,Cr,Pb,Hg,Ni,Ag,Se,Zn)	EPA 6020/7471A	0.005-0.025 µg/dry kg	17

Bioassay Samples

Bioassay analysis shall be performed by an accredited laboratory that has conducted sediment toxicity testing for marine species. Samples shall be tested for acute toxicity using two marine species, an amphipod (*Eohaustorius estuarius*) and a polychaete (*Neanthes arenaceodentata*). It is estimated that a total of five bioassay tests will be conducted on the discrete samples collected from the Type 1 and 2 boreholes located in the proposed realigned channel or marsh/transitional habitat areas.

Because these sediments have been buried and under low oxygen environments and ammonia spikes are possible, sample acclimation with sea water will be required. Sample preparation and analysis shall be in accordance with EPA methods as defined in the Inland Testing Manual (ITM; USEPA and USACE, 1998). In order to acclimate the test sediments, samples shall be placed into test chambers and filled with raw (unfiltered, untreated) sea water. The overlying water will be gently aerated and replenished twice daily for a period of approximately one week depending on ammonia concentrations, which will be monitored throughout the acclimation. Bioassay tests will be initiated once ammonia concentrations are reduced to levels appropriate for each test specification.

Test conditions for the *E. estuarius* and *N. arenaceodentata* bioassays are summarized in Table 2-5.

Table 2-5. Test Conditions for Solid Phase Bioassay Tests

Test Conditions: 10 day Solid Phase Tests		
Sediment Sample Information	**Test Species**	
	E. estuarius	***N. arenaceodentata***
Holding Time Requirements	14 days, maximum 6 weeks	
Test Sample storage conditions	4°C, dark, minimal head space	
Control Sediment Source	From organism suppliers	
Supplier	Northwestern Aquatic Sciences, Newport, OR	Aquatic Toxicology Support, Bremerton, WA
Age/Size class	Mature, 3 – 5 mm	2-3 weeks post-emergence
Test Procedures	ITM (USEPA & USACE 1998); USEPA 1994; ASTM E1367-03 (2010)	
Test type/duration	Acute SP / 10 days	
Control water	Natural seawater, 3 µm filtered	
Test temperature	15 ± 2°C	20 ± 1°C
Test Salinity	20 ± 2 ppt	28 ± 2 ppt
Test dissolved oxygen	≥ 60% saturation	≥ 65% saturation
Test pH	Monitor for pH drift	
Test interstitial total ammonia	< 60 mg/L	No recommended concentration; bring ammonia down to laboratory historical threshold.
Test interstitial un-ionized ammonia	< 0.8 mg/L	
Test photoperiod	Constant light	12 hours light:12 hours dark
Illuminance	500-1000 lux	
Test chamber	1 L glass test chamber	
Replicates/treatment	5	
Organisms/replicate	20	10
Exposure volume	2 cm sediment; 800 mL water	
Feeding	None.	
Water renewal	None.	
Test Acceptability Criteria	Control survival ≥ 90%	

Agronomy Testing

The Chemical Characterization of sediment sampling also includes the assessment of sediment for suitability to establish vegetation for the proposed wetland and upland habitats. This assessment will require analysis of selected samples for agronomy testing. For the agronomy soil sampling, sediment from within Area A that will be used for upland materials and wetland surface will be analyzed for agronomy constituents. Because materials from within the levees will likely be used to construct the new levees and not uplands, no agronomy analysis is planned for samples collected within the levees. Therefore samples for agronomy analysis shall be collected from A-HSA016, A-HAS-018 and B-RW043. At these locations, the composite samples from above or below the water table and of discrete samples of the original marsh materials shall be collected and analyzed for agronomy analysis. In addition, the sample that is collected below the design depth shall also be analyzed for agronomy constituents. Agronomy testing will include: pH, salinity, sodium and the five soluble and exchangeable major nutrients, sulfate, boron, USDA texture, organic matter content, and micronutrients. In addition, samples will be analyzed for neutralization/ acid generation potential (N/AGP). The N/AGP test measures the theoretical potential of the sediment to generate and neutralize that acid so that leaching conditions can be ruled out. The N/AGP test also determines if a buffered WET analysis is necessary, which uses buffered acidic extraction to determine the leachable fraction of metals from soil and sediment. Samples for agronomy testing shall be transported to the designated laboratory conducting these analyses.

Documentation and Chain-of-Custody

Chain-of-custody (COC) procedures will be initiated during sample collection. A COC record will be provided with each sample or sample group. Each person who had custody of the samples will sign the form and ensure that the samples will not be left unattended unless properly secured. Completed COC forms will be placed in a plastic envelope inside the ice chest containing the listed samples. The COC form will be signed by the person transferring custody of the samples. The condition of the samples will be recorded by the receiver. COC records will be included in the final analytical report prepared by the laboratory, and will be considered an integral part of that report. Samples will be considered to be in custody if they are (1) in the custodian's possession or view, or (2) retained in a secured place (under lock) with restricted access. The principal documents used to identify samples and to document possession will be COC records and field logbooks. COC procedures will be used for all samples throughout the collection, transport, and analytical process and for all data and data documentation, whether in hard copy or electronic format.

2.6 Report Preparation and Beneficial Use Assessment

The remaining effort will entail preparation of a draft report that will compile all collected data, present an analysis of these data, provide a preliminary evaluation of potential beneficial use alternatives and potential handling and disposal restrictions, and provide recommendations for further, regulatory-compliant assessment. The draft findings will be presented for comments prior to preparation of the final report. Chemistry and geotechnical data from the sediment sampling results will be compiled and analyzed. The draft report will present an analysis of these data, provide an evaluation of potential beneficial use alternatives and potential handling and placement restrictions, and provide recommendations for further study. The evaluation of beneficial use alternatives will include feasibility, material suitability, compliance with relevant environmental regulations, and economic feasibility. It is anticipated that any further study to be recommended would be to a regulatory compliance level for beneficial use as wetland material if constituent concentration and bioassay results do not meet the screening levels discussed in this section.

The screening tool that is proposed for evaluation of the sediment sampling results is presented in Figure 2-2. The screening tool was developed using the current guidance for use of sediments in wetland restoration prepared by the Regional Water Quality Control Board for restoration within the San Francisco Bay and other ecological and human health screening criteria that were mentioned in the introduction. Because the San Francisco Bay guidance is location specific as it uses local ambient concentrations for screening, a conservative screening tool that is applicable to Ballona Wetland is proposed. This screening tool uses the ER-L criteria to compare with constitute concentrations along with the results of the bioassay to determine suitability for use as wetland materials. Comparisons to ambient conditions are also made, but not used directly in determining suitability. This is because the existing sediment quality in the Ballona Estuary is impacted from urban runoff from the Ballona Creek Watershed. A total maximum daily load (TMDL) has been established for multiple constituents and impairments including toxics for the Ballona Creek. It is the goal of these TMDLs to reduce the constituent loading from Ballona Creek in the next 10-20 years and reduce the potential impact to restored areas within the estuary including the proposed Restoration Project.

Suitability of materials for use as surface wetland material will also be based on the detection of bioaccumulative constituents that include mercury and persistent organic pollutants such as PCBs, DDT, and chlordane. The proposed screening tool includes bioaccumulative effects as part of the assessment of the sediments and provides options for beneficial use depending on the chemical results and decision regarding using the sediments as surface wetland materials or as sub-surface materials that would be overlain by at least three feet of suitable surface materials. Bioaccumulation bioassays are not planned for this phase of the work and not included as part of this Work Plan. Bioaccumulation testing would be conducted based on the results of the chemical and bioassay testing presented this Work Plan, and by the Design and Management Team for the Restoration Project based on the cost benefit of conducting these tests and the greater flexibility in the use of on-site materials.

The sediment chemistry and bioassay sampling and analysis proposed as part of the Geotechnical Investigation will also provide baseline condition data in which future assessment data can be compared. The adopted Sediment Quality Objectives cannot be applied unless the sediment is under full tidal conditions and the benthic community has been established in restored areas. The chemistry and bioassay results can be used to compare with future assessment sampling and analysis using the SQO methods when the benthic community is established in the marsh habitats. Key to these future assessments will be the potential impact from Ballona Creek on the restored estuary wetlands.

The screening tool as shown on Figure 2-2 also provides for assessment of existing materials for use as upland material using ER-M criteria compared to constituent concentrations. Human health criteria are also used to assess potential risk along with data on background concentrations.

The draft findings report will include maps that include data and observations. These maps will be used to present information and facilitate a discussion. The draft final will then be reviewed and comments incorporated for final review before the document is finalized.

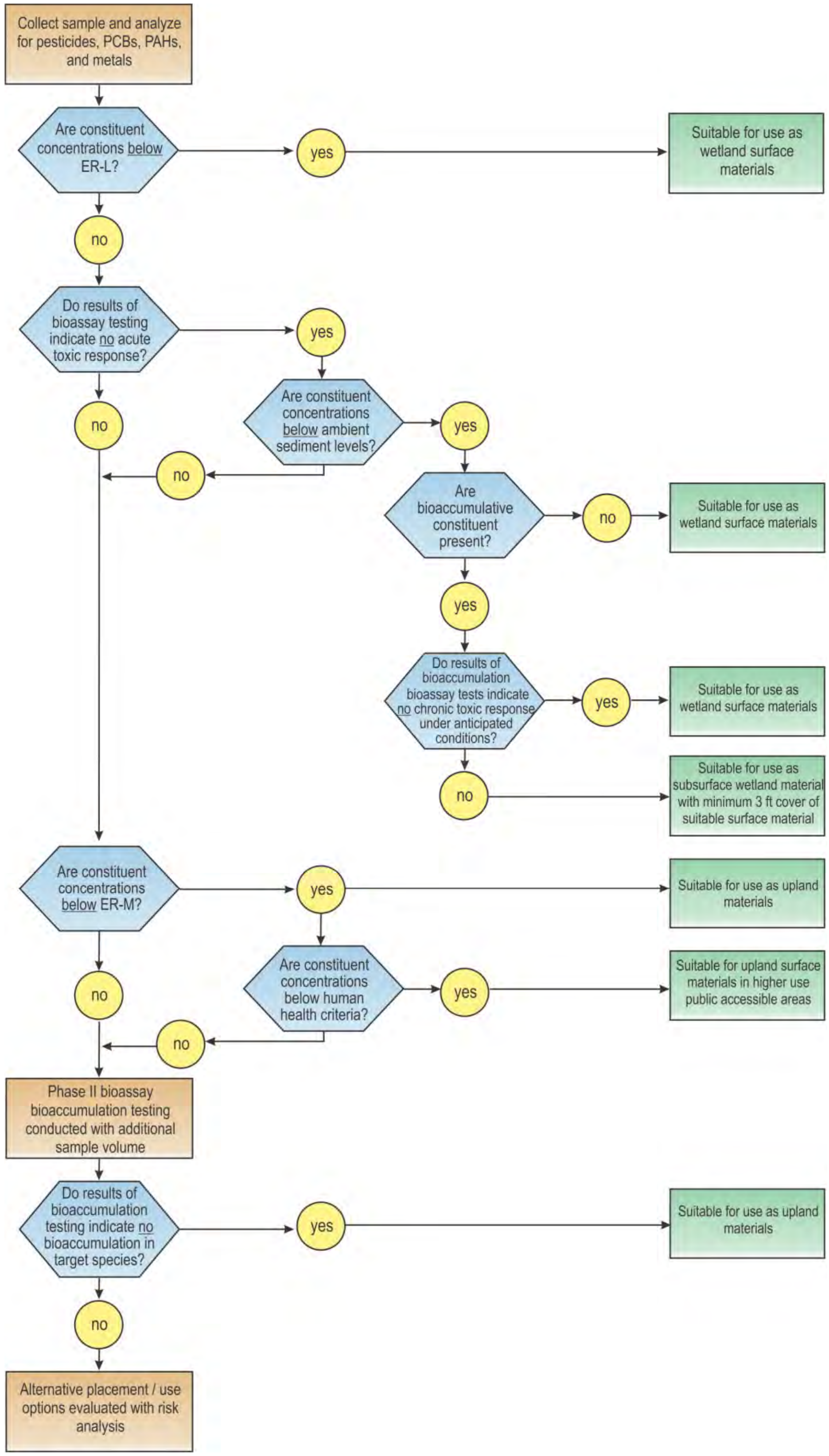


Figure 2-2. Sediment Beneficial Use Screening Tool

APPENDIX A

Geotechnical Borings Coordinates and Existing and Proposed Grading Depths

Boring	Type	Lat	Long	EG ft NAVD	FG ft NAVD	Area B West Levee Alt A-1	Alt A-2	Alt B	Alt C	Environmental Sample
a-cpt012*	CPT	33.9769	-118.437	13.8	13.6					
a-cpt019	CPT	33.9709	-118.4412	16.8	5.3					
a-cpt021	CPT	33.9719	-118.4394	16.6	0.8					
a-cpt022	CPT	33.9728	-118.4379	20.1	4.6					
a-cpt024	CPT	33.9742	-118.4359	16.9	6.4					
a-rw009	RW	33.9741	-118.4436	16.7	10.7					
a-hsa016	HSA	33.972	-118.4425	15.3	7.4					See SAP Table, 2. Area A and B Boreholes - Located in Proposed Marsh Habitat & Transition Zone
a-hsa017	HSA	33.9739	-118.4408	14.5	7.8					
a-hsa018	HSA	33.9731	-118.4391	14.6	-4.0					See SAP Table, 1. Area A and B Boreholes in/near Proposed Channel
a-hsa064	HSA	33.9694	-118.4441	17.3	10.5					
a-hsa066	HSA	33.9702	-118.442507	21.1	TBD					See SAP Table, 4. Area A and B Boreholes near Existing Gas Wells (surface sample)
a-hsa067	HSA	33.9761	-118.4369	13.5	9.6					See SAP Table, 3. Area A Boreholes - Located in Upland Areas
a-rw002	RW	33.9701	-118.4453	17.8	20.5					
a-rw006	RW	33.9719	-118.4448	15.3	10.8					
a-rw008	RW	33.9744	-118.4439	16.0	20.6					
a-rw011	RW	33.9755	-118.4406	15.8	20.6					
a-rw013	RW	33.9769	-118.437	13.8	13.6					
a-rw015	RW	33.9769	-118.4348	16.6	20.6					
a-rw020	RW	33.9715	-118.4399	17.7	-4.4					See SAP Table, 1. Area A and B Boreholes in/near Proposed Channel
a-rw023	RW	33.9727	-118.4377	21.2	4.8					
a-rw065	RW	33.974	-118.4351	20.5	5.4					

APPENDIX A

Geotechnical Borings Coordinates and Existing and Proposed Grading Depths

Boring	Type	Lat	Long	EG ft NAVD	FG ft NAVD	Area B West Levee Alt A-1	Area B West Levee Alt A-2	Area B West Levee Alt B	Area B West Levee Alt C	Environmental Sample
b-cpt029*	CPT	33.9621	-118.4466	5.0	-	9.9	9.9	9.9	9.7	
b-cpt035*	CPT	33.9658	-118.4422	7.4	-	13.1	13.0	13.0	13.0	
b-cpt038	CPT	33.9658	-118.4447	8.4	11					
b-cpt040	CPT	33.9676	-118.4408	6.9	12.2					
b-cpt046	CPT	33.9716	-118.4363	10.6	6.3					
b-cpt049	CPT	33.9732	-118.4346	17.6	12					
b-cpt050	CPT	33.9737	-118.4335	20.2	20.5					
b-cpt052	CPT	33.965	-118.4491	6.9	5					
b-cpt054	CPT	33.9676	-118.4444	15.3	-3.6					
b-cpt056	CPT	33.9685	-118.4428	15.4	-4.5					
b-cpt057	CPT	33.9693	-118.4414	14.6	-4.0					
b-cpt059	CPT	33.9703	-118.4395	18.7	5.1					
b-hsa028*	HSA	33.9638	-118.4503	4.5	-	8.4	-	-	-	
b-hsa051*	HSA	33.9723	-118.4323	6.3	25					
b-rw030	RW	33.9619	-118.4464	6.6	-	19.4	19.4	19.4	19.2	
b-rw032	RW	33.9636	-118.4441	7.5	-	7.4	7.4	6.7	7.8	
b-rw033	RW	33.9633	-118.4437	6.5	-	18.3	18.3	18.3	20.3	
b-rw036	RW	33.9656	-118.4418	8.7	-	20.6	20.6	20.6	20.6	
b-rw039	RW	33.9663	-118.4436	8.2	11					
b-rw041	RW	33.9674	-118.4405	7.3	20.5					
b-rw043	RW	33.9694	-118.4394	8.8	6					See SAP Table, 2. Area A and B Boreholes - Located in Proposed Marsh Habitat & Transition Zone
b-rw044	RW	33.9693	-118.4387	9.2	20.5					
b-rw047	RW	33.9713	-118.436	11.7	20.2					
b-rw053	RW	33.9655	-118.4482	8.5	5					

APPENDIX A

Geotechnical Borings Coordinates and Existing and Proposed Grading Depths

Boring	Type	Lat	Long	EG	FG	Area B West Levee				Environmental Sample
				ft NAVD	ft NAVD	Alt A-1	Alt A-2	Alt B	Alt C	
b-rw055	RW	33.968	-118.4436	16.9	-5.6					See SAP Table, 1. Area A and B Boreholes in/near Proposed Channel
b-rw058	RW	33.9699	-118.4403	17.8	-4.8					
c-cpt060	CPT	33.9779	-118.4333	14.6	30					
c-cpt062	CPT	33.9779	-118.4303	23.0	40					
c-hsa061	HSA	33.9801	-118.4314	16.0	30					
c-hsa063	HSA	33.9791	-118.4288	23.2	40					
b-hsa064	DPT?									See SAP Table, 4. Area A and B Boreholes near Existing Gas Wells (surface sample)
Del Rey 16 (abandoned well in Area A)										See SAP Table, 4. Area A and B Boreholes near Existing Gas Wells (surface sample)

Prepared by ESA PWA, 9/12/12 draft

EG = Existing grade

FG = Proposed finished grade/design grade

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APPENDIX F5
Sediment Quality Investigation

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BALLONA WETLANDS RESTORATION PROJECT

Sediment Quality Investigation

Prepared for
California State Coastal Conservancy

May 2015

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BALLONA WETLANDS RESTORATION PROJECT

Sediment Quality Investigation

Prepared for
California State Coastal Conservancy

May 2015

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CHAPTER 1
Purpose of the Investigation

The purpose of the sediment characterization program is to assess the sediments within Areas A and B for beneficial use within the proposed Ballona Wetland Restoration Project, located in Los Angeles, California. More specifically, the purpose of the sediment sampling and analytical program was to determine their suitability for use as upland and/or wetland material within the Ballona Wetland Restoration Project. This memo also identifies next steps, including additional investigations to confirm suitability for possible in-ocean placement of excess excavated material. Design specifications for sediment management will be developed during subsequent phases of the design based on the Project EIR/S and regulatory requirements.

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CHAPTER 2
Scope of the Sediment Investigation

The field program for the sediment characterization was conducted from September 24 to 25, 2012 in accordance with the Sampling and Analysis Plan (SAP) (Weston 2012). A summary of the scope of the field and laboratory program is presented in Table 1. Sediment sample selection and boring profile descriptions were led by Weston under contract with ESA, and in coordination with Group Delta Consultants, Inc. (GDC). GDC lead the geotechnical investigation and contracted the driller and analytical laboratory for the sediment characterization program. GDC also provided a geologist to support Weston in the logging of the boreholes. Weston selected the samples for analysis and provided GDC with the prepared samples and chain of custodies for delivery to the analytical laboratory. American Environmental Testing Laboratory in Burbank, CA analyzed the selected sediment samples for the analyses listed in Table 2.

A total of seven direct push borings were completed using the depth and sampling criteria outlined in the SAP (Weston, 2012). The locations of the borings are presented in Figure 1, overlain onto the proposed restoration plan showing the new habitat types. Modifications to the SAP to respond to field conditions and observations are highlighted in the table and summarized as followed:

- **Relocation of Boring on Existing Levee** – Boring A-RW-020 and B-RW-055 were relocated down off the levee and approximately 350 feet from the toe of slope, due the presence of large rip rap. The relocation of these boring was noted in the field and the revised locations were surveyed. The depth of the samples specified in the Work Plan was modified to accommodate for the new existing ground elevation and the anticipated depth of excavation.
- **Modification of Samples Selected for Analysis** – As noted in Table 1, several samples were added for analysis at several boring locations where potential petroleum hydrocarbon contamination was observed and where readings above background were noted from the head space analysis of samples for volatile organic compound (VOC) vapors. Samples were collected where the sediment was observed to have been impacted, and above and below, in order to define the potential extent of contamination. In addition, several designated samples were not analyzed based on field observation that included no evidence of impacted soils near and adjacent to the gas wells.

Samples were transported to the analytical laboratory for chemical testing, and to Nautilus for bio-assay testing. PSOMAS surveyed the locations and ground elevations of the borings. Analytical, bioassay, and survey data have been provided and are summarized in this Technical Report.

TABLE 1
SEDIMENT CHARACTERIZATION PROGRAM – CHEMICAL AND BIOASSAY ANALYSIS OF SELECTED SEDIMENT SAMPLES

Borehole Sites	Sampling Objective	Sample Selection Process	Chemical Analysis	Bioassay Analysis	Samples Collected – ID and Depth
1. Area A and B Boreholes in/near Proposed Channel - A-RW020 - A-HSA018 - B-RW055	Wetland Surface/Foundation Suitability	Proposed Channel Elev.	General Chemistry, Organics, Inorganics (See Table 2)	Acute, 2 Species of Amphipods and 1 species of Polychaete after sample acclimation	Chemistry: A-RW-020-D1 (20'-28'); B-RW-055-D1 (10'-14'), A-HSA-018-D2 (16'-19'), A-HSA- (20'-24') Bioassay: A-RW-020-D1 (20'-28') composited with A-HSA-018-D1 (20'-28'); B-RW-055-D1 (10'-16') composited with B-RW-043- D3 (6.5'-10')
	Wetland Surface Suitability	Change in Material +/-5 ft. within Prop. Channel Elev. (e.g. old marsh mat'l) – if no change – collect 2.5 to 10 ft. below Channel Elev.	(See Table 2)	No bioassay	No change was observed below marsh material. Chemistry and bioassay performed on material located close to the proposed final grades. Samples listed above.
	Use for Upland Placement/ Wetland Grading	Material above the water table – 10 ft interval of similar sediment	(See Table 2)	No bioassay	A-RW-020-C3 (4'-9'), A-RW-020-D3 (12'-16') A-HSA-018-C3 (4'-8'),A-HAS-018-D3 (10'-12') B-RW-055-C1 (0'-3.5'); B-RW-055-C2 (4'-8')
	Use for On-site Grading/ Wetland Surface	Material below the water table – 10 ft interval of similar sediment	(See Table12)	No bioassay	A-RW-020-D2 (16'-19') A-HSA-018-D2 (16'-19')
2. Area A and B Boreholes – Located in Proposed Marsh Habitat & Transition Zone - A-HSA016 - B-RW043	Wetland Surface Suitability	Proposed Wetland Restoration Elev.	(See Table 2)	Acute, 3 Species	Chemistry: A-HSA-016-D1 (10.5'-12'); A-HAS-016-D2 (14'-16'); B-RW-043-D1 (3'-6'); B-RW-043-D2 (6'-6.5'); B-RW-043- D3 (8'-10'); B-RW-043- D5 (10'-16') Bioassay : A-HSA-016- (8'-12'); B-RW-043- D3 (6.5'-10') composited with B-RW-055-D1 (10'-16')
	Use for Upland Placement/wetland Grading	Material above the water table – 10 ft interval of similar sediment	(See Table 2)	No bioassay	A-HSA-016-C1 (0'-6')
	Use for On-site Grading – Wetland Surface	Material below the water table – 10 ft interval of similar sediment	(See Table 2)	No bioassay	A-HSA-016-C2 (6'-10.5') B-RW-043-C1 (0'-3')
3. Areas A Boreholes – Located in Upland Areas - A-HSA067	Use of Material for Upland Placement/Site Grading	Material above the water table – 10 ft interval to straddle proposed excavation depth	(See Table 2)	No bioassay	A-HAS-067-C1 (0'-6')

TABLE 2
LIST OF ANALYTES AND SAMPLES ANALYZED FOR SOIL CHEMISTRY

Samples for Soil Chemistry Analysis	Depth (ft)	Trace Metals	Trace Mercury	Organotins	Polynuclear Aromatic Hydrocarbons	Phthalates	Acid Extractable Compounds	Organochlorine Pesticides & PCBs	Percent solids	pH	Salinity	TOC	Total Sulfides	Dissolved sulfides	TPH diesel	TPH gas	Ammonia as N in Sediment Determination	TRPH in Sediment Determination
In/near proposed channel																		
A-RW-020-D1 (20' –28')	20-28	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-RW-020-D2 (16' –19')	16-19	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-RW-020-D3 (12'-16')	12-16	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-RW-020-C3 (4'-9')	4-9	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA018-D2 (16' –19')	16-19	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA018-D3 (10' –12')	10-12	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA018-D1 (20'-24')	20-24	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA018-C3 (4'-8')	4-8	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-055-C1 (0' –3.5')	0-3.5	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-055-C2 (4' –8')	4-8	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-055-D1 (10' –14')	10-14	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
In proposed marsh/trans.																		
A-HSA-016-D1 (10.5'–12')	10.5–12	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA-016-D2 (14'–16')	14-16	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA-016-C2 (6' -10.5')	6-10.5	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
A-HSA-016-C1 (0' –6')	0-6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-043-C1 (0' –3')	0-3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-043-D1 (3' –6')	3-6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-043-D2 (6' –6.5')	6-6.5	NA	NA	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-043-D3 (8'-10')	8-10	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
B-RW-043-D5 (10'-16')	10-16	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Upland																		
A-HSA-067-C1 (0' -6')	0-6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

NA – not analyzed for these constituents

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J:\1793_Ballona\Fieldwork\SoilSampleLocations.mxd

SOURCE: Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Ballona Wetlands. D120367

Figure 1

Soil Sample Locations

ESA PWA

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CHAPTER 3
Summary of Results

The results are presented here in four parts. The first part provides a summary of the previous results from the geotechnical investigation of Area A conducted by Weston in 2008 for the Port of Los Angeles. The second part presents the subsurface conditions observed with regard to the type of soils, evidence of impacted sediment, and evidence of original marsh soils. In the third section, the results of the chemical and bioassay testing are summarized. Finally, historic results are presented in the last section.

3.1 Results of 2008 Geotechnical Investigation in Area A

A preliminary geotechnical investigation was completed by Weston under contract with the Port of Los Angeles in 2008. The primary objective of the Preliminary Study was to provide geotechnical and chemical data to characterize approximately 4.5 million cubic yards (cy) of dredge material that has been placed on Area A and which is being considered for removal in support of the Restoration Project. This study was used to determine potential beneficial uses of the dredge material, to identify any special handling or disposal restrictions that may be required based on sediment and leachate chemistry, and to guide any further assessment deemed necessary. The results of the Preliminary Investigation were used to scope the 2012 sediment characterization SAP.

This program included the collection of sediment samples from direct push cores for chemical and geotechnical analysis. The locations of the completed borings are shown in Figure 2 and a summary of constituents above soil screening criteria and sediment quality guidelines are discussed below and presented in Table 3 and Table 4, respectively. The screening criteria that were used to assess the results are summarized in Appendix A. The complete results can be found in the Area A Preliminary Geotechnical Investigation and Beneficial Use Assessment (Weston, 2009).

3.1.1 Comparison to Hazardous Waste Criteria

No chemicals were detected at concentrations greater than the TTLC or greater than 10 times the STLC value. Results of TCLP analyses indicated no analytes above the toxicity characteristic standards USEPA 40 CFR Part 261 values (USEPA, 2006). Therefore, the material was not classified as a hazardous waste and is suitable for upland placement options.

Figure 2. Preliminary Geotechnical Investigation Boring Locations

TABLE 3
SUMMARY OF 2008 SAMPLE RESULTS IN COMPARISON TO HUMAN HEALTH CRITERIA

				Residential Land Use[1]		Commercial/Industrial Land Use Only[1]		S10-060208-6-7	S11-070208-14-15	S11-S15-S28-14-20	S15-080208-15-16	S15-S28-15-16	S17-080208-10-11	S17-S18-10-12	S18-080208-7-8	S21-080208-6-7	S21-S25-6-8
Group	**Analyte**	**Units**	**RL**	**CHHSLs**	**PRG**	**CHHSLs**	**PRG**	**Discrete**	**Discrete**	**Composite**	**Discrete**	**Composite**	**Discrete**	**Composite**	**Discrete**	**Discrete**	**Composite**
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Iron (Fe)	µg/dry g	5		23000		100,000	15890	37840	41390	38250	32840	28970	37170	37940	30390	32920
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	<5	<5	<5	<5	<5	<5	<5	<5	7.3	6.8

				Residential Land Use[1]		Commercial/Industrial Land Use Only[1]		S23-080208-12-13	S23-S24-S26-21-24	S27-S29-S30-6-8	S29-070208-6-7	S3-11-12-15-16	S4-S10-5-7	S5-060208-15-16	S5-S6-15-16	S5-S6-S9-3-4	S9-060208-3-4
Group	**Analyte**	**Units**	**RL**	**CHHSLs**	**PRG**	**CHHSLs**	**PRG**	**Discrete**	**Composite**	**Composite**	**Discrete**	**Composite**	**Composite**	**Discrete**	**Composite**	**Composite**	**Discrete**
Metals	Arsenic (As)	µg/dry g	0.05	0.07	0.39	0.24	1.60	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Iron (Fe)	µg/dry g	5		23000		100000	27480	36000	31170	26180	34330	18770	35380	26340	20140	14270
PAHs	Benzo[a]pyrene	ng/dry g	5	38	15	130	210	3.4 J	<5	39.7	<5	6.1	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
[yellow box] - Concentration exceeds respective soil screening criteria.
[1] California Human Health Screening Levels (CHHSLs) and Preliminary Remediation Goal (PRGs) – see Appendix A for more detailed discussion of these criteria.

TABLE 4
SUMMARY OF 2008 SAMPLE RESULTS IN COMPARISON TO ECOLOGICAL CRITERIA

				Dredged Material Placement Screening Criteria[1]		S10-060208-6-7	S11-070208-14-15	S11-S15-S28-14-20	S15-080208-15-16	S15-S28-15-16	S17-080208-10-11	S17-S18-10-12	S18-080208-7-8	S21-080208-6-7	S21-S25-6-8
Group	Analyte	Units	RL	ER-L	ER-M	Discrete	Discrete	Composite	Discrete	Composite	Discrete	Composite	Discrete	Discrete	Composite
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	5.129	4.086	4.557	12.61	7.145	3.59	3.816	3.561	9.254	9.218
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.262	0.201	1.243	0.836	0.684	0.089	0.595	0.307	0.614	0.57
	Copper (Cu)	µg/dry g	0.05	34	270	11.15	33.62	22.17	39.25	28.84	18.03	28.89	28.99	31.63	35.6
	Lead (Pb)	µg/dry g	0.05	46.7	218	4.742	7.802	4.583	7.924	6.104	3.783	5.758	6.194	24.94	50.72
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.043	0.053	0.055	0.068	0.052	0.041	0.049	0.06	0.303	0.215
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	14.69	27.15	21.2	25.37	21.42	17.05	24.09	23.61	22.55	23.94
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.04 J	0.035 J	0.072	0.038 J	0.113	0.042 J	0.173	0.052	1.079	1.027
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	11.6

				Dredged Material Placceement Screening Criteria[1]		S23-080208-12-13	S23-S24-S26-21-24	S27-S29-S30-6-8	S29-070208-6-7	S3-11-12-15-16	S4-S10-5-7	S5-060208-15-16	S5-S6-15-16	S5-S6-S9-3-4	S9-060208-3-4
Group	Analyte	Units	RL	ER-L	ER-M	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete	Composite	Composite	Discrete
Metals	Arsenic (As)	µg/dry g	0.05	8.2	70	13.73	4.814	8.977	3.848	7.636	4.666	7.393	3.038	5.73	5.802
	Cadmium (Cd)	µg/dry g	0.05	1.2	9.6	0.67	0.482	0.63	0.257	0.499	0.199	0.175	0.147	0.255	0.208
	Copper (Cu)	µg/dry g	0.05	34	270	25.64	30.61	37.79	20.12	28.08	14.52	27.21	21.25	12.81	9.257
	Lead (Pb)	µg/dry g	0.05	46.7	218	5.361	7.187	31.96	8.573	19.58	4.625	4.742	3.514	6.364	3.383
	Mercury (Hg)	µg/dry g	0.02	0.15	0.71	0.028	0.083	0.189	0.077	0.089	0.065	0.067	0.058	0.046	0.053
	Nickel (Ni)	µg/dry g	0.05	20.9	51.6	26.33	25.27	25.6	19.71	26.05	15.74	20.98	16.44	15.2	13.25
	Silver (Ag)	µg/dry g	0.05	1	3.7	0.105	0.221	0.224	0.129	0.174	0.096	<0.05	0.258	0.138	0.04 J
Pesticides	4,4'-DDE	ng/dry g	5	2.2	27	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Notes:
J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
Yellow - Concentration exceeds respective sediment screening criteria.
1 [1] Effects Range-Low (E-RL) and Effects Range Medium (E-RM) are used in dredged material evaluation for Ocean Disposal in combination with the results of bioassay testing and bioaccumulation testing. (Long et al. , 1995). See Appendix A for more detailed discussion of screening criteria

3.1.2 Comparison to Human Health Criteria

The analyzed organic chemicals of concern were PAHs, PCBs, and organochlorine pesticides. With the exception of one soil sample, none of the Area A samples contained concentrations of PAHs, PCBs, or pesticides above the CHHSLs and PRGs soil criteria. The concentration of benzo [a] pyrene at Station 27 was 39.7 µg/kg dry weight, which exceeded the human health screening level (set at 38 µg/kg dry weight) for potential residential land use.

While most of the chemical screening values are below levels of concern for human health, arsenic and iron were measured at ambient concentrations greater than residential CHHSLs and PRGs. The concentrations of arsenic and iron are consistent with natural concentrations in marine sediments. A summary of soil samples that exceeded soil criteria is shown in Table 3.

During the boring and sampling operations, PID readings were taken to identify potential “hot” zones which might contain elevated VOC concentrations. Soil samples from five stations showed elevated PID readings in the field and were subsequently selected for s-VOC and VOC analysis. The results of the laboratory analysis showed that none of the five samples exceeded CHHSLs or PRGs criteria for residential and commercial land use.

Due to the historic and current presence of gasoline production and transportation in Area A, the 20 soil stations were analyzed for total petroleum hydrocarbons (TPHg and TPHd) and benzene, ethylbenzene, toluene, and xylenes (BETX). None of the soil samples had concentrations of TPHg, TPHd or BETX above the Residential Soil Screening Criteria for Groundwater Protection as defined by the California Regional Water Quality Control Board, San Francisco Bay Region. However, during drilling operations at Station 25 and 26, the field engineer noted evidence of soil staining throughout the soil core. These two stations are closest to the compressed natural gas line that runs north-to-south through Area A.

3.1.3 Comparison to Ecological Criteria

Long et al. (1995) developed criteria to evaluate dredged material for ocean disposal, including the Effects Range- Low (ER-L) and Effects Range-Median (ER-M) values (Appendix A). The criteria are helpful in assessing the potential biological impact of elevated constituents of concern.

Concentrations of metals in the sediment samples were compared to ER-L and ER-M values. Several metals slightly exceeded the corresponding ER-L values, including arsenic, cadmium, copper, lead, mercury, nickel, and silver (Table 4). No metals exceeded the corresponding ER-M values, indicating relatively low concentrations.

3.2 Results of 2012 Subsurface Conditions In Areas A and B

Figure 1 presented the boring locations and the profile transects. The borehole profiles for the proposed channel alignment, Area A, and Area B are presented on Figure 3- Figure 5, respectively. The boring profiles include the observed geotechnical observations, field observations and screening, and the results of the comparison of the constituent concentrations to relevant and applicable criteria/guidelines. The following summary highlights the observed sediment characteristics and the field observations compared to the analytical results:

3.2.1 Area A Proposed Channel Location

Two borings (A-RW020 and A-HSA018) were completed within the proposed channel in Area A (Figure 3). Both of these borings were advanced to below the proposed elevation of the channel into original marsh materials for a total depth of 28 feet below ground surface (bgs). The sediment at these locations is predominantly silty and sandy with low plasticity clays that transition to a high plasticity clay at approximately 14 ft bgs. Above this depth is a lens of more sandy wet clay from 10-14 ft bgs. At approximately 10-14 ft bgs a petroleum odor and dark staining was observed. This potentially impacted sediment is likely limited to an approximately 2-4 foot layer between 10-14 ft bgs. Discrete samples were taken from this layer at 12 to 14 ft bgs in A-RW020 and 10-12 ft in A-HSA018, where the greater petroleum order and staining was observed. Samples were collected for analysis above and below this potentially impacted layer to define the extent of the layer. Head space analysis of samples placed in plastic sealed bags indicated the potentially impacted layers appear to be limited to the sandy clay layer between 10-14 ft bgs. The results of the chemical analysis of these samples indicate TPH was detected at the highest concentrations in A-HSA-018-D3 (10'-12'), and also detected above this sample at lower concentrations in A-HSA-018-D3 (4'-8'). TPH was also detected in A-RW-020-D2 (12'-16'), but not in samples above and below this interval. However, the concentrations of TPH were all below the residential soil screening levels for shallow and deep soils. PAHs, which may include breakdown products of petroleum hydrocarbons, were not detected above the biological or human health criteria in these samples. This layer is above the final excavation depth of the proposed channel that is estimated at 22 ft and 18.5 ft bgs for boring locations A-RW020 and A-HSA018, respectively. The original marsh materials were encountered at approximately 19-20 ft bgs in both borings. Sediment for bioassay testing to assess the suitability of existing materials for wetland surface were collected from depths of 20-28 ft bgs in each boring.

3.2.2 Area A Transition Zone

Two direct push borings (A-HSA016 and A-HSA067) were completed in Area A within transitional habitat zones requiring less excavation (Figure 4). Anticipated excavation depths range from approximately 4 ft bgs at A-HSA067 to 8 ft bgs at A-HSA016. The sediment profile in both of these borings is characterized by sandy silt in the upper 6 ft, transitioning into a more silty clay. The depth of the boring at A-HSA067 was 8 ft bgs or 4 ft below the anticipated excavation depth. A composite sample of the materials from the surface to 6 ft bgs was collected. The results of the analysis indicated total DDT exceeded the most stringent ER-L value, but not the wetland surface criteria developed by the SFRWQCB. A-HSA016 was advanced to 16 ft bgs or 8 ft below anticipated final grades. At 10.5 ft bgs a petroleum odor and staining was observed. Head space analysis of the sediment from 6-8 ft bgs and from 10.5 to 12 ft bgs, which was placed in a sealed plastic bag, was 0.4 and 0.6 units. The petroleum odor and staining appeared to be limited to 10.5 to 12 ft bgs. The results of the analytical analysis of these samples detected TPH as Heavy Hydrocarbons in the sample from 10.5 ft to 12 ft, but not in samples above and below this depth indicating the impact is limited to this depth. Additionally, the concentrations of TPH were all below the residential soil screening levels for shallow and deep soils. PAHs, which may include breakdown products of petroleum hydrocarbons, were not detected above the biological or human health criteria in these samples.

3.2.3 Area B Channel and Wetland

Two borings were completed in Area B to assess the existing material for use as wetland surface material and beneficial use of excavated materials. B-RW043 was completed in the proposed wetland area with an anticipated excavation depth of 3 ft (Figure 5). B-RW055 was completed in the proposed channel with an anticipated excavation depth of 22.5 ft (Figure 3). B-RW055 was moved off the existing levee due to the potential of encountering boulders and re-located at the toe of the levee. The original marsh materials were encountered in both borings at approximately 10-12 ft bgs. The materials above the original marsh sediments were observed to range from more sandy silts at the surface to silty clays of low and high plasticity. In both borings, a petroleum odor and staining was observed at approximately 6 to 6.5 ft bgs in B-RW043 and less evidently between 4-8 ft bgs in B-RW055. The results of the sample analysis indicated TPH was detected from 0 to 3.5 ft bgs in B-RW055 and B-RW043, but not in the samples below. The concentrations of TPH were, however, all below the residential soil screening levels for shallow and deep soils. PAHs, which may include breakdown products of petroleum hydrocarbons, were not detected above the biological or human health criteria in these samples. Samples for bioassay were collected from the original marsh materials below the potential impacted sediments at depth of 6.5 to 10 ft bgs in B-RW043 and from 10-16 ft bgs in B-RW055. The depth of the samples collected for bioassay were below the anticipated final grade at B-RW043, because of the field observations of potentially impacted sediment, and the potential for over-excavation to the original marsh materials.

3.3 Results of 2012 Sediment Characterization Investigation in Areas A and B

3.3.1 Results of Sediment Characterization Compared to Human Health Criteria/Guidelines

The results of the analytical analysis, compared to relevant California Human Health Screening criteria, are presented in Table 5. Arsenic concentrations are above these criteria in all of the 21 samples that were collected and analyzed. These are similar findings to those in the Area A Geotechnical Investigation conducted in 2008 (Weston, 2009). As reported in the 2008 study, these concentrations are characteristic of marine sediment.

Table 6 presents the results of the TPH analysis and comparison to the Residential Soil Screening Criteria for Groundwater Protection. Although there were multiple detections of TPH as diesel, TPH as Heavy Hydrocarbons, and Total Recoverable Petroleum Hydrocarbons, none of the concentrations were above the residential criteria. Residual concentrations of petroleum products were anticipated in soils within Areas A and B based on the historical uses of the property which was used for oil and gas extraction. Gas production wells remain active on the site. The soils in the areas around the existing gas wells were inspected and only minor surface staining was observed and did not extend below the surface of the soil (area less than one foot squared and only in 3-4 places). Shallow 10 foot boreholes were advanced around the existing well heads, but due to the lack of evidence of sediment impacts, no sampling was collected for analysis.

3.3.2 Results of Sediment Characterization Compared to Ecological Criteria/Guidelines

The summary of results of the Sediment Investigation compared to the ecological criteria is presented in Table 7.

In addition to the ER-L and ER-M criteria, discussed in Section 3.1.3, another measure of potential ecological impacts is the Beneficial Reuse criteria for wetland restoration, developed by the San Francisco Regional Water Quality Control Board (2000) and refined for use outside of San Francisco Bay by Germano & Associates (2004). The Beneficial Reuse criteria have different values for material that will be used as wetland surface (more conservative) and wetland foundation material (less conservative). Appendix A provides more detailed discussion of these screening criteria. The analytical results are compared to the Beneficial Reuse guidelines and historical average concentrations in sediment in the Area B marsh.

Additionally, the TMDL set goals for the estuary that apply to sediments within the tidal zone of Ballona Creek, which would likely apply to the reconfigured channel and tidal wetlands. These goals corresponded to the conservative ER-L values, but were revised based on results of the sediment characterization study conducted as part of the TMDL Reconsideration. The study indicated that the ER-L sediment quality guideline values used as target concentrations for the chemicals listed in the TMDL were inaccurate and highly conservative. The ER-Ls for some metals were below background concentrations typical of estuarine environments. For the organic compounds, ER-Ls were several orders of magnitude below toxicity thresholds for benthic organisms (SCCWRP, 2010). Therefore use of these guidelines for sediment screening purposes may not be applicable for the Ballona Estuary. In the 2013 TMDL Reconsideration, goals for the organic compounds were updated based on recent data in Table 7 includes the updated TMDL goals.

TABLE 5
SUMMARY OF SOIL SAMPLES WITH ANALYTES THAT EXCEED CALIFORNIA HUMAN HEALTH SCREENING LEVELS OR PRELIMINARY REMEDIATION GOALS

Error! Reference source not found.A: In/near Proposed Channel

Group	Analyte	Units	PQL	Residential Land Use[1]		Commercial/Industrial Land Use Only[1]		A-RW-020-D1 (20' –28')	A-RW-020-D2 (16' –19')	A-RW-020-D3 (12'-16')	A-RW-020-C3 (4'-9')	A-HSA018-D2 (16' –19')	A-HSA018-D3 (10' –12')	A-HSA018-D1 (20'-24')	A-HSA018-C3 (4'-8')	B-RW-055-C1 (0' –3.5')	B-RW-055-C2 (4' –8')	B-RW-055-D1 (10' –14')
				CHHSLs	PRG	CHHSLs	PRG											
Metals	Arsenic (As)	µg/dry g	0.120	0.07	0.39	0.24	1.60	2.32	1.79	0.953	2.60	0.953	16.6	1.71	5.30	1.88	2.80	1.78

Error! Reference source not found.B: In Proposed Marsh and Transition Zone

Group	Analyte	Units	PQL	Residential Land Use[1]		Commercial/Industrial Land Use Only[1]		A-HSA-016-D1 (10.5'–12')	A-HSA-016-D2 (14'–16')	A-HSA-016-C2 (6' -10.5')	A-HSA-016-C1 (0' –6')	B-RW-043-C1 (0' –3')	B-RW-043-D1 (3' –6')	B-RW-043-D3 (8'-10')	B-RW-043-D5 (10'-16')
				CHHSLs	PRG	CHHSLs	PRG								
Metals	Arsenic (As)	µg/dry g	0.120	0.07	0.39	0.24	1.60	2.67	1.77	2.57	2.01	1.91	0.895	1.20	2.01

Error! Reference source not found.C: Upland

Group	Analyte	Units	PQL	Residential Land Use[1]		Commercial/Industrial Land Use Only[1]		A-HSA-067-C1 (0' -6')
				CHHSLs	PRG	CHHSLs	PRG	
Metals	Arsenic (As)	µg/dry g	0.120	0.07	0.39	0.24	1.60	2.93

Notes:

J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)

Yellow - Concentration exceeds respective soil screening criteria.

1 California Human Health Screening Levels (CHHSLs) and Preliminary Remediation Goal (PRGs) – see Appendix A for more detailed discussion of these criteria

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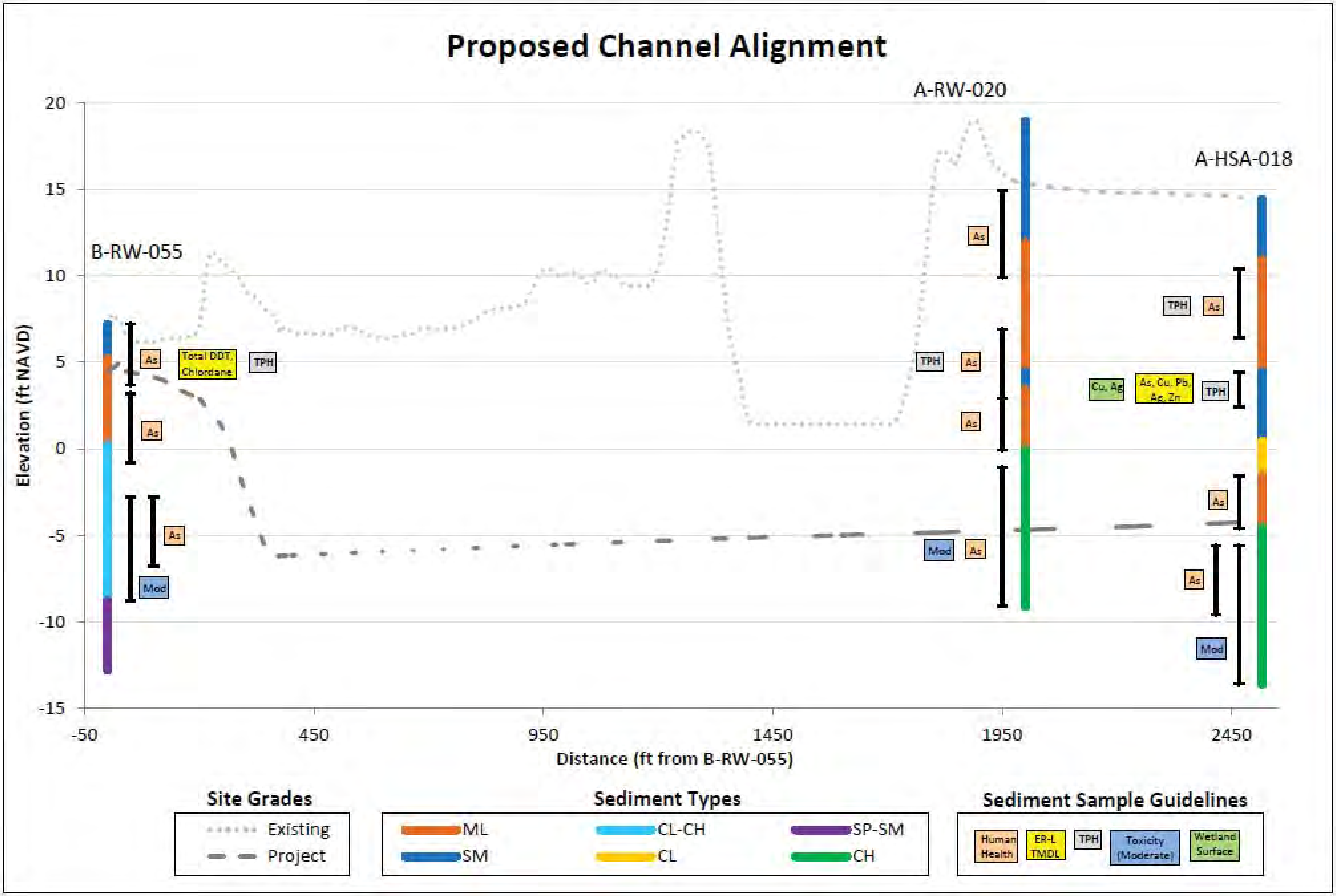

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Figure 3

Boring Profiles for Transect Along Proposed Channel Alignment

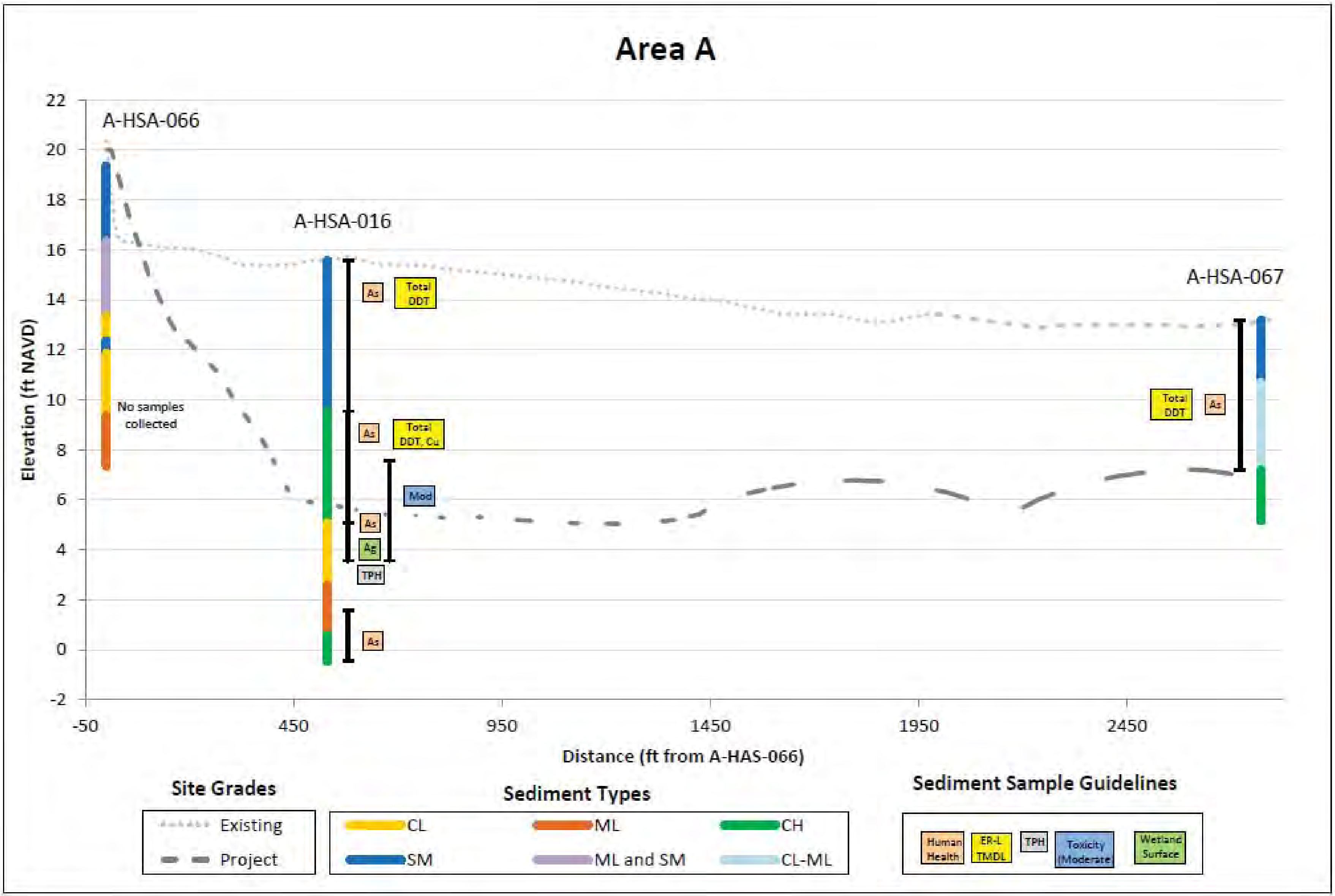

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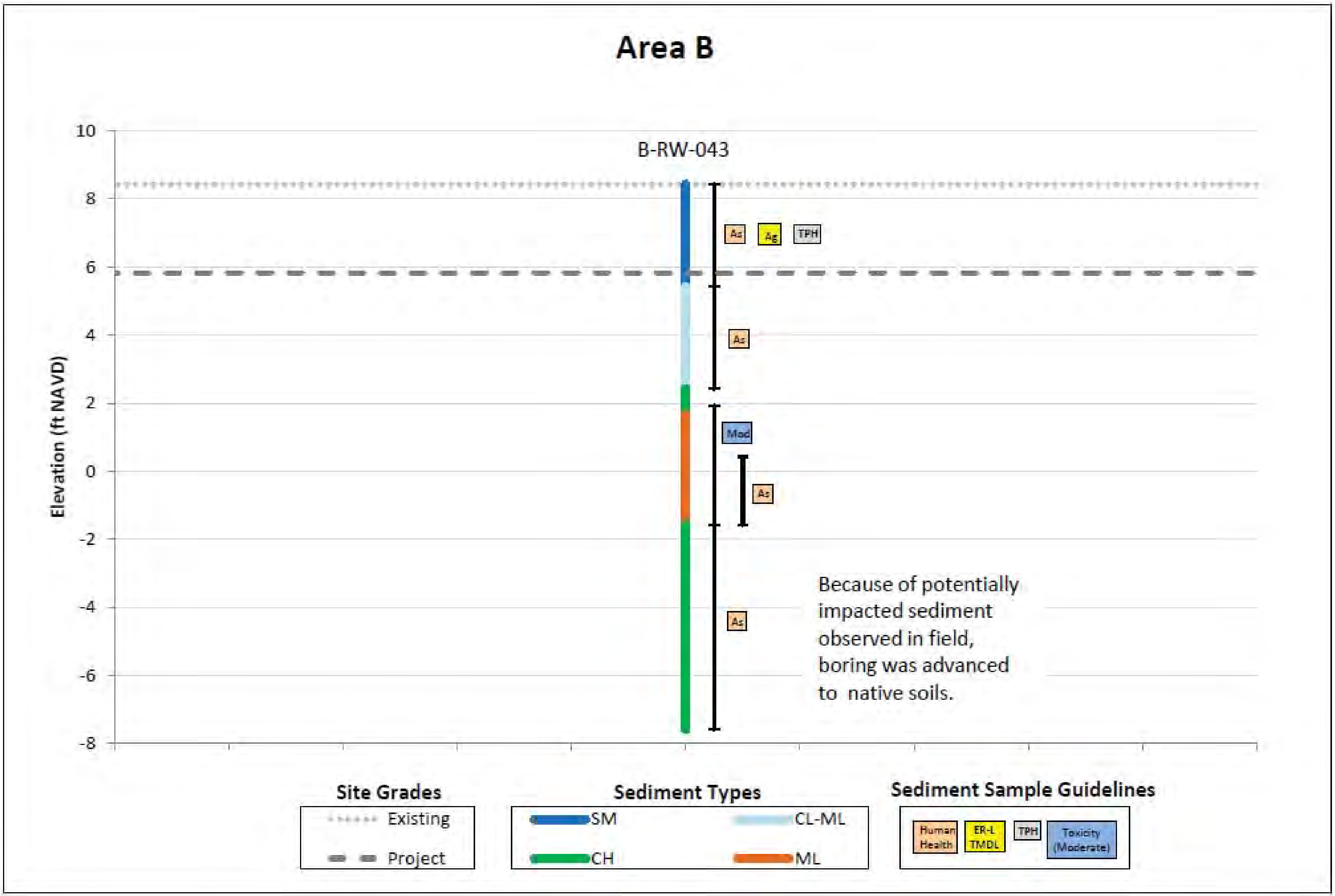
Figure 4

Boring Profiles for Transect in Area A



Ballona Wetlands. D120367

Figure 5

Boring Profile for Area B

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TABLE 6
SUMMARY OF TPH AND TRPH RESULTS IN SOIL SAMPLES

Table 6A: In/near Proposed Channel

Analyte	Units	PQL	Soil Screening Criteria – Residential (Shallow Soils <3m)**	Soil Screening Criteria – Residential (Deep Soils >3m)**	A-RW-020-D1 (20’ –28’)	A-RW-020-D2 (16’ –19’)	A-RW-020-D3 (12’-16’)	A-RW-020-C3 (4’-9’)	A-HSA018-D2 (16’ –19’)	A-HSA018-D3 (10’ –12’)	A-HSA018-D1 (20’-24’)	A-HSA018-C3 (4’-8’)	B-RW-055-C1 (0’ –3.5’)	B-RW-055-C2 (4’ –8’)	B-RW-055-D1 (10’ –14’)
TPH as Gasoline and Light Hydrocarbons	µg/dry g	1.000	83	83	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
TPH as Diesel	µg/dry g	5.0	83	83	<0.10	<0.10	12.9	<0.10	<0.10	11.1	<0.10	<0.10	<0.10	<0.10	<0.10
TPH as Heavy Hydrocarbons	µg/dry g	5.0	370	5000	<0.10	<0.10	72.8	<0.10	<0.10	149	<0.10	5.26	<0.10	<0.10	<0.10
Total Recoverable Petroleum Hydrocarbons	µg/dry g	5.0			<1.0	<1.0	<1.0	<1.0	<1.0		<1.0	<1.0		<1.0	<1.0

Table 6B: In Proposed Marsh and Transition Zone

Analyte	Units	PQL	Soil Screening Criteria – Residential (Shallow Soils <3m)	Soil Screening Criteria – Residential (Deep Soils >3m)	A-HSA-016-D1 (10.5’–12’)	A-HSA-016-D2 (14’–16’)	A-HSA-016-C2 (6’ -10.5’)	A-HSA-016-C1 (0’ –6’)	B-RW-043-C1 (0’ –3’)	B-RW-043-D1 (3’ –6’)	B-RW-043-D2 (6’ –6.5’)	B-RW-043-D3 (8’-10’)	B-RW-043-D5 (10’-16’)
TPH as Gasoline and Light Hydrocarbons	µg/dry g	1.000	83	83	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
TPH as Diesel	µg/dry g	5.0	83	83	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
TPH as Heavy Hydrocarbons	µg/dry g	5.0	370	5000	13.0	<0.10	<0.10	<0.10	43.5	<0.10	<0.10	<0.10	<0.10
Total Recoverable Petroleum Hydrocarbons	µg/dry g	5.0			<1.0	<1.0	<1.0	<1.0	130	<1.0	<1.0	<1.0	<1.0

Table 6C: Upland

Analyte	Units	PQL	Soil Screening Criteria – Residential (Shallow Soils <3m)	Soil Screening Criteria – Residential (Deep Soils >3m)	A-HSA-067-C1 (0’ -6’)
TPH as Gasoline and Light Hydrocarbons	µg/dry g	1.000	83	83	<0.10
TPH as Diesel	µg/dry g	5.0	83	83	<0.10
TPH as Heavy Hydrocarbons	µg/dry g	0.10	370	5000	<0.10
Total Recoverable Petroleum Hydrocarbons	µg/dry g	5.0			<1.0

Notes: ** SFRWCQB, 2007.

J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)

[shaded box] - Detections of Constituents Listed.

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The results of the 2012 Sediment Characterization Investigation in Areas A and B are also presented based on the three types of final use/habitat types which were defined in the SAP and which formed the basis for the scope and focus of the investigation. The results are presented for samples collected:

1. in or near the proposed re-aligned channel – Table 7A;
2. in the proposed marsh or transition zones – Table 7B; and,
3. from proposed upland habitat areas –Table 7C.

Material Used for Wetland Surface in Proposed Realigned Channel

The results of the analytical analysis of samples taken at the proposed depth of the re-aligned channel indicate concentration of metals, pesticides, PAHs and PCB are all below the most stringent guidelines including the ER-L values (Young et. al., 1995) and the Beneficial Reuse wetland surface criteria (Germano & Associates, 2004). The concentrations are all well below the historical ranges and averages reported for the existing Area B tidal marsh channel sediments. Historical data on sediment characteristics in the existing Ballona Creek Estuary are discussed in Section 3.5.

A bioassay study was conducted on the samples collected within the anticipated depth of the new marsh surface. Results indicated low to moderate toxicity for one of the marine arthropods, *Eohaustorius estuarius*. These samples contained low concentrations of contaminants and a high percentage of fine sediments, leading to speculation that the toxicity was related to sediment grain size characteristics that were outside of the tolerance range of the toxicity test species (Kendall, 1999 and SCCWRP, Bight'08 Toxicology Lab. Manual). As an additional study to further evaluate the cause of the toxicity result, a toxicity identification evaluation (TIE) study was conducted by the Southern California Coastal Water Research Project (SCCWRP) in 2014 (Greenstein and Bay 2014; included as Appendix C). This TIE study concluded that multiple lines of evidence indicated that nonchemical factors, possibly related to sediment texture, were the most likely cause of toxicity for the sediment (Greenstein and Bay 2014). The result suggests that toxicity was impacted by some physical characteristic, such as clay content. The implication is that the physical sediment properties (e.g., texture, clay content) are not suitable for supporting the marine arthropod, *Eohaustorius estuaries* because this species is adapted to inhabiting environments with sandier sediment. Therefore, the bioassay and TIE results indicate that the fine-grained sediment at Ballona is not likely to support *Eohaustorius estuaries* and that the low concentrations of chemical contaminants are not likely to impact benthic communities.

Material Used for Wetland Surfaces in Areas A and B

The results of the analytical analysis of samples taken at approximately the proposed depth of the new marsh surface indicate the concentration of copper and total DDT are above the ER-L guidelines and similar TMDL goals, but below the Beneficial Reuse wetland surface criteria. Silver concentrations are above the wetland surface guidelines in two samples that could be used for this purpose. The silver and total PCB concentration are within the range of concentration detected in sediment within existing Area B marsh channel sediments, but above the average concentrations in several samples. The copper concentration that is above the ER-L in sample A-HAS-016-C2 (6'-10.5'), is below the average concentration in the existing Area B marsh. The bioassay results on the samples collected within the anticipated depth of the new marsh surface indicated low to moderate toxicity for one of the marine arthropods, *Eohaustorius estuaries*. As discussed above, the TIE study concluded this is most likely due to sediment texture and not chemical contamination (Greenstein and Bay 2014; Appendix C).

Material Used for Potential On-site Wetland Grading and/or Upland

The results of the analytical analysis of samples taken within the depths that will be excavated and used for either wetland grading or predominantly upland placement, indicate the concentration of silver and total DDT are above the most stringent ER-L guidelines and similar TMDL goals in two of nine and three of nine samples, respectively. These concentrations were below the criteria for wetland surface criteria (Germano & Associates, 2004) with the exception of silver in A-HSA018-D3 (10'-12'). At this borehole location, copper concentrations were also higher than the wetland surface criteria. The silver and total PCB concentration are within the range of concentration detected in sediment within existing Area B marsh channel sediments, but above the average concentrations in two and one of the nine samples, respectively. Arsenic was above the average of Area B marsh sediments in A-HSA018-D3 (10'-12'). This borehole location had the highest and greatest number of constituents above the ER-L values and the only two constituents in all 21 total samples collected in Area A and B that were above the Beneficial Reuse wetland surface criteria. No bioassay testing was performed on this material.

Material Used for Wetland Foundation

The concentrations of constituents in the samples collected from depths that are anticipated to be below the proposed marsh surfaces and serve as wetland foundation material are all below the ER-L values with the exception of silver concentrations in one of eight samples (A-HAS-016-D1 -10.5'-12'). The concentrations for these materials are not above the guidelines for Beneficial Reuse wetland foundation material. The bioassay results on the samples collected within the anticipated depth of wetland foundation material indicated low to moderate toxicity for one of the marine arthropods, *Eohaustorius estuaries*. As discussed above, the TIE study concluded this is most likely due to sediment texture and not chemical contamination (Greenstein and Bay 2014; Appendix C).

Material Used for Potential Off-site Discharge in Marine Waters

The scope of this sediment investigation did not include sediment sampling and analyses for comparison to criteria for off-site discharge in marine waters (e.g., offshore disposal at the LA-2 disposal site). The proposed project includes potential off-site ocean disposal or open water placement (e.g., off-site shallow water habitat creation or either confined aquatic disposal (CAD) or CAD cover). Any material to be used for off-site ocean or open water placement will be tested and assessed in accordance with applicable EPA and USACE guidance as discussed in Section 4.

3.4 Ballona Creek Estuary Sediment Characteristics- Historical Results

Based on the current restoration plan for Ballona Wetlands, areas of the existing Ballona Creek will be filled and covered, while other parts of the channel will remain intact. Therefore, portions of the current sediment within the Ballona Creek Estuary will continue to serve as estuarine habitat. Investigation of the characteristics of these sediments and their suitability for use as wetland surface materials were not part of the field and laboratory sediment characterization

TABLE 7
SUMMARY OF SEDIMENT SAMPLES RESULTS AND COMPARISON TO BENEFICIAL USE GUIDELINES AND AREA B MARSH SEDIMENT QUALITY

Table 7A: Samples in/near Proposed Channel

Group	Analyte	Units	PQL	Dredged Material Screening Criteria[1] ER-L	ER-M	Wetland Benefial Use Guidelines[2] Wetland Surface	Wetland Foundation	Range of Concen. Ballona Area B[3]	Average Concen. Area B[4]	Ballona Estuary TMDL Goals (ER-L)[5]	A-RW-020-C3 (4'-9')	A-RW-020-D3 (12'-16')	A-RW-020-D2 (16' –19')	A-RW-020-D1 (20'-28')	A-HSA018-C3 (4'-8')	A-HSA018-D3 (10' –12')	A-HSA018-D2 (16' –19')	A-HSA018-D1 (20'-24')	B-RW-055-C1 (0' –3.5')	B-RW-055-C2 (4' –8')	B-RW-055-D1 (10' – 14')
Metals	Arsenic (As)	µg/dry g	0.120	8.2	70	40	40	3.7-14.6	8.43		2.60	0.953	1.79	2.32	5.30	**16.6**	0.953	1.71	1.88	2.80	1.78
	Cadmium (Cd)	µg/dry g		1.2	9.6	0.250	0.620	0.49-6.16	2.44	1.2	**0.639**	**0.927**	0.0623	**0.329**	**0.369**	**0.963**	0.101	**0.309**	**0.381**	0.161	**0.46**
	Chromium (Cr)	µg/dry g		81	370	119	320	18-97.2	55.34		16.8	17.3	16.4	18.2	17.2	20.6	20.7	16.2	15.3	15.2	14.1
	Copper (Cu)	µg/dry g	0.030	34	270	50	150	17-440	77.71	34	28.5	14.9	21.9	19.4	26.5	**53.7**	19.5	27.4	22.9	19.3	25.2
	Lead (Pb)	µg/dry g	0.010	46.7	218	200	200	20.8-265	88.16	46.7	7.00	4.74	2.42	4.23	7.64	**58.7**	5.20	6.10	11.2	5.03	6.21
	Mercury (hg)	µg/dry g		0.15	0.71	1.18	1.18	.041-.272	0.16		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Nickel (Ni)	µg/dry g		20.9	51.6	230	230	9.2-39.29	24.78		15.6	15.8	13.1	15.2	15.8	17.8	13.8	13.5	13.9	13.7	18.0
	Silver (Ag)	µg/dry g	0.020	1	3.7	0.28	2.00	0.05-3.77	1.15	1.0	**0.794**	0.164	0.0159 (J)	0.0545	0.110	**1.44**	0.0296	0.0748	**0.285**	0.083	0.0349
	Zinc (Zn)	µg/dry g	0.160	150	410	1200	1200	54.9-1770	285.54	150	67.9	46.0	56.0	41.5	60.8	**187**	60.9	52.2	59.9	45.4	53.3
Pesti-cides & PCBs	Total DDT	ng/dry g	2.0	1.58	46.1	250	250	0-17.1	4.41	1.9*	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**4.27**	<1.0	<1.0
	Total Chlordane	ng/dry g	2.0	0.5	6	69.2	69.2	0-51.4	6.03	1.3*	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**2.42**	<1.0	<1.0
	Total PCB	ng/dry g	2.0	22.7	180	600	600	0-36	10.8	3.2*	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.85 (J)	<1.0	<1.0
	Total PAHs	µg/dry g		4.022	44.79	6.3		0-3.25	0.434	4.022	<0.010	0.1159	<0.010	0.0134	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bioassay	*Eohaustorius estuaries – 10 day survival*	%						98.6-9.38	79					79				79			69
Potential Beneficial Use (Wetland Surface (WS), Wetland Foundation (WF), Wetland Grading, Upland (WG/UP))											**WG/UP**	**WG/UP**	**WG/WS**	**WS**	**WG/UP**	**WG/UP**	**WS**	**WS/WF**	**UP/WG**	**UP/WG**	**WS/WF**

Table 7B: Samples in Proposed Marsh and Transition Zone

Group	Analyte	Units	PQL	Disposal Option Sediment Screening Criteria[1] ER-L	ER-M	Bay Area Recommended Guidelines[2] Wetland Surface	Wetland Foundation	Range of Concen. Ballona Area B[3]	Average Concen. Area B[4]	Ballona Estuary TMDL Goals (ER-L)[5]	A-HSA-016-C1 (0' –6')	A-HSA-016-C2 (6' - 10.5')	A-HSA-016-D1 (10.5'–12')	A-HSA-016-D2 (14'–16')	B-RW-043-C1 (0' –3')	B-RW-043-D1 (3' –6')	B-RW-043-D2 (6' –6.5')	B-RW-043-D3 (8'-10')	B-RW-043-D5 (10'-16')
Metals	Arsenic (As)	µg/dry g	0.120	8.2	70	40	40	3.7-14.6	8.43		2.01	2.57	2.67	1.77	1.91	0.895	N/A	1.2	2.01
	Cadmium (Cd)	µg/dry g		1.2	9.6	0.250	0.620	0.49-6.16	2.44	1.2	0.177	**0.537**	**0.779**	0.244	**0.460**	**0.441**	N/A	0.0713	**0.506**
	Chromium (Cr)	µg/dry g		81	370	119	320	18-97.2	55.34		9.75	23.0	19.8	14.1	11.9	13.6	N/A	11.3	15.1
	Copper (Cu)	µg/dry g	0.030	34	270	50	150	17-440	77.71	34	7.3	**35.6**	28.7	24.0	22.6	19.1	N/A	13.5	22.4
	Lead (Pb)	µg/dry g	0.010	46.7	218	200	200	20.8-265	88.16	46.7	2.26	6.84	24.2	4.69	42.6	9.11	N/A	2.52	5.29
	Mercury (hg)	µg/dry g		0.15	0.71	1.18	1.18	.041-.272	0.16		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	<0.1
	Nickel (Ni)	µg/dry g		20.9	51.6	230	230	9.2-39.29	24.78		9.3	19.9	17.2	13.6	9.72	14.8	N/A	9.9	15.0
	Silver (Ag)	µg/dry g	0.020	1	3.7	0.28	2.00	0.05-3.77	1.15	1.0	0.039	0.114	**1.53**	.0174J	**1.25**	0.110	N/A	0.0583	0.103
	Zinc (Zn)	µg/dry g	0.160	150	410	1200	1200	54.9-1770	285.54	150	20.1	55.8	86.1	55.7	1.25	45.9	N/A	45.4	43.9
Pesti-cides & PCBs	Total DDT	ng/dry g	2.0	1.58	46.1	250	250	0-17.1	4.41	1.9*	**3.12**	**18.62**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Total Chlordane	ng/dry g	2.0	0.5	6	69.2	69.2	0-51.4	6.03	1.3*	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
	Total PCB	ng/dry g	50	22.7	180	600	600	0-36	10.8	3.2*	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Total PAHs	µg/dry g		4.022	44.79	6.3		0-3.25	0.434	4.022	<0.010	<0.010	<0.010	<0.010	0.20	<0.010	<0.010	<0.010	<0.010
Bioassay	*Eohaustorius estuaries – 10 day survival*	%						98.6-9.38	79			86	86					69	
Potential Beneficial Use (Wetland Surface (WS), Wetland Foundation (WF), Wetland Grading, Upland (WG/UP))											**WG/UP**	**WS/WG**	**WS/WF**	**WF**	**WS/WG**	**WS/WF**	**WF**	**WF**	**WF**

Table 7C: Samples from Proposed Upland

Group	Analyte	Units	PQL	Dredged Material Screening Criteria[1] ER-L	ER-M	Wetland Beneficial Use Guidelines[2] Wetland Surface	Wetland Foundation	Range of Concen. Ballona Area B[3]	Average Concen. Area B[4]	Ballona Estuary TMDL Goals (ER-L)[5]	A-HSA-067-C1 (0'–6')
Metals	Arsenic (As)	µg/dry g	0.120	8.2	70	40	40	3.7-14.6	8.43		2.93
	Cadmium (Cd)	µg/dry g		1.2	9.6	0.250	0.620	0.49-6.16	2.44	1.2	**0.374**
	Chromium (Cr)	µg/dry g		81	370	119	320	18-97.2	55.34		21.2
	Copper (Cu)	µg/dry g	0.030	34	270	50	150	17-440	77.71	34	25.7
	Lead (Pb)	µg/dry g	0.010	46.7	218	200	200	20.8-265	88.16	46.7	7.74
	Mercury (hg)	µg/dry g		0.15	0.71	1.18	1.18	.041-.272	0.16		
	Nickel (Ni)	µg/dry g		20.9	51.6	230	230	9.2-39.29	24.78		19.1
	Silver (Ag)	µg/dry g	0.020	1	3.7	0.28	2.00	0.05-3.77	1.15	1.0	0.106
	Zinc (Zn)	µg/dry g	0.160	150	410	1200	1200	54.9-1770	285.54	150	53
Pesti-cides & PCBs	Total DDT	ng/dry g	2.0	1.58	46.1	250	250	0-17.1	4.41	1.58	**31.04**
	Total Chlordane	ng/dry g	2.0	0.5	6	69.2	69.2	0-51.4	6.03	0.5	<0.1
	Total PCB	ng/dry g	50	22.7	180	600	600	0-36	10.8	22.7	<25
	Total PAHs	µg/dry g		4.022	44.79	6.3		0-3.25	0.434	4.022	<0.010
Potential Beneficial Use (Wetland Surface (WS), Wetland Foundation (WF), Wetland Grading, Upland (WG/UP))[6]											WG/UP

Notes:

J – Below the Reporting Limit (RL) but above the Method Detection Limit (MDL)
[yellow box] - Concentration exceeds the ER-L and/or the TMDL Goals
[green box] - Concentration exceeds wetland beneficial use guidelines (see footnote 2) for wetland surface criteria
[blue box] - Concentration exceeds wetland beneficial use guidelines (see footnote 2) for wetland surface and foundation criteria
* Updated with TMDL Reconsideration
Footnotes:
[1] Effects Range-Low (E-RL) and Effects Range Medium (E-RM) are used in dredged material evaluation for Ocean Disposal in combination with the results of bioassay testing and bioaccumulation testing.
[2] Sediment Reuse Criteria for Wetland Restoration – Criteria for assessing sediment for wetland surface and foundation beneficial uses were first developed by the San Francisco Regional Water Quality Control Board (SFCRWQCB, 2000). The guidelines presented are based on revised guidelines based on a Floating Percentile Method for predicting acute amphipod toxicity (Germano & Associates, 2004), and can therefore be applied to application outside of the Bay area. However, these criteria need to be used in combination with site-specific background data (see range and average concentrations for Area B in Table) and bioassay testing results on site sediments.
[3] The range of sediment concentration is based on the results presented in Table 2 in Appendix B from sediment sampling and analysis in Area B for the Ballona Wetlands Ecological Reserve Baseline Assessment Program (Santa Monica Bay Restoration Commission, 2011 and Weston, 2006).
[4] The average concentration is based on historical sediment concentrations for Area B as presented in Table2 in AppendixB.
[5] These are concentration based waste load allocations from the Ballona Estuary Toxics TMDL and based on the E-RL. This TMDL is being re-evaluated. See Appendix A for more discussion of sediment screening criteria. Based on toxicity testing, these guidelines were found to be inaccurate and highly conservative (SCCWRP, 2000).
[6] Potential beneficial use based on elevation of the material from proposed final grades. Wetland surface material is within ±5 ft of proposed final grades. Material above this may be used for wetland grading or upland material. Material 3-5 ft below the proposed final grade is wetland foundation material (WF). If sample is between these depths, dual designated use is shown.

studies conducted as part of the Restoration Design. However, historical data was reviewed to assess suitability and potential sediment quality issues for materials within the Ballona Creek Estuary, which are within the Proposed Project limits. Previous studies, which include chemistry and toxicity testing of sediment within the Ballona Creek Estuary as part of the Bight ’03 program, reported that sediments within Ballona Creek Estuary are contaminated and toxic to marine life (LARWQCB &USEPA Region 9, 2005). This prevalence of toxicity led to an Environmental Protection Agency 303(d) listing and the subsequent development of a total maximum daily load (TMDL) for multiple trace organics, metals, and sediment toxicity (LARWQCB &USEPA Region 9, 2005).

In support of the TMDL, a three-year study was conducted to determine the current extent of chemical contamination within the estuary and to identify the likely causes of toxicity. Advanced chemical analysis and toxicity identification evaluation (TIE) methods were used in this study. The results indicated that chemical contamination and toxicity were widespread in the estuary (SCCWRP, 2010). Concentrations of TMDL listed compounds, including DDT, DDE, and chlordane, often exceeded target levels. However, the results of toxicity testing indicated that the concentration of these constituents were 10 to 10000 times below toxicity thresholds either developed in this study or reported in other studies. Sediment concentrations of PAHs and PCBs were also below levels likely to cause direct sediment toxicity. Metals concentrations in field sampled sediment porewater were below California water quality standards for the protection of aquatic life (SCCWRP, 2010).

TIE analyses of whole sediments and porewater found that pyrethroid pesticides were likely the primary source of toxicity within the estuary. Comparison of these pesticides’ toxicity thresholds to chemical analysis results confirmed that sufficient pyrethroids were present in the estuary sediments to cause toxicity. Another currently used pesticide, fipronil, was detected in estuary sediments and may also be of concern (SCCWRP, 2010). The issue of synthetic pyrethroids impacts on the sediment in the Ballona Estuary that will remain exposed per the Proposed Project needs to be addressed. Design measures to address this issue may include removal of the sediments to a depth that does not contain concentrations that are toxic and preserves the designated beneficial uses.

Guidelines for sediment quality for the Ballona Estuary are presented in the Toxics Pollutants TMDL developed by the Los Angeles Regional Water Quality Control Board (LARWQCB, 2005). These guidelines are based on the Effects Range-Low (E-RL) criteria. The results of the sediment characterization study as part of the TMDL Reconsideration, indicated the E-RL sediment quality guideline values used as target concentrations for the chemicals listed in the TMDL were found to be inaccurate and highly conservative. The ER-Ls for some metals were below background concentrations typical of estuarine environments. For the organic compounds, ER-Ls were several orders of magnitude below toxicity thresholds for benthic organisms (SCCWRP, 2010). Therefore use of these guidelines for sediment screening purposes may not be applicable for the Ballona Estuary. In the 2013 TMDL Reconsideration, goals for the organic compounds were updated based on recent data. Table 7 includes the updated TMDL goals.

CHAPTER 4
Ocean Disposal Requirements

On-site sediment that is not used for on-site beneficial use as wetland surface, wetland foundation or upland placement may be designated for alternative placement depending on final cut and fill balance quantities. The suitability of on-site excavated sediment for placement at a designated ocean dredged material disposal site such as LA-2 offshore of San Pedro, would require a Tier III evaluation in accordance with Evaluation of Dredged material Proposed for Discharge in Waters of the U.S. – Testing Manual (ITM; USEPA/USACE 1998, Section 6.7) and Evaluation of Dredged Material Proposed for Ocean Disposal – Testing Manual (OTM; USEPA/USACE 1991) guidelines. Sampling and testing requirements under these protocols include:

- **Sampling Frequency -** The general rule is a minimum of two composite samples will be used for the first 100,000 cubic yards (CY) and one composite sample will be used per subsequent 100,000 CY. However, additional composites or analyses of individual cores may be required if contaminant hot spots are identified.
- **Geotechnical Testing -** Physical analysis should include grain size, specific gravity, and total solids. Atterberg limits are also recommended to estimate strength and settlement characteristics of the sediment.
- **Chemical Testing -** Chemical analysis of bulk sediment should include general chemistry (i.e., ammonia, total sulfides, and total organic carbon [TOC]), trace metals, chlorinated pesticides, PCB Congeners, PAHs, other semivolatile organic compounds (i.e., phenols and phthalates), and organotins.

Similar to the assessment of the suitability of the project's excavated sediment for use as on-site wetland surface and foundation materials, the chemical analyses results may be compared to ER-L and ER-M values. The values are helpful in assessing the potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analysis. While these screening level values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. As presented previously, the results of chemical analyses of on-site sediment samples indicated concentrations of lead, copper, zinc, silver, and total DDT above the ER-L in several samples. Concentrations were not above the ER-Ms.

The additional biological testing that is required under the ocean disposal guidance includes:

- **Solid Phase Toxicity Testing -** Two solid phase (SP) 10-day acute tests performed on whole sediment are conducted to estimate potential adverse effects of ocean disposed dredged material on benthic organisms. One SP test may be conducted using an amphipod species. The species should be selected based on grain size tolerance (i.e., *Eohaustorius estuarius* prefer primarily coarse-grained sediment while *Ampelisca abdita* prefer fine-grained sediment) to reduce confounding effects unrelated to contaminants. The polychaete *Neanthes arenaceodentata* may be used.

- **Suspended particulate phase (SPP) Toxicity Testing** – Three suspended particulate phase (SPP) tests are required. SPP tests are conducted to estimate the potential adverse effects of ocean disposed dredged material on organisms that live in the water column. These tests are performed on sediment elutriates, prepared at a ratio of one part sediment and four parts site water in accordance with ITM (USEPA/USACE 1998) and OTM (USEPA/USACE 1991) guidelines. SPP tests may be performed using the mysid shrimp *Americamysis bahia* (formerly *Mysidopsis bahia*), the fish *Menidia beryllina*, and the larvae of a bivalve. The bivalve species may include *Mytilus galloprovincialis*; however, if gravid mussels are not available, an alternate species should be selected in consultation with USEPA and USACE. Both the mysid shrimp and fish SPP tests are 96-hour acute tests, while the *M. galloprovincialis* SPP test is a 48-hour chronic test that measures both survival and development.

- **Bioaccumulation Potential Testing**—The Bioaccumulation Potential (BP) testing consists of a 28-day test performed on whole sediment. The purpose of the BP tests is to estimate the potential of benthic organisms to bioaccumulate contaminants of concern from ocean disposed dredged material. BP tests may be conducted using the bivalve *Macoma nasuta* and the polychaete *Nereis virens*; however, *Nephthys caecoides* may be used as an alternative polychaete species. At test termination, bioaccumulation tissue samples should be submitted for chemical analysis. The tissue analyte list should focus on those chemicals present at levels of concern in sediment (i.e., greater than ER-M values) and based on approval by the Contaminated Sediment Task Force prior to analysis of tissue samples.

The biological testing that has been performed to date on the on-site sediment for assessing suitability for on-site beneficial use has included solid phase toxicity testing. As discussed previously, the result of this toxicity testing indicated a significant difference from the control for one of the three species tested. The differences from the control sample were observed for the *Eohaustorius estuaries,* which is likely the result of the fine-grained nature of the sediment samples as discussed.

Based on the available results, the placement of on-site excavated sediments (not used for on-site wetland restoration and upland habitat) at a designated ocean disposal or open water placement site remains a potential option, if needed. However, the determination of suitability will require further biological testing in accordance with ITM (USEPA/USACE 1998) and OTM (USEPA/USACE 1991) guidelines as outlined above. The additional testing will include running the solid phase toxicity testing using a fine-grained control, and SSP and BP testing as discussed above.

For SPP testing, results are compared to the control. If a median lethal concentration (LC50) or median effective concentration (EC50) can be calculated, a dilution water model should be used to perform a comparison with water quality standards. A short-term fate (STFATE) mixing zone model should be used to determine if LPC requirements will be met; water column concentrations must not exceed 1 percent of the LC50 or EC50 outside the mixing zone 4 hours after dredged material disposal.

For BP testing, tissue concentrations are compared with applicable U.S. Food and Drug Administration (FDA) action levels, and tissue concentrations of organisms exposed to reference sediment. If tissue concentrations of organisms exposed to test sediment are statistically elevated compared to the organisms exposed to reference sediment, results should be assessed based on the criteria specified in the OTM (USEPA/USACE 1991; e.g., toxicological importance of contaminants, magnitude of exceedance, and propensity to biomagnify).

The biological testing for the evaluation of suitability for on-site beneficial use and ocean disposal was performed using a phased approach to avoid the need for unnecessary testing. Additional testing will be performed as needed in accordance with applicable requirements.

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CHAPTER 5
Conclusions and Recommendations

Based on the sediment characterization results to date for Areas A and B, the following key conclusions and recommendation are presented:

Wetland Surface Materials

The results of the sediment characterization indicate that constituent concentrations in the sediments that are located at depths that are anticipated to serve as wetland surface material are below the Beneficial Reuse guidelines (SFBRWQCB, 2000 and Germano & Associates, 2004) with the exception of silver in two out of the nine samples tested. The concentrations of silver in these two samples are above both the ER-L (and therefore, TMDL) and Beneficial Reuse values. As discussed in Section 3.4, the results of the sediment characterization study conducted as part of the TMDL Reconsideration indicated the ER-L sediment quality guideline values used as target concentrations for the chemicals listed in the TMDL were inaccurate and highly conservative. Therefore use of these guidelines for sediment screening purposes may not be applicable for the Ballona Estuary. Additional investigation may be warranted to demonstrate that these concentrations are within the range of marine sediments, do not demonstrate toxic levels, and fall within the range of the concentrations measured in historical monitoring of the existing Area B tidal marsh.

Per the screening methodology presented in the SAP and shown on Figure 6, samples that have concentrations above the Beneficial Reuse guidelines for wetland surfaces underwent bioassay testing. The results of the bioassay tests on these samples indicate moderate to low toxicity for one of the three species tested. An additional TIE study concluded that multiple lines of evidence indicated that nonchemical factors, possibly related to sediment texture, were the most likely cause of toxicity for the sediment (Greenstein and Bay 2014; Appendix C). As discussed, the toxicity response in this arthropod species is likely due to fine-grained sediments despite the absences of chemical stressors (Kendall, 1999 and SCCWRP, Bight'08 Toxicology Lab Manual, Greenstein and Bay 2014). The results to date indicate that the materials that are anticipated for use as wetland surface and foundation materials are suitable.

Material Used for Wetland Grading and Upland Placement

The results of the sediment characterization indicate that constituent concentrations in the sediments that are located above the proposed restoration elevation that would be used for either wetland final grading or upland placement are below the Beneficial Reuse guidelines for wetland surface (SFBRWQCB, 2000 and Germano & Associates, 2004) with the exception of silver and copper in one sample (A-HAS-018-D3 -10'-12') out of the eight samples tested. The concentrations of silver and copper in this one sample are above both the ER-L (and therefore TMDL) and Beneficial Reuse values. Concentrations of arsenic, lead, and zinc are also above the ER-Ls in this sample. Total DDT concentrations in three of the eight samples are above the ER-L values. Additional investigation may be warranted to demonstrate that these concentrations are within the range of marine sediments.

Per the screening methodology presented in the SAP and shown on Figure 6, samples that have concentrations above the wetland surface guidelines underwent bioassay testing. The results of the bioassay tests on these samples indicate moderate to low toxicity for one of the three species tested. As discussed, the toxicity response observed is likely due to the fine-grained nature of the sediments. The results indicated no concentrations above the wetland foundation guidelines. Testing of consolidated materials during the restoration phase should be considered prior to placement on-site to verify these results. Material used for wetland grading should undergo testing at a higher frequency compared to soils that will be used for upland placement.

Wetland Foundation Materials

The results of the sediment characterization indicate that sediments that will be used below the wetland surface are below the Beneficial Use guidelines for wetland foundation (SFBRWQCB, 2000 and Germano & Associates, 2004). One of the eight samples collected and analyzed contains silver concentrations above the ER-L value.

Ocean Disposal

Based on the available results, the possible placement of on-site excavated sediments (not used for on-site wetland restoration and upland habitat) at a designated ocean disposal or open water placement site remains a potential alternative if needed. However, the determination of suitability will require further biological testing in accordance with ITM (USEPA/USACE 1998) and OTM (USEPA/USACE 1991) guidelines as outlined in Section 4 above. The additional testing will include running the solid phase toxicity testing using a fine-grained control, and suspended solid phase toxicity and bioaccumulation potential testing.

TABLE 8
SUMMARY OF BIOASSAY RESULTS

Bioassay	Species	Endpoint	Laboratory Control	Thresholds for Toxicity Categories (Bight'08)	A-HSA-016 (8'-12')	B-RW-043- (6.5'-10') B-RW-055- (10'-16') Composite	A-HSA-018-D1(20'-28') A-HAS-020-D1(20'-28') Composite
10-day Solid Phase Test	*Ampelisca abdita Marine amphipod*	Mean Survival (%)	95.0		94.0	82.0	91.0
10-day Solid Phase Test	*Neanthes arenaceodentata Marine polychacte*	Mean Survival (%)	100		100	96.0	92.0
10-day Solid Phase Test	*Eohaustorius estuaries Marine amphipod*	Mean Survival (%)	96.0	90-100 –Nontoxic 82-89 – Low Toxicity 59-81 – Moderate Toxicity <59 High Toxicity	86.0	69.0	79.0
Grain Size Characteristics*					CL Low Plasticity Clay, Silty Clay	CH High Plasticity Clay, Silty Clay	CH High Plasticity Clay, Silty Clay

Notes: * SCCWRP, 2011 Annual Report, Greenstein, D. & Steven Bay

[yellow box] - Significant difference between Laboratory Control and test.

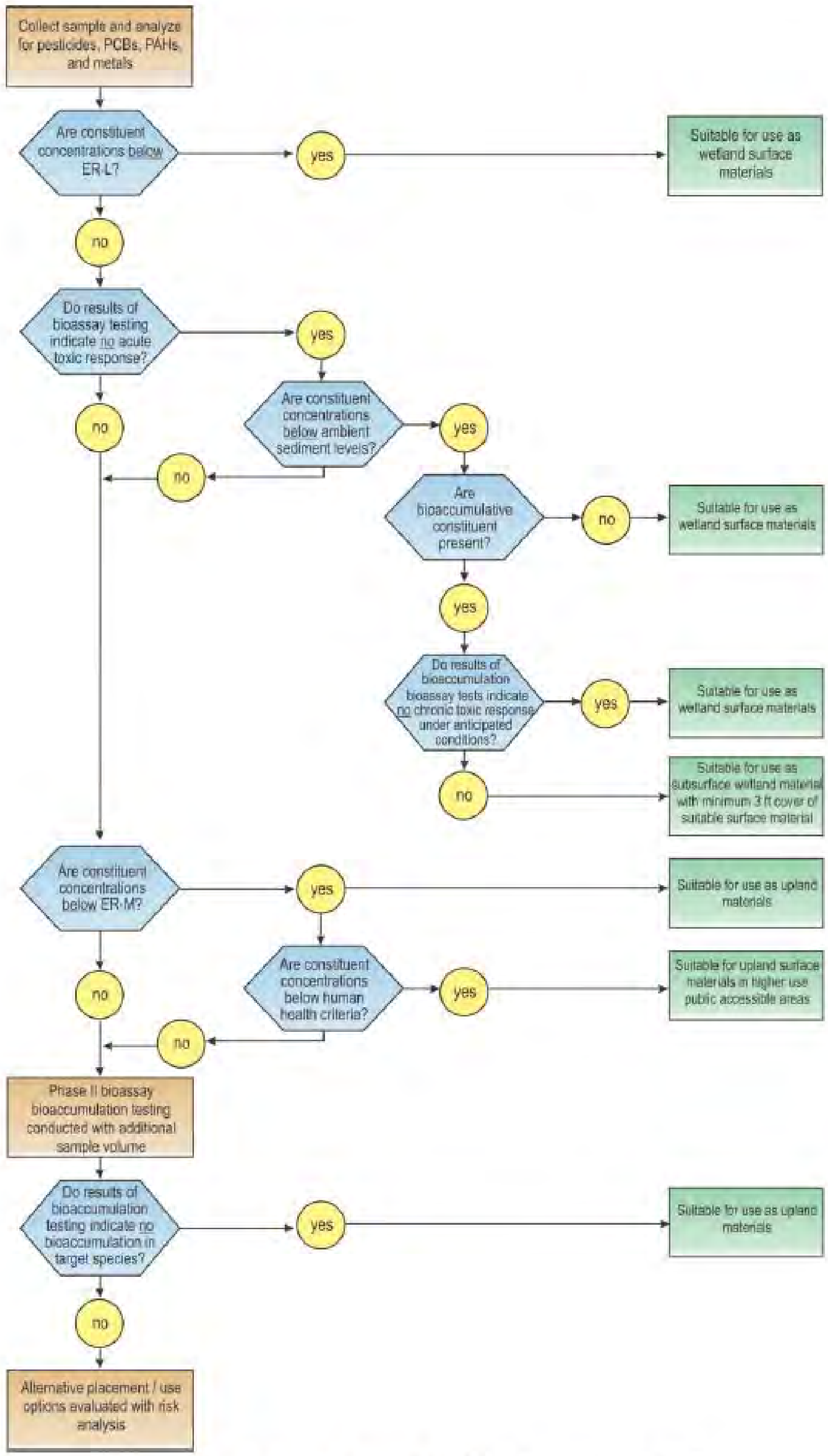

Figure 6. Sediment Beneficial Use Screening Tool

CHAPTER 6
Steps forward

Based on the conclusions and recommendations presented for this sediment characterization study, the following Steps Forward are presented to inform the Environmental Impact Report for the Proposed Ballona Restoration Project:

1. **Suitability of Upland Material** – Materials that are planned for use as upland material shall not possess constituent concentrations above the ER-M. These materials shall also be below the Soil Screening Criteria for shallow and deep soils, where applicable, depending on the depth of the final placement (SFRWCQB, 2007). Materials that are to be used as surface upland materials (top six inches) shall meet the applicable California Human Health Screening Levels (CHHSLs) and Preliminary Remediation Goal (PRGs), or demonstrate that the constituent concentrations are within the typical range of marine sediments and do not exhibit a potential human health risk. For the sediments sampled to date, the only constituent that is above these criteria is arsenic.

   If these materials are not able to be shown suitable for use as surface materials for upland areas based on the CHHSLs, then they shall be covered with a minimum one foot clean layer of soil that shall meet all the above criteria listed for suitability as surface upland materials for both ecological and human health criteria. The top foot of material shall also meet the agronomical requirements for establishing the designated upland habitat. Material below the one foot of clean cover shall still meet the PRGs and Soil Screening Criteria (SFRWCQB, 2007).

2. **Suitability for Potential Marine Discharge** – Any materials that are planned for off-site ocean disposal or open water placement shall be further tested and assessed in accordance with ITM (USEPA/USACE 1998) and OTM (USEPA/USACE 1991) guidelines. The testing results to date do not preclude this alternative, but require further biological testing to meet the applicable guidelines. This additional testing will include running the solid phase toxicity testing using a fine-grained control, and suspended solid phase toxicity and bioaccumulation potential testing. If the material is determined to be suitable for this placement alternative, specific permitting for ocean disposal or open-water placement will be required for the designated site.

3. **Sampling and Analysis Plan** – The methods and frequency for testing excavated sediment for use as the various proposed beneficial uses will be defined in coordination with the permitting agencies in a Sampling and Analysis Plan for any additional sampling performed during the restoration design and/or implementation.

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CHAPTER 7
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APPENDIX A.
Relevant Screening Criteria for Area A Sediments

Analytical results will be compared to relevant soil screening levels, sediment quality guidelines, and hazardous waste criteria to determine suitability of material for specific beneficial uses or placement options. Relevant numeric standards for comparisons include:

- **<u>Ecologically Relevant Screening Criteria</u>**
  - **Effects Range-Low (ER-L) and Effects Range-Median (ER-M) Values**: Effect range values are used in dredged material evaluations for ocean disposal. These values were developed by Long et al. (1995), and are helpful in assessing the potential significance of elevated sediment-associated COCs, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., toxicity tests, benthic community effects) and chemical analysis were available for individual samples. To derive these guidelines, the chemical values for paired data demonstrating benthic impairment were sorted in according to ascending chemical concentration. The ER-L was then calculated as the lower tenth percentile of the observed effects concentrations and the ER-M as the 50^{th} percentile of the observed effects concentrations. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. For dredged material evaluations, the ER-L and ER-M sediment quality values are used in conjunction with bioassay testing and are included for comparative purposes only. For certain pesticide compounds (i.e., chlordane and dieldrin) the ER-L and ER-M levels are so low as to make it largely impractical to detect them in typical harbor sediments using routine analytical procedures. Accordingly, having non-detect results that were greater than the ER-L, ER-M, or method detection limits (MDLs) would not require re-analysis. The use of ER-L and ER-M for use as screening criteria for sediments in Area A is appropriate when used as a tiered approach that includes using bioassay results to determine actual toxic effects to the benthic community.
  - **Sediment Reuse Criteria for Wetland Restoration -** These criteria were first developed by the San Francisco Regional Water Quality Control Board (SFBRWQCB) and presented in the Draft Staff Report entitled, *Beneficial Reuse of Dredged Materials: Sediment Screening and Testing Guidelines* dated May 2000. The document was prepared to assist in planning beneficial reuse projects in the Bay Area by establishing general screening guidelines and general sediment testing requirements. The guidelines include specific criteria for reuse of sediments in wetland and upland beneficial uses. The guidelines for the wetland foundation use are based on the Effects-Range Medium (ER-M) concentrations (Long et. al.,

1995). Ambient concentrations in the San Francisco Bay were used to develop the guidelines for re-use of sediments for wetland surface. These guidelines are to be used in combination with bioassay testing to determine suitability of the materials for use in wetland restoration projects (SFBRWQCB, 2000).

Additional ambient sediment chemical and toxicity testing were performed following the Draft Staff Report in 2000. A statistical analysis was performed on the historical and more recent analytical data to develop a statically derived set of recommended sediment chemistry screening guidelines for beneficial reuse. The results of this analysis and recommended guidelines were presented in *An Evaluation of Existing Sediment Screening Guidelines for Wetland Creation/Beneficial Reuse of Dredged Material in the San Francisco Bay Area along with a Proposed Approach for Alternative Guideline Development* (Germano & Associates, 2004) that was funded by the California State Coastal Conservancy. The recommended guidelines presented in the 2004 report are based on the Floating Percentile Method for predicting acute amphipod toxicity. These guidelines presented in the 2004 Germano & Associates report, therefore can be applied to sites outside of the Bay area as they are based on toxicity testing results rather than ambient concentrations in San Francisco Bay. These guidelines are presented in the results summary tables to compare with constituent concentrations in sediment from Area A to assess the suitability of these materials for wetland surface and foundation beneficial uses.

- **Ballona Estuary Total Maximum Daily Loads (TMDL) Guidelines -** These guidelines for the Ballona Estuary are presented in the Toxics Pollutants TMDL developed by the Los Angeles Regional Water Quality Control Board (LARWQCB, 2005). As part of the TMDL Reconsideration, a study on the toxicity of the sediments in the Ballona Creek Estuary was performed by the Southern California Coastal Water Research Project (SCCWRP) and documented in the report on Toxicity Identification Evaluation (TIE) of Sediment in Ballona Creek Estuary (SCCWRP, 2010).

  The TIE testing was performed to determine the cause of the toxicity response in sediments and to compare the TMDL guidelines to actual ambient concentrations in the wetland. The TIE analyses of whole sediments and pore water found that pyrethroid pesticides were the likely primary source of toxicity within the estuary. Comparison of these pesticides' toxicity thresholds to chemical analysis results confirmed that sufficient pyrethroids were present in the estuary sediments to cause toxicity. Concentrations of TMDL listed compounds often exceeded target levels, but there was a poor correlation between these concentrations and toxicity. The Effects Range Low (ER-L) sediment quality guideline values used as target concentrations for the chemicals listed in the TMDL were found to be inaccurate and highly conservative. The ER-Ls for some metals were below background concentrations typical of estuarine environments. For the organic compounds, ER-Ls were several orders of magnitude below toxicity thresholds for benthic organisms. Based on these results, it can be anticipated that the current Toxics TMDL will be revised to reflect that the primary constituents of concern in the estuary are synthetic pyrethroid pesticides, and that the TMDL goals will be modified for the metals and organic compounds currently listed. The use of the TMDL goals based on the ER-L for screening purposes may not be applicable based on these reported results. The TMDL goals are presented with in the summary results tables for sediment chemistry for information purposes.

- **Bight '08 Toxicity Criteria -** The level of toxicity associated with each sediment sample that underwent toxicity testing was calculated using thresholds established for the SQO program (Bay *et al*. 2009) and presented in the Bight '08 Sediment Toxicity Report (SCCWRP, 2008). The thresholds are specific to each of the toxicity test methods as shown on Table A-1 taken from the Bight '08 Sediment Toxicity Report. Using the thresholds, each sample was classified as Nontoxic, Low Toxicity, Moderate Toxicity, or High Toxicity. Each of these toxicity categories reflects both severity of toxicity and the confidence that the effects are real.
  - **Nontoxic**: Response is not substantially different from that expected in sediments that are uncontaminated and have optimum characteristics for the test species (e.g., control sediments).
  - **Low Toxicity**: A response that is of relatively low magnitude; the response may not be greater than test variability.
  - **Moderate Toxicity**: High confidence that a statistically significant toxic effect is present.
  - **High Toxicity**: High confidence that a toxic effect is present and the magnitude of response includes the strongest effects observed for the test.

TABLE-A-1
THRESHOLDS FOR CALCULATING TOXICITY CATEGORIES.

Test Species/Endpoint	Nontoxic (Percent)	Low Toxicity (Percent of Control)	Moderate Toxicity (Percent of Control)	High Toxicity (Percent of Control)
Eohaustorius estuaries Survival	90 to 100	82 to 89[a]	59 to 81[b]	< 59
Mytilus galloprovincialis Normal	80 to 100	77 to 79[a]	42 to 76[b]	< 42

a If the response is not significantly different from the negative control, then the category becomes Nontoxic.
b If the response is not significantly different from the negative control, then the category becomes Low toxicity.

- **Sediment Quality Objectives (SQOs) -** California's SQOs are described in the *Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality* (SWRCB and CA EPA, 2009). The goals of the SQOs are to determine whether pollutants in sediments are present in quantities that are toxic to benthic organisms and/or will bioaccumulate in marine organisms to levels that may be harmful to humans. The SQOs are based on a multiple lines of evidence (MLOE) approach in which sediment toxicity, sediment chemistry, and benthic community condition are the lines of evidence (LOE). The MLOE approach evaluates the severity of biological effects and the potential for chemically mediated effects to provide a final station level assessment. The use of SQOs require that the site be fully submerged under tidal conditions and assumes establishment of a benthic community. These conditions will not exist until after the restoration in Area A, therefore the use of the SQOs is not applicable. The SQOs ratings cannot be applied without the use of benthic data, and therefore are not applicable at this time to assess Area A sediments. However, in the absence of clearly defined criteria for evaluating use of sediment in Area A for wetland surface material, chemical and bioassay methods and screening used for SQOs may be used for planning purposes and establishing baseline data as part of multiple screening criteria.

- **Human Health Screening Levels**
  - **California Human Health Screening Levels (CHHSLs)**: Concentrations of 54 hazardous chemicals in soil that the California Environmental Protection Agency (Cal/EPA) considers to be below thresholds of concern for risks to human health based on ingestion, inhalation, and dermal absorption. The CHHSLs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) on behalf of Cal/EPA, and are contained in their report entitled "Human-Exposure-Based Screening Numbers are Developed to Aid Estimation of Cleanup Costs for Contaminated Soil". Any exceedances of the CHHSLs do not indicate that the levels are of concern, but suggest that further evaluation of potential human health concerns may be considered. Residential CHHSLs are recommended for use by the California Department of Toxic Substances Control (DTSC) for human health screening evaluation described in the Preliminary Endangerment Assessment (PEA) Guidance Manual.
  - **Preliminary Remediation Goals (PRGs)**: For contaminants that CHHSLs are not developed, the PRGs are used. The PRGs were developed by USEPA Region IX as a risk-based screening tool for evaluating and cleaning up contaminated sites. The Region IX PRGs were developed prior to the CHHSLs and are similar or slightly less stringent. The values are calculated from current human health toxicity values with standard exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that are considered by the Agency to be health protective of human exposures (including sensitive groups), over a lifetime. As with CHHSLs, exceedances do not indicate that the levels present are a human health concern, however, more evaluation may be required.
  - **Soil Screening levels (ESLs):** These screening levels for soils and groundwater were developed by the California Regional Water Quality Control Board, San Francisco Bay Region and are presented in the Interim Final Report, "Screening Criteria for Environmental Concerns at Sites with Contaminated Soil and Groundwater (SFBRWQCB, 2007 – revised May 2008). These screening criteria include ELSs for shallow soils (</- 3m below ground surface (BGS)) and deep soils (>3m BGS), and are further distinguished between sites that are underlain with groundwater that is currently or is a potential drinking water sources and those that are not. These ELSs include criteria for metals, organic compound and petroleum hydrocarbon compounds and constituents. These ESLs are used to screen the sediment samples that contained total petroleum hydrocarbon compounds and constituents.

- **Hazardous Waste Criteria**
  - **Total Threshold Limit Concentration (TTLC) and Soluble Threshold Limit Concentration (STLC)**: TTLC and STLC are used to determine the hazardous waste characterization under California State regulations as outlined in Title 22 of the California Code of Regulations (CCR).Concentrations of contaminants in project soil were compared to TTLC and 10 times the STLC. If concentrations

exceed 10 times the STLC, a Waste Extraction Test (WET) must be performed to estimate the contaminant leachate. If concentrations of contaminants in soil exceed the TTLC or leachate from the WET exceed the STLC, the material is classified as hazardous waste. If a waste is determined to be a hazardous waste, specific regulations and statutes regarding the management, storage, transportation and disposal must be met.

- **Toxicity Characteristic Leaching Procedure (TCLP):** TCLP is the characterization for hazardous waste based on Federal guidelines. TCLP analysis was performed to provide an estimate of the soil contaminant leachate and to determine if this material is classified as hazardous waste or if it is considered suitable for upland placement. Analytes leaching from the soil were compared to USEPA Title 40 Code of Federal Regulations (CFR) Part 261 values (USEPA, 2006).

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APPENDIX B

Additional Result Tables

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TABLE 1
SUMMARY OF GENERAL CHEMISTRY RESULTS IN SOIL SAMPLES

TABLE 1A: IN/NEAR PROPOSED CHANNEL

Analyte	Units	PQL	A-RW-020-D1 (20' –28')	A-RW-020-D2 (16' –19')	A-RW-020-D3 (12'-16')	A-RW-020-C3 (4'-9')	A-HSA018-D2 (16' –19')	A-HSA018-D3 (10' –12')	A-HSA018-D1 (20'-24')	A-HSA018-C3 (4'-8')	B-RW-055-C1 (0' –3.5')	B-RW-055-C2 (4' –8')	B-RW-055-D1 (10' –14')
Salinity	salinity unit	1.0	10.9	8.41	3.63	4.58	4.68	5.30	7.35	4.78	4.66	3.91	5.17
Total Solids	%	1.0	67.5	74.2	70.5	69.1	71.2	70.1	57.0	78.8	83.0	50.9	65.1
pH	pH unit	1.00	7.86	8.01	8.08	7.48	7.97	7.82	7.86	7.80	8.03	8.01	8.05
Ammonia as Nitrogen	µg/dry g	1.00 - 10	35.8	11.0	27.4	31.4	15.3	58.6	35.0	20.1	17.9	8.82	40.0
Total Organic Carbon	µg/dry g	500	8,800	2,700	14,000	9,900	2,300	6,500	28,000	6,600	12,000	1,800	8,600
Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.50 - 5	5.38	3.92	9.26	5.18	1.10	136	8.22	2.78	3.58	<0.50	14.5
Dissolved Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50

TABLE 1B: IN PROPOSED MARSH AND TRANSITION ZONE

Analyte	Units	PQL	A-HSA-016-D1 (10.5'–12')	A-HSA-016-D2 (14'–16')	A-HSA-016-C2 (6' -10.5')	A-HSA-016-C1 (0' –6')	B-RW-043-C1 (0' –3')	B-RW-043-D1 (3' –6')	B-RW-043-D2 (6' –6.5')	B-RW-043-D3 (8'-10')	B-RW-043-D5 (10'-16')
Salinity	salinity unit	1.0	6.10	6.71	6.18	2.03	ND	4.71	5.44	5.92	8.57
Total Solids	%	1.0	71.2	72.8	63.1	83.0	81.4	69.8	67.9	75.0	62.8
pH	pH unit	1.00	8.11	7.88	8.07	7.94	8.39	7.93	8.02	7.96	7.84
Ammonia as Nitrogen	µg/dry g	1.00 - 10	53.6	21.8	40.8	10.8	31.8	41.9	54.2	6.96	47.7
Total Organic Carbon	µg/dry g	500	9,200	6,400	10,000	3,600	5,000	14,000	12,000	1,400	12,000
Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.5 – 5.0	34.4	3.30	13.9	4.88	1.42	5.54	1.46	3.02	4.76
Dissolved Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50

TABLE 1C: UPLAND

Analyte	Units	PQL	A-HSA-067-C1 (0' -6')
Salinity	salinity unit	1.0	8.79
Total Solids	%	1.00	70.2
pH	pH unit	1.00	7.45
Ammonia as Nitrogen	µg/dry g	1.00	19.9
Total Organic Carbon	µg/dry g	500	8,200
Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.50	9.02
Dissolved Sulfides, Acid-Soluble and Acid-Insoluble	µg/dry g	0.50	<0.50

TABLE 2
ANALYTICAL RESULTS FOR BALLONA MARSH SEDIMENTS

Parameter	Units	MDL	ERL[1]	ERM[1]	WSC[2]	BWS-1[3]	BWS-3[3]	BWS-4[3]	BWS-5[3]	BWS-8[3]	BWS-9[3]	BWS-10[3]	BWS-11[3]		BW1[4]	BW4[4]	BW5[4]	BW6[4]	BW7[4]	BW8[4]	BW9[4]	BW1[5]	BW4[5]	BW5[5]	BW6[5]	BW7[5]	BW8[5]	Range[6]	Ave.[7]
Toxicity																													
Mean *Eohaustorius estuarius* survival (relative to control)	%					94.79	98.96	91.67	**64.58**	96.88	**34.38**	**60.42**	**9.38**		96.0	87.0	95.0	88.0	94.0	92.0	82.0							98.6-**9.38**	**79**
Sediment Size and TOC																													
Gravel	%					0	0	0	0	0	0	0	0																
Sand	%					51.2	70.2	79.7	22.8	47.4	37	30.5	47.4		48.1	45.6	12.8	24.9	8.4	63.6	20.7								
Silt	%					41.8	24	16.6	51.5	46.6	51.5	57.9	45.1		40.1	44	56.8	50.4	58.2	22.9	49.2								
Clay	%					7.11	5.98	3.73	25.8	6	11.5	11.6	7.47		11.4	10.4	30.4	24.7	32.4	12.3	29.7								
Median size	microns					66	250	360	13	56	40	28	56																
Mean size	microns					110	470	470	5.9	140	60	55	55																
Total Organic Carbon	%	0.001				0.919	0.777	0.372	0.597	1.15	1.04	0.41	4.64																
Metals																													
Arsenic	mg/kg	0.22	8.2	70	40	6.13	3.7	4.26	**12.4**	**10.3**	**8.45**	5.56	**14.6**		4.6	5.67	**10.84**	**10.55**	**12.25**	5.3	**11.78**	0.05	0.31	0.48	0.5	1.18	0.87	3.7-12.25	**8.43**
Cadmium	mg/kg	0.02	1.2	9.6	0.250	**2.39**	**2.12**	**1.83**	**4.5**	**4.66**	**3.67**	**3.32**	**6.16**		0.49	0.74	**1.66**	0.84	**1.27**	1.2	**1.82**	0.02	0.06	0.12	0.05	0.14	0.1	0.49-**6.16**	**2.44**
Chromium	mg/kg	0.1	81	370	119	29.2	21.9	18	70.2	52.1	35.4	33.4	64.3		38.9	60.7	**89.54**	**82.67**	**97.2**	40.15	**96.45**	0	0	0	0.03	0	0.13	18-**97.2**	55.34
Copper	mg/kg	0.18	34	270	50	**35.3**	30.6	17	**60.8**	**82.9**	**48.8**	**39.3**	**440**		**60**	**50.4**	**76.8**	**50.83**	**84.05**	28.7	**60.12**	0.13	0.04	0.11	0.86	0.13	1.21	17-**440**	**77.71**
Lead	mg/kg	0.15	46.7	218	200	46.6	26.9	20.8	**103**	**92.5**	**62.6**	24	**248**		23.1	**59.6**	**105.4**	**65.57**	**104.9**	**74.05**	**265.4**	2.93	12.53	16.3	16.46	4.03	56.47	20.8-**265.5**	**88.16**
Mercury	mg/kg	4E-04	0.15	0.71	1.18	0.122	0.065	0.041	**0.229**	**0.272**	0.143	0.0976	**0.29**		0.07	0.14	**0.2**	0.13	**0.21**	0.14	**0.19**	0	0	0	0	0	0	0.041-**.272**	**0.16**
Nickel	mg/kg	0.2	20.9	51.6	230	16	13.4	9.2	**30.7**	**27.9**	20.5	**21.7**	**38.5**		17.1	**25.9**	**37.44**	**29.11**	**39.29**	13.1	**31.93**	0.47	0.49	0.85	0.21	0.83	0.89	9.2-**39.29**	**24.78**
Silver	mg/kg	0.02	1	3.7	0.280	**1**	0.43	0.27	**3.77**	**1.54**	**1.85**	0.43	0.46		<0.05	0.61	**2.25**	0.5	**2**	0.63	**1.5**	0	0	0	0	0	0	0.05-**3.77**	**1.15**
Zinc	mg/kg	0.21	150	410	1200	**155**	109	54.9	**190**	**330**	**192**	124	**1770**		130.1	**176**	**238.2**	**172.5**	**304.9**	129.7	**206.8**	2.24	1.99	2.21	2.68	0.78	11.74	54.9-**1770**	**285.54**
Selenium	mg/kg	0.35				0.48	0.56	0.55	<0.35	1.61	<0.35	0.42	0.55		0.36	0.63	3.22	2.15	2.27	1.79	0.78							0.35-3.22	1.02
PAHs																													
Total detectable PAHs	mg/kg		4.022	44.79	6.3	0	0	0	0	0	0	0	1.5		.0308	0.333	0.225	3.25	0.215	0.679	0.281							0-3.25	0.434
Pesticides																													
Total detectable DDT	ug/kg		1.58	46.1	250	**3.6**	**17.1**	0	1.2	**7.3**	**5.6**	1	**9.6**		1.5	**3.1**	1.4	**2.7**	**3.3**	**4.2**	**4.6**							0-**17.1**	**4.41**
Total detectable chlordane	ug/kg		0.5	6	69.2	**4.5**	**51.4**	0	**1.2**	**2.4**	**2.7**	**1.2**	**6.7**		<1	**1.5**	**1.2**	<1	**1.1**	**5.9**	**9.7**							0-**51.4**	**6.03**
Pyrethroids																													
Bifenthrin	ug/kg					ND	ND	ND	ND	ND	ND	ND	34J																
PCBs																													
Total detectable PCBs	ug/kg		22.7	180	600	16	**25**	0	0	0	**36**	0	**24**		<1	4.4	11.8	<1	<1	17.2	**24.4**							0-36	10.8
Mean ERM quotient						0.22	0.80	0.07	0.32	0.32	0.26	0.15	0.84																

MDL = Method Detection Limit is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as defined in 40 CFR Part 136 Appendix B.
Toxicity results in bold = moderately toxic (per Bight criteria)*
Toxicity results in bold = highly toxic (per Bight criteria)*
Chemistry results in bold = exceeds ERL*
Chemistry results in bold = exceeds ERM*
J - Estimated value

FOOTNOTES:
1 Effects Range-Low (E-RL) and Effects Range Medium (E-RM)(Long et al. , 1995)*
2 WSC – Wetland Surface Criteria based on the Sediment Reuse Criteria for Wetland Restoration first developed by the San Francisco Regional Water Quality Control Board (SFBRWQCB)*
3 Pohl, D. & Hartman, C., Weston Solutions, Inc., July 18, 2006. "Summary of Results from Sediment Sampling in Area B – Ballona Marsh." (Technical Memo to PWA)
4 The Ballona Wetlands Ecological Reserve Baseline Assessment Program 2010-2011 Final Report, Santa Monica Bay Restoration Commission, June 2012 – Year 2 (2011) data.
5 The Ballona Wetlands Ecological Reserve Baseline Assessment Program 2010-2011 Final Report, Santa Monica Bay Restoration Commission, June 2012 – Year 1 (2010) data. These results were not used for determining the average and range because the laboratory reports were not presented in the report in order to verify quality control/quality assurance data. These results were also not consistent with the two other sets for data presented in this table for which laboratory reports were available.
6 Range of results is based on the data presented in the Weston memo dated 2006 and the 2011 data presented in the Santa Monica Bay Restoration Commission Report dated June 2012.
7 Average of results is based on the data presented in the Weston memo dated 2006 and the 2011 data presented in the Santa Monica Bay Restoration Commission Report dated June 2012.

*See Appendix A for more detailed discussion of screening criteria

APPENDIX C
Toxicity Evaluation of Ballona Wetlands Sediment Cores

Note: As discussed in Section 3.3.2, the following toxicity identification evaluation (TIE) study was conducted by the Southern California Coastal Water Research Project (SCCWRP) in 2014 (Greenstein and Bay). This TIE study concluded that multiple lines of evidence indicated that nonchemical factors, possibly related to sediment texture, were the most likely cause of toxicity for the sediment. The result suggests that toxicity was impacted by some physical characteristic, such as clay content. The implication is that the physical sediment properties (e.g., texture, clay content) are not suitable for supporting the marine arthropod, *Eohaustorius estuaries* because this species is adapted to inhabiting environments with sandier sediment. Therefore, the bioassay and TIE results indicate that the fine-grained sediment at Ballona is not likely to support *Eohaustorius estuaries* and that the low concentrations of chemical contaminants are not likely to impact benthic communities. Results to date indicate that the materials that are anticipated for use as wetland surface and foundation materials are suitable.

Toxicity Evaluation of Ballona Wetlands Sediment Cores

November 7, 2014
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Southern California Coastal Water Research Project

Introduction

As part of an investigation into the feasibility of restoration of the Ballona Wetlands, subsurface sediment core samples were tested for toxicity to the amphipod *Eohaustorius estuarius* in 2012 (ESA PWA 2013). These core samples were taken at a depth approximate to the projected estuary surface following restoration. These tests indicated low levels of toxicity in a few samples, but the cause of the toxicity could not be determined. These samples contained low concentrations of contaminants and a high percentage of fine sediments, leading to speculation that the toxicity was related to sediment grain size characteristics that were outside of the tolerance range of the toxicity test species.

The goal of the current study was to determine the cause of the sediment toxicity detected in the previous study. Five core locations from the 2012 study were resampled and tested to verify the presence of toxicity. If toxicity was observed, then a sediment toxicity identification evaluation (TIE) would be conducted on one core sample in an effort to identify the cause of the toxicity. The TIE study plan included novel techniques to investigate whether sediment grain size was indeed a causative factor.

Methods

Subsurface sediment samples were collected on December 19 and 20, 2013 by push core using a hollow stem auger rig (Group Delta, Torrance, CA). Samples were taken from three sites in Area A and two sites in Area B (Figure 1). Sediment was collected at depths similar to those taken in 2012 and represented the location of the original grade of the wetland before the addition of fill material. Location and depth records for each sample are shown in Table 1. Multiple cores from each location were composited to provide sufficient sample for testing. Subsamples were stored in precleaned plastic or glass jars for analysis of toxicity/TIEs, contaminants, or grain size characteristics.

The sediment samples were manipulated to make them amenable for toxicity testing. The samples had a very low water content causing them to be difficult to homogenize. A small volume of sea water (20 psu) was slowly mixed into the samples to make them pliable. The volume of water added to the sample from each station was recorded.

The samples were tested for toxicity using the amphipod *Eohaustorius estuarius* and standard USEPA methods (1994) on January 10, 2014. Briefly, 150 ml of homogenized sediment was added to each 1 L glass canning jar, and 800 ml of 20 psu sea water added above the sediment. For each of the five replicate jars, 20 amphipods were added at the start of the test. A sample of fine sandy sediment from amphipod supply site in Oregon was also included in the test as a control. The exposure was conducted at 15°C, under constant light and with gentle aeration. The only departure from standard methods was that the sediment was added to the jars four days prior to the addition of the animals and 50% of the overlying water was changed daily. This change was made because of the unusual nature of the sediments, having come from a buried, terrestrial source, rather than a marine surface sediment normally tested with this organism. The additional time gave the sediments a chance to better equilibrate with the overlying marine water. At the end of the 10 day exposure period the sediment was passed through a 0.5 mm mesh sieve and the surviving amphipods were enumerated.

The TIE experiment was initiated on February 21, 2014, and was conducted on a single sample that was selected based on the results of the initial screening test. The treatments included in the TIE are listed in Table 2. Treatments 1-9 comprise a typical basic TIE analysis for the purposes of characterizing the principal chemical toxicant type present (USEPA 2007). Each of the typical treatments included a corresponding blank treatment in which the TIE manipulation was carried out on control sediment to verify that the treatment itself was not toxic. Numerous additional treatments were included in this experiment to help determine whether toxicity was related to nonchemical factors, especially sediment texture (i.e., particle grain size and stickiness). These additional treatments consisted primarily of adding clean sediment containing various grain size characteristics, ranging from fine sand (control) to a sediment formulated to approximate the grain size distribution of the test sample (texture reference), to the test sample. The purpose of these additional treatments was to separate out the influence of contaminant dilution and grain size variations on sample toxicity. For all additions of clay, a 1:1 by dry weight mixture of two forms of Bentonite (IBEX200, a calcium ion dominated form and HPM20 a sodium ion dominated form, both from Aardvark Clay and Supplies, Santa Ana, CA) were used. The clays were hydrated with deionized water to form a paste before being mixed with the sediment.

Pore water extracted from the test sediment sample was also tested for toxicity. This test eliminated the physical influence of sediment particles on the test organism. Pore water was extracted from the sediment by centrifugation at 3000 x g for 30 minutes. After centrifugation, 10 ml of the pore water was pipetted into each of five 22 ml glass shell vials. Five *E. estuarius* were added to each vial. The animals were exposed to the pore water for 10 days at 15°C, in darkness and without aeration. At the end of the exposure the number of surviving amphipods was enumerated.

Chemical analysis of sediment from TIE test sample was conducted by Physis (Anaheim, CA). Chlorinated pesticides, PCBs, PAHs were measured using EPA Method 8270D, which includes final analysis by Gas Chromatograph with a Mass Spectrometer (GCMS). Trace metals were analyzed by EPA Method 6020 which includes final analysis by Inductively Coupled Plasma – Mass Spectrometry (ICPMS). Total organic carbon and total nitrogen were analyzed by EPA Method 9060.

Physical characteristics of the test sample and selected TIE treatments were also measured. Sediment particle size was measured using EPA Method 2560D on a laser diffraction particle size analyzer. Atterburg limits to measure sediment plasticity were analyzed by Group Delta (Torrance, CA) using ASTM D-4318.

Results

Results of the initial screening of the five stations indicated that all were toxic to varying degrees (Table 3). The survival ranged from 68 to 22% which represented a higher level of toxicity than was observed in 2012 (86 to 69% survival). Stations B-RW-043 and B-RW-055 exhibited the highest toxicity, with 22% survival in each. It was noted during termination of this test that there was a varying degree of difficulty getting the sediments to pass through a 0.5 mm sieve and that the difficulty seemed to match toxicity; the more difficult the screening, the greater the toxicity. This observation indicated that sediment texture might be playing a role in the observed toxicity.

Based on results of the initial testing, sample B-RW-055 (BW55) was selected for the TIE. Results of the TIE experiment are summarized in Table 4. The control was nontoxic (indicating that the test organisms were of good quality) and the BW55 test sample was still highly toxic, with 15% survival (Table 4). Each treatment is referenced by number to Table 2. Generally, the results for each specific treatment (except for blanks) are compared to that for BW55 (treatment 3) for interpretation. Results of the TIE indicated that none of the TIE treatments specific for chemicals (#4, 6, 8) affected toxicity; this indicates that organic chemicals, metals and ammonia are unlikely to be the cause of toxicity. The addition of fine sand to BW55 did reduce toxicity (#10, 11), while addition of a similar amount of a high silt/clay sediment similar to BW55 in grain size characteristics (#15, 16) did not reduce toxicity; these results are evidence sediment texture is a likely cause of BW55 toxicity.

Pore water from BW55 was tested as an additional line of evidence. No significant toxicity was detected in amphipods exposed to BW55 pore water (Table 5). Contact with dissolved chemicals in the pore water is considered to be a primary route of exposure of sediment-dwelling organisms to sediment contamination. Exposing the animals to the pore water alone removes any effects of sediment particle size that may be contributing to effects in the whole sediment test. Since the pore water was nontoxic, a conclusion that physical characteristics not related to chemical contaminants are the likely cause of the whole sediment toxicity is further supported.

The concentrations for all measured chemical analytes in BW55 were quite low (Tables 6-9). The only chlorinated hydrocarbon that was detectable was p,p'-DDT (Table 6). Only two PCB congeners were detected, the concentrations of both being between the method detection limit and the reporting limit (Table 7). Most PAHs were not detected and those that were had concentrations below 10 µg/kg (Table 8). None of the trace metals usually associated with toxicity were present at concentrations considered to be elevated (Table 9).

The chemical constituents were present at concentrations associated with a low probability of toxicity. All concentrations, except for p,p'-DDT, were below the Effects Range-Low (Long et al. 1995) guidelines, representing a low probability of toxicity to amphipods (Tables 6-9). The concentration of p,p'-DDT in this sample is similar to background levels in unimpacted sediments throughout the region, and is also more than 100 times less than the concentration found to cause toxicity to the toxicity test species used in this study (Greenstein et al. 2014). Evaluation of the chemistry data using methods specified in California Sediment Quality Objectives (SQO) guidance results in a classification category for BW55 of Low Exposure for sediment contaminants. The SQO exposure classification includes four categories: Minimal, Low, Moderate, and High. This classification is based on two sediment quality guidelines, the

Chemical Score Index (CSI) and California Logistic Regression Model (CALRM). The individual CSI and CALRM exposure categories were Moderate and Minimal, respectively.

Measurements of the physical properties of samples, representing a range of toxicity, were conducted. The results indicated the percentage of sediment fines (combination of silt and clay) was greater than 80% for both A-HAS-016 and B-RW-055 (Table 10). Each of these samples had a clay content of about 25% which is considerably higher than what is usually encountered in the marine environment in southern California. The Dana Pt. Reference is a typical example of fine grained marine sediments with fines around 75%, but less than 10% being clay. The total organic carbon content of the wetland core samples was in the range typically observed in the marine environment. The plasticity limits indicated the Ballona samples were in the medium plasticity range (PI 15-30).

The grain size analysis of the dilutions of BW55 with control sediment (treatments #11 and 12) did not yield as high a percentage of sand as was expected based on mass balance calculations (Table 10). This is apparently due to a previously undetected analytical issue related to the combination of very fine clay particles and the fine sand in the mixtures. The analysis method has a bias against the fine sand which is normally sieved out from coarse grained samples and analyzed separately from the silts and clays. Treatment number #12 was reanalyzed with a different sieving method and the percentage of sand was much closer to the expected value. There was not sufficient material available for treatment #11 for reanalysis.

Summary and Conclusions

Multiple lines of evidence with the capability to distinguish between chemical and nonchemical causes of toxicity were evaluated in this TIE. Comparison of these lines of evidence supports a conclusion that nonchemical factors possibly related to sediment texture were the most likely cause of toxicity for sediment from station B-RW-055 (Table 11). Three independent lines of evidence indicate that chemical factors were not a cause of toxicity. First, the three treatments that removed common types of contaminants (# 4, 6, and 8) had no effect on toxicity. Second, dilution of BW55 sediment with different types of reference or control sediments had variable effects on toxicity (e.g., #10, 12, and 15). This result suggests that toxicity was impacted by some physical characteristic, such as clay content, that varied among the treatments. Had the toxicity been related to chemical contamination in BW55, a consistent reduction in toxicity would have been observed in each sample having the same degree of dilution by reference or control sediment. The third line of evidence, lack of pore water toxicity, is also consistent with a nonchemical cause.

Measures of the physical properties of the wetland sediment samples were consistent with observations made during the toxicity test that the sediment was sticky and difficult for the test organisms to burrow through. The BW55 sediment had moderate plasticity and high clay content relative to the Dana Pt. Reference sediment. Unexpected values were obtained from the physical analysis of the texture reference TIE treatment (#13). Both the clay content and plasticity index of this sample were similar to that of treatment 2, although it was expected that these parameters would be higher than treatment 2 and similar to BW55. This may have been due to a disconnect between the samples analyzed for the TIE and those analyzed for physical parameters There was not a sufficient amount of this sample to both conduct the TIE and measure particle size and Atterburg limits. A second batch of this mixture was created at a later date for the physical property analyses and may not have been representative of what was used in the TIE.

Direct evidence that sediment characteristics associated with clay content may be a cause of toxicity to *E. estuarius* is provided by the results for TIE treatment 13 (texture reference). This sample was composed of nontoxic natural fine-grained sediment from southern California (74% fines) that had been amended with natural clay to produce the same nominal percentage of clay as BW55. This amended sample was highly toxic, while a blank sample consisting of a similar amount of clay added to sand was nontoxic (# 14). Evidence for a sediment texture-related cause of toxicity is further supported by the results for treatments 10 and 11, where a reduction in percentage of clay in BW55 due to the addition of sandy sediment reduced the toxicity of the sample.

The magnitude of effect and specific aspects of sediment texture affecting *E. estuarius* survival is poorly understood. Previous studies by other researchers (unpublished) have reported either no effect or a much lower level of toxicity associated with additions of similar amounts of clay as used in this study. However, these other studies used different types of clay, did not conduct a detailed analysis of sediment physical characteristics, and may have used different methods to prepare the treatments. Additional research is needed to determine which specific characteristics of Ballona Wetlands sediment are responsible for the sediment toxicity measured in recent investigations, but the TIE and chemical analyses conducted in this study indicate that chemical contamination is not responsible. The more likely explanation is that the physical properties of the sediment in the core samples were not compatible with this particular toxicity test species, whose typical habitat is sandy estuarine sediment. Since this amphipod is not indigenous to the Ballona Creek Estuary and is not a species of special status, this incompatibility should not be a cause for concern.

Table 1. Location and depth of core samples taken from the Ballona Wetlands for toxicity testing.

Station	Latitude	Longitude	Depth (Feet below ground surface)
A-HSA-016	33.9720	-118.4425	8-12
A-HSA-018	33.9731	-118.4391	20-28
A-RW-020	33.9715	-118.4398	20-28
B-RW-043	33.9696	-118.4394	6.5-10
B-RW-055	33.9680	-118.4437	10-16

Figure 1. Map of coring stations within the Ballona Estuary.

Table 2. Sediment toxicity identification evaluation (TIE) treatments used on the Ballona Creek Wetland core sample.

#	Treatment or Sample	Description	Purpose	Interpretation
1	Control	Sandy sediment from amphipod collection site	Verification that the test animals are in good health	Mean survival of the amphipods must be greater than 90% for test to be valid. Results for other samples and blanks are compared to this control.
2	Fine sediment control	Silty sediment from a reference location off of Dana Pt.	Verification that finer grained sediments are not causing toxicity	High amphipod survival indicates minimal effect of fine sediments typical of southern California. Results for some treatments are compared to this treatment.
3	B-RW-055 Baseline	Unmodified test sample	Verification that test sample is still toxic following storage	Survival less than 70% of control indicates that sample is highly toxic and a TIE is feasible.
4	Coconut charcoal	Amendment of test sample with coconut charcoal at 15% (w/w)	Reduces bioavailable concentration of organic contaminants	Decrease in toxicity indicates nonpolar organic compounds as likely cause of toxicity.
5	Coconut charcoal blank	Amendment of control sediment with coconut charcoal at 15% (w/w)	QA sample to test for treatment artifacts	Survival similar to the control indicates the charcoal is not toxic.
6	Cation exchange resin	Amendment of test sample with cation exchange resin at 20% (w/w)	Reduces bioavailable concentration of cationic metals (e.g. copper, cadmium, zinc)	Decrease in toxicity indicates cationic metals as likely cause of toxicity.
7	Cation exchange resin blank	Amendment of control sediment with cation exchange resin at 20% (w/w)	QA sample to test for treatment artifacts	Survival similar to the control indicates the resin is not toxic.
8	Zeolite	Amendment of test sample with zeolite at 20% (w/w)	Reduces bioavailable concentration of ammonia	Decrease in toxicity indicates ammonia as likely cause of toxicity.
9	Zeolite blank	Amendment of control sediment with zeolite at 20% (w/w)	QA sample to test for treatment artifacts	Survival similar to the control indicates the zeolite is not toxic.
10	Dilution with control sediment - 20%	Amendment of test sample with control sediment at 20% (w/w)	Test for physical dilution effect of TIE amendments on sample toxicity. Likely to increase grain size characteristics of sample.	Decrease in toxicity similar to that obtained with chemical-specific treatments (charcoal, resin, and zeolite) indicates that those treatments were likely effective due to nonspecific dilution effects rather than binding of toxic substances. Difference in toxicity relative to other dilution treatments indicates sediment texture as a likely cause.

Table 2. Continued.

#	Treatment or Sample	Description	Purpose	Interpretation
11	Dilution with control sediment – 40%	Amendment of test sample with control sediment at 40% (w/w)	Test for effects of physical dilution and sediment texture change on test sample toxicity.	A reduction in toxicity would indicate toxicity caused by either contaminants in the sample or by sediment texture. A difference in toxicity relative to equivalent dilution by the texture reference indicates sediment texture as a likely cause.
12	Dilution with fine sediment control – 20%	Amendment of test sample with fine sediment control at 20% (w/w)	Test for physical dilution effect of TIE amendments on sample toxicity without substantially changing sediment texture.	Decrease in toxicity similar to that obtained with chemical-specific treatments indicates that those treatments were likely effective due to nonspecific dilution effects rather than binding of toxic substances. Difference in toxicity relative to other dilution treatments indicates sediment texture as a likely cause.
13	Texture reference	Mixture of Dana Pt. sediment and bentonite clay to match silt and clay content Ballona test sample.	Simulate sediment texture characteristics of test sample without presence of chemical toxicity	Increase in toxicity relative to control or fine sediment control indicates sediment texture as a likely cause of toxicity.
14	Texture reference blank – 20%	Amendment of control sediment with the texture reference at 20% (w/w)	QA sample to test for treatment artifacts	Survival similar to control indicates lack of chemical toxicity in treatment.
15	Dilution with texture reference – 20%	Amendment of test sample with texture reference sediment at 20% (w/w)	Test for physical dilution effect of TIE amendments on sample toxicity without changing sediment texture.	Decrease in toxicity similar to that obtained with chemical-specific treatments indicates that those treatments were likely effective due to nonspecific dilution effects rather than binding of toxic substances. Difference in toxicity relative to other dilution treatments indicates sediment texture as a likely cause.
16	Dilution with texture reference – 40%	Amendment of test sample with texture reference at 40% (w/w)	Test for effect of physical dilution without texture change on test sample toxicity	A reduction in toxicity indicates toxicity caused by contaminants. A difference in toxicity relative to equivalent dilution using the control sediment indicates texture as a likely cause.

Table 3. Sediment toxicity results for initial screening of core samples.

Sample	Mean Survival	Standard Deviation	Number of Replicates
Control Sediment	99	2.2	5
B-RW-043	22	8.4	5
B-RW-055	22	13.5	5
A-HAS-016	68	15.2	5
A-HAS-018	51	5.5	5
A-RW-020	28	9.7	5

Table 4. Toxicity results summary for toxicity identification evaluation treatments.

#	Treatment or Sample	Mean Survival (%)	Standard Deviation	Number of Replicates
1	Control Sediment	100	0.0	5
2	Fine Sediment Control	92.5	9.6	4
3	B-RW-055 Baseline	15	12.9	4
4	B-RW-055 Coconut Carbon	17.5	5.0	4
5	Coconut Carbon Blank	62.5	9.6	4
6	B-RW-055 Cation Exchange	12.5	12.6	4
7	Cation Exchange Blank	100	0.0	4
8	B-RW-055 Zeolite	12.5	12.6	4
9	Zeolite Blank	100	0.0	4
10	B-RW-055 Dil. Control 20%	35	5.8	4
11	B-RW-055 Dilution Control 40%	52.5	17.1	4
12	B-RW-055 Dil. Fine Sed. Control	15	5.8	4
13	Texture Reference	45	20.8	4
14	Texture Reference Blank	95	5.8	4
15	B-RW-055 Dil. Texture Reference 20%	27.5	5.0	4
16	B-RW-055 Dil. Texture Reference 40%	17.5	17.1	4

Table 5. Toxicity results summary for pore water.

#	Treatment or Sample	Mean Survival (%)	Standard Deviation	Number of Replicates
17	Control water	96	8.9	5
18	B-RW-055 pore water	88	17.9	5

Table 6. Chlorinated pesticide concentrations in sediment from station B-RW-055.

Analyte	Concentration (µg/kg dry wt)	Method Detection Limit	Reporting Limit	Effects Range Low Threshold
2,4'-DDD	ND	1	5	NA
2,4'-DDE	ND	1	5	NA
2,4'-DDT	ND	1	5	NA
4,4'-DDD	ND	1	5	NA
4,4'-DDE	ND	1	5	NA
4,4'-DDT	2.4	1	5	2.2
Aldrin	ND	1	5	NA
BHC-alpha	ND	1	5	NA
BHC-beta	ND	1	5	NA
BHC-delta	ND	1	5	NA
BHC-gamma	ND	1	5	NA
Chlordane-alpha	ND	1	5	NA
Chlordane-gamma	ND	1	5	NA
cis-Nonachlor	ND	1	5	NA
Dieldrin	ND	1	5	NA
Endosulfan sulfate	ND	1	5	NA
Endosulfan-I	ND	1	5	NA
Endosulfan-II	ND	1	5	NA
Endrin	ND	1	5	NA
Endrin aldehyde	ND	1	5	NA
Endrin ketone	ND	1	5	NA
Heptachlor	ND	1	5	NA
Heptachlor epoxide	ND	1	5	NA
Hexachlorobenzene	ND	1	5	NA
Methoxychlor	ND	1	5	NA
Mirex	ND	1	5	NA
Oxychlordane	ND	1	5	NA
Perthane	ND	5	10	NA
trans-Nonachlor	ND	1	5	NA

ND= Not detected
NA= Not available

Table 7. Polychlorinated biphenyl (PCB) congener concentrations in sediment from station B-RW-055.

Analyte	Concentration (µg/kg dry wt)	Method Detection Limit	Reporting Limit	Effects Range Low Threshold
PCB003	ND	1	5	NA
PCB008	ND	1	5	NA
PCB018	ND	1	5	NA
PCB028	ND	1	5	NA
PCB031	ND	1	5	NA
PCB033	ND	1	5	NA
PCB037	ND	1	5	NA
PCB044	ND	1	5	NA
PCB049	ND	1	5	NA
PCB052	ND	1	5	NA
PCB056(060)	ND	1	5	NA
PCB066	ND	1	5	NA
PCB070	ND	1	5	NA
PCB074	ND	1	5	NA
PCB077	ND	1	5	NA
PCB081	ND	1	5	NA
PCB087	ND	1	5	NA
PCB095	ND	1	5	NA
PCB097	ND	1	5	NA
PCB099	ND	1	5	NA
PCB101	ND	1	5	NA
PCB105	ND	1	5	NA
PCB110	ND	1	5	NA
PCB114	ND	1	5	NA
PCB118	ND	1	5	NA
PCB119	ND	1	5	NA
PCB123	ND	1	5	NA
PCB126	ND	1	5	NA
PCB128	ND	1	5	NA
PCB138	2	1	5	NA
PCB141	ND	1	5	NA
PCB149	ND	1	5	NA
PCB151	ND	1	5	NA
PCB153	1.5	1	5	NA
PCB156	ND	1	5	NA
PCB157	ND	1	5	NA
PCB158	ND	1	5	NA
PCB167	ND	1	5	NA
PCB168+132	ND	1	5	NA
PCB169	ND	1	5	NA

Table 7. Continued.

Analyte	Concentration (µg/kg dry wt)	Method Detection Limit	Reporting Limit	Effects Range Low Threshold
PCB170	ND	1	5	NA
PCB174	ND	1	5	NA
PCB177	ND	1	5	NA
PCB180	ND	1	5	NA
PCB183	ND	1	5	NA
PCB187	ND	1	5	NA
PCB189	ND	1	5	NA
PCB194	ND	1	5	NA
PCB195	ND	1	5	NA
PCB199(200)	ND	1	5	NA
PCB201	ND	1	5	NA
PCB206	ND	1	5	NA
PCB209	ND	1	5	NA
Total PCBs	3.5	1	5	22.7

ND= Not detected
NA= Not available

Table 8. Polynuclear aromatic hydrocarbon concentrations in sediment from station B-RW-055.

Analyte	Concentration (µg/kg dry wt)	Method Detection Limit	Reporting Limit	Effects Range Low Threshold
1-Methylnaphthalene	ND	1	5	NA
1-Methylphenanthrene	4.2	1	5	NA
2,3,5-Trimethylnaphthalene	ND	1	5	NA
2,6-Dimethylnaphthalene	ND	1	5	NA
2-Methylnaphthalene	ND	1	5	70
Acenaphthene	ND	1	5	16
Acenaphthylene	ND	1	5	44
Anthracene	ND	1	5	85.3
Benz[a]anthracene	ND	1	5	261
Benzo[a]pyrene	1.2	1	5	430
Benzo[b]fluoranthene	1.2	1	5	NA
Benzo[e]pyrene	1.2	1	5	NA
Benzo[g,h,i]perylene	ND	1	5	NA
Benzo[k]fluoranthene	1.4	1	5	NA
Biphenyl	ND	1	5	NA
Chrysene	2.1	1	5	384
Dibenz[a,h]anthracene	ND	1	5	63.4
Dibenzothiophene	ND	1	5	NA
Fluoranthene	6.2	1	5	600
Fluorene	1.4	1	5	19
Indeno[1,2,3-c,d]pyrene	ND	1	5	NA
Naphthalene	1	1	5	160
Perylene	ND	1	5	NA
Phenanthrene	6.2	1	5	240
Pyrene	7.8	1	5	665

ND= Not detected
NA= Not available

Table 9. Trace metal concentrations in sediment from station B-RW-055.

Analyte	Concentration (mg/kg dry wt)	Method Detection Limit	Reporting Limit	Effects Range Low Threshold
Arsenic (As)	6.204	0.025	0.05	8.2
Cadmium (Cd)	0.913	0.0025	0.005	1.2
Chromium (Cr)	43.083	0.0025	0.005	81
Copper (Cu)	33.519	0.0025	0.005	34
Lead (Pb)	11.928	0.0025	0.005	46.7
Nickel (Ni)	26.02	0.01	0.02	20.9
Selenium (Se)	0.372	0.025	0.05	NA
Silver (Ag)	0.32	0.01	0.02	1
Tin (Sn)	1.56	0.025	0.05	NA
Zinc (Zn)	84.826	0.025	0.05	150

ND= Not detected
NA= Not available

Table 10. Physical attributes of sediment from Ballona Wetlands and TIE samples.

#	Sample	Sand (%)	Silt (%)	Clay (%)	TOC (%)	Plasticity Index
3	B-RW-055	14.3	61.4	24.7	1.57	26
	A-HAS-016	21.4	59.1	19.3	1.83	20
1	Control Sediment	97.6	1.6	0.5	NA	NA
2	Fine Sediment Control	26.1	66.2	7.8	1.04	11
13	Texture Reference	25.2	62.1	12.4	NA	5
10	B-RW-055 Dilution with Control 20%	18.4	57.7	23.7	NA	NA
11	B-RW-055 Dilution with Control 40%	18.8	55.5	26.3	NA	NA
16	B-RW-055 Dilution with Texture Ref. 40%	15.7	60.6	23.2	NA	23

NA= Not analyzed

Table 11. TIE treatment interpretation summary. Treatment numbers refer to Tables 4 and 5. Definitions for stressor type indications: No = results indicate stressor type not likely to influence sample toxicity; Possible = toxicity result is plausible for stressor type but treatment is not specific for that stressor; Yes = results indicate stressor type has a major influence on sample toxicity; na = treatment not informative for this stressor type.

#	Treatment	Toxicity Change	Stressor Type Indicated: Chemical	Stressor Type Indicated: Texture
4	Trace organics removal	No effect	No	Possible
6	Trace metals removal	No effect	No	Possible
8	Ammonia removal	No effect	No	Possible
10	Dilution with control sediment 20%	Decrease	Possible	Yes[1]
11	Dilution with control sediment 40%	Decrease		
15	Dilution with texture reference 20%	Slight decrease	No	Yes[1]
16	Dilution with texture reference 40%	No effect		
12	Dilution with fine sediment control 20%	No effect	No	Possible[1]
13	Texture reference	Increase	na	Yes
18	Pore water	Non toxic	No	Possible

[1] Conclusion based on comparison among results for all dilution treatment types.

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APPENDIX F6
Water Quality Technical Report

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Ballona Wetlands
Restoration Project

WATER AND SEDIMENT QUALITY TECHNICAL REPORT

Draft – Subject to Revision

September 28, 2015

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Ballona Wetlands Restoration Project Water and Sediment Quality Technical Report

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1. Existing Water and Sediment Quality Conditions

The following discussion presents a summary of the existing water and sediment quality conditions as a basis to assess both potential impacts to the environment from the Ballona Wetlands Restoration Project (Figure 1 [Ballona Wetlands Restoration Project Site]) and potential impacts of the environment to the Project. Alternative 1, which is expected to have the greatest impacts, is assessed for simplicity. This summary of existing conditions is based on available water and sediment data. References to source documents are provided for further detail. The section is organized into two parts. Section 1.1 (Existing Conditions Summary for Impact Assessment from the Project) summarizes existing data applicable to the project site for analysis of potential impacts of the project on the environment during and following restoration construction. Section 1.2 (Existing Conditions Summary for Impact Assessment of the Environment on the Project) focuses on water and sediment quality results that are applicable to the assessment of potential impacts on the project from potential in-flows to the restored wetland areas.

1.1 Existing Conditions Summary for Impact Assessment from the Project

The water and sediment quality data summary presented in this subsection will be used to assess the following questions on potential impacts from the Project on the environment during and following construction of the restoration project:

During Construction

- What are the potential impacts of sediment migration from the Project site during grading activities due to wind borne emissions and construction equipment that can then be carried by stormwater runoff to adjacent water bodies that include Ballona Creek, existing tidal marsh, and Marina del Rey?
- What are the potential impacts of sediment migration from the Project site during construction from disturbed areas that can then be carried by stormwater runoff to adjacent water bodies that include Ballona Creek, existing tidal marsh, and Marina del Rey?
- What are the potential impacts from on-site sediments that are excavated and placed in a permitted marine placement site?

Post Construction

- What is the potential impact of site sediments on water quality and biological resources within the created and existing tidal wetlands and uplands?
- What is the potential impact of site sediments on groundwater below the site?
- What is the potential impact of site sediments on the public that may visit the site?
- Are the requirements of the Ballona Wetland TMDL achieved by the Project?

Ballona Wetlands Restoration Project

Figure 1
Ballona Wetlands Restoration Project Site

1.1.1 West Area B Existing Marsh

Sediment data collected by Weston (2006) and SMBRC (2011) indicate a potential impact from both flows from Ballona Creek and urban runoff on the sediments in West Area B. To assess the sediment samples for potential biological impact due to elevated constituents of concern, the Effects Range – Low (ER-L) and Effects Range-Median (ER-M) values can be used. The ER-Ls and ER-Ms were developed by Long et al. (1995) to evaluate dredged material for ocean disposal. In West Area B, arsenic, cadmium, copper, lead, mercury, nickel, silver, and zinc exceeded the more conservative ER-Ls in 2006 and 2011. In 2006, silver exceeded the ER-M in the most northeastern extent of the channel network. Copper, lead, and zinc exceeded the ER-Ms, as well, in the channel near Culver Boulevard, which indicates that runoff from adjacent residential communities and transportation corridors is likely impacting sediment quality in the marsh.

2006 samples near the SRT gate (Figure 1) show that the sediment is potentially impacted by pesticides, specifically chlordane and DDT, from Ballona Creek; however, 2010 and 2011 samples showed that pesticides were below limits. In 2006 and 2011, metal concentrations near the SRT gate were higher than those observed in Ballona Creek. West Area B may be acting as a sink for these metals due to the limited tidal circulation and flushing.

1.1.2 Proposed Uplands or Off-Site Disposal

The Project proposed to enhance and restore upland habitat around the site primarily using sediment excavated from Area A. Public access is also proposed in upland areas and human health criteria are discussed below in addition to ecological criteria. Sediment samples in Area A showed chemical concentrations below levels that would classify it as hazardous waste per the USEPA Title 40 Code of Federal Regulations Part 261 (USEPA 2006, Appendix A).

Human Health Criteria

Samples taken by Weston in 2008 and in 2012 indicate that all chemicals of concern, including PAHs, PCBs, pesticides, VOCs, TPHg, TPHd, BETX, and metals were below the California Human Health Screening Levels (CHHSL) or Preliminary Remediation Goal (PRG) soil criteria for potential residential land use, with the following exceptions (Weston 2009, Appendix A). Arsenic and iron were measured at ambient concentrations greater than residential CHHSLs and PRGs, but at concentrations consistent with natural marine sediments. Additionally, one sample showed elevated concentrations of PAHs just above the CHHSLs for residential land use, but well below soil criteria for potential commercial or industrial land use.

Ecological Criteria

The criteria (ER-Ls and ER-Ms) developed by Long et al. (1995) are helpful in assessing the potential biological impact of elevated constituents of concern. Another measure of potential ecological impacts is the Beneficial Reuse criteria for wetland restoration, developed by the San Francisco Regional Water Quality Control Board (2000) and refined for use outside of San Francisco Bay by Germano & Associates (2004). The Beneficial Reuse criteria have different values for material that will be used as wetland surface (more conservative) and wetland foundation material (less conservative). The use of these screening criteria for sediments in the Ballona Wetlands is appropriate when used as a tiered approach, including bioassays to determine actual toxic effects to the benthic community.

The 2008 and 2012 sediment samples were compared to the ER-Ls, ER-Ms, and Beneficial Reuse values to determine potential ecological impacts. The results showed that several metals slightly exceeded the ER-L values, including arsenic, cadmium, copper, lead, mercury, nickel, silver, zinc, total DDT, and total chlordane (Appendix A). However, no metals exceeded the corresponding ER-M or wetland surface Beneficial Reuse values, except silver, indicating relatively low concentrations. While silver exceeded the wetland surface Beneficial Reuse value, it was below the wetland foundation value and within the range of concentrations historically found in the existing Area B wetland.

1.1.3 Proposed Wetland Surface

Public access trails and paths would be located only in upland or transitional habitats, so the proposed wetland surface material is only compared to the ecological criteria and not the human health criteria.

In the 2012 investigation, the results of the analytical analysis of samples taken at approximately the proposed depth of the new marsh surface indicate that copper and total DDT in the proposed wetland surface exceeded the ER-L values, but were below the wetland surface criteria. Silver exceeded the ER-L and wetland surface Beneficial Reuse criteria, but was within the range of concentrations found historically in Area B (Appendix A).

A bioassay study was conducted on the samples collected within the anticipated depth of the new marsh surface. Results indicated low to moderate toxicity for one of the marine arthropods, *Eohaustorius estuarius*. These samples contained low concentrations of contaminants and a high percentage of fine sediments, leading to speculation that the toxicity was related to sediment grain size characteristics that were outside of the tolerance range of the toxicity test species. A toxicity identification evaluation (TIE) study, conducted in 2014, concluded that multiple lines of evidence indicated that nonchemical factors, possibly related to sediment texture, were the most likely cause of toxicity for the sediment (Greenstein and Bay 2014).

1.1.4 Proposed Wetland Foundation

Since the proposed wetland foundation material would be buried, it is only compared to the ecological criteria and not the human health criteria.

The 2012 investigation showed that the samples collected from depths that are anticipated to be below the proposed marsh surfaces and serve as wetland foundation material were all below the ER-Ls, with the exception of the silver concentration of one sample. However, the silver exceedance was still below the wetland foundation Beneficial Reuse value. These samples were also tested for toxicity and found to have low to moderate toxicity, but this is likely due to sediment texture as described above in Section 1.1.3 (Proposed Wetland Surface).

1.1.5 Proposed Material in Realigned Channel

Since the proposed material in the realigned channel would be below water, it is only compared to the ecological criteria and not the human health criteria.

The results of the analytical analysis of samples taken at the proposed depth of the realigned channel indicate that concentration of metals, pesticides, PAHs, and PCB are all below the most stringent guidelines including the ER-L values and the wetland surface criteria. These samples were also tested for toxicity and found to have low to moderate toxicity, but this is likely due to sediment texture as described above in Section 1.1.3.

1.2 Existing Conditions Summary for Impact Assessment of the Environment on the Project

The water and sediment quality data summary presented in this subsection will be used to assess the potential impact from the following inflows to the restored areas:

- **Ballona Creek** –The Ballona Creek Watershed covers approximately 130 square miles located in the western portion of the Los Angeles Basin. The watershed drains predominantly urbanized areas with less than 21% open space concentrated in the upper portion of the watershed. The Ballona Creek is defined as the part of the creek upstream of the zone of tidal influence.
- **Ballona Estuary Creek Channel** – The Ballona estuary includes the downstream portion of the creek that is tidally influenced.
- **Marina Del Rey – Fiji Ditch** –As shown in Figure 1, the outfall of Ballona Creek to Santa Monica Bay is separated from the entrance channel to Marina Del Rey by a jetty. The Marina Del Rey entrance channel runs adjacent to Area A. Fiji Ditch is located on the northern border of Area A and extends to Area C as shown in Figure 1. Fiji Ditch is connected to Basin H in Marina del Rey.
- **Freshwater Marsh** – The Freshwater Marsh is located in the eastern portion of Southeast Area B as shown in Figure 1, and receives stormwater runoff flows from the central inlet, which drains the Playa Vista development, and the Jefferson Boulevard inlet. Water is added during the dry weather months to maintain the marsh. The marsh will also receive water from the riparian corridor restoration project that runs between Loyola Marymount University and the Playa Vista development. Water in the Freshwater Marsh flows to either a northern outlet structure, which discharges into Ballona Creek, or over a weir into South Area B during storm events.
- **Urban Runoff and Stormwater** – Urban runoff and stormwater discharge into the wetlands from various locations. Stormwater from the developed area east of Lincoln Boulevard discharges into the Freshwater Marsh. Urban runoff from the residential communities along the bluff to the south discharge into the channel that flows through south Area B under Culver Boulevard and into West Area B as shown in Figure 1. Stormwater along Culver Boulevard and from developed areas of Playa del Rey also flow into West and South Area B.
- **Groundwater** – Potential in-flow of groundwater into Area B is evident by the less salt water tolerant plant species (willows) along the base of the bluff slope along the southern portion of the site. The amount and characteristics of groundwater inflows to the project area has not been fully investigated to quantify or characterize at this time.

Based on the existing and applicable water and sediment quality data summarized in this subsection, the following potential impact questions will be assessed:

- **Ballona Creek Water Quality** – What are the potential impacts of water quality from dry and wet weather flows (including dissolved and solid fraction constituents and sediment) in Ballona Creek on the restoration project, based on existing water and transported sediment quality data, anticipated pollutant reductions required under the TMDLs, and estimated project implementation schedule?

- **Ballona Estuary Creek Channel Sediment Quality** – What are the potential impacts of sediment quality from sediments within the Ballona Estuary Creek Channel on the restoration project based on existing sediment quality data?
- **Marina del Rey – Fiji Ditch** – What are the potential impacts of water quality from tidal flows (including dissolved and solid fraction constituents and sediment) from Marina del Rey on the restoration project based on existing water quality data, anticipated pollutant reductions required under the TMDLs, and estimated project implementation schedule?
- **Freshwater Marsh** – What are the potential impacts of water quality from dry and wet weather flows (including dissolved and solid fraction constituents and sediment) from the Freshwater Marsh on the restoration project based on existing water quality data?
- **Urban Runoff and Stormwater –** What are the potential impacts of water quality from urban runoff and stormwater flows from adjacent urbanized areas and roadways on the restoration project based on existing water quality data and anticipated pollutant reductions from proposed stormwater best management practices (BMPs)?
- **Groundwater** – What are the potential impacts to the restored habitat of the Project due to continued groundwater inputs?

1.2.1 Ballona Creek

Water Quality

Historical and current water quality data indicate that dry weather flows from Ballona Creek exceed water quality objectives for bacteria indicators, metals, and other constituents (Stein and Tiefenthaler 2004, Weston 2005, LARWQCB 2003, 2005, 2007, SMBRC 2011). Storm water flows frequently exceed water quality objectives for bacteria, metals, PAHs, and pesticides in the creek as well. In response to these exceedances, two TMDLs were put into place to address bacteria and metals in the water column. A third, discussed in the Sediment Quality Section below, addressed toxic pollutants in sediment and fish tissue. The 2007 Bacteria TMDL established water quality targets and waste load and load allocations for sources of bacteria within the watershed that are protective of the designated water contact recreation use. The 2008 Metals TMDL was developed to address impairments in the water column in Ballona Creek for copper, lead, selenium, and zinc. The TMDL set numeric targets based on the numeric water quality criteria contained in the California Toxics Rule (CTR). Table 1 presents the implementation schedule for both TMDLs in comparison with the construction schedule for the Ballona Wetlands Restoration. The reductions for all three TMDLs should be achieved by 2021, which corresponds with Phase 1 of Project construction (in Alternative 1).

In 2013, a reconsideration of the Toxics (discussed below) and Metals TMDLs used additional data to update the targets (LARWQCB 2013). Based on more recent selenium data, staff recommended removing selenium from the TMDL, but maintaining monitoring requirements. Additional data on flow rate, hardness, and conversion factors compelled revision of the dry and wet-weather targets, as well as WLAs for metals.

TABLE 1
TMDL IMPLEMENTATION AND PROJECT CONSTRUCTION SCHEDULE

Date	Bacteria TMDL	Toxics TMDL	Metals TMDL	Project Schedule
January 11, 2006		Effective Date		
April 27, 2007	Effective Date			
October 29, 2008			Effective Date	
January 11, 2011			Reconsideration	
January 11, 2012		Reconsideration		
January 11, 2013		25% reduction	25% reduction	
April 27, 2013	Compliance for dry weather achieved			
January 11, 2016		50% reduction	50% reduction	
January 11, 2017		75% reduction	75% reduction	
July 1, 2017 (earliest)				Start Phase 1 Construction
January 11, 2021		Compliance achieved	Compliance achieved	Area A breached (~3.5 yr after start)
April 27, 2021	Compliance for wet weather achieved			
March 2022				Finish Phase 1 Construction
May 2023 (earliest)				Start Phase 2 Construction
January 2025				Finish Phase 2 Construction

Sediment Quality

The Metals TMDL for Ballona Creek (2008 Metals TMDL) was approved by EPA on October 29, 2005, and revised by the LARWQCB on December 5, 2013. The revised TMDL combined this 2008 Metals TMDL for the water column in Ballona Creek (above the tidal prism or above Centinela Channel) with the Ballona Estuary Toxic Pollutant TMDL (2006 Toxics TMDL) for sediment in the channel (within the tidal prism). These were combined because constituents in the water column are carried with suspended sediment in storm flows from the watershed to the estuary, where sediments often settles out at the fresh water and salt water interface. Constituents that include PAHs and pesticides are hydrophobic and will adsorb to sediment particles carried by storm flows. Metals can also be present in the dissolved phase within the water column or adsorbed to sediment particles that may be carried during storm event down to the estuary. The water quality of storm flows from the watershed has direct impacts to the quality of sediments within the estuary. For this reason the two TMDLs have been combined to require both pollutant reductions from waste load allocation of metals (copper, lead, zinc and selenium) within the water column from the watershed, and attainment of protective categories based on the Sediment Quality Objectives. The reductions will reduce the potential for impacts to the Projects as this combined TMDL is implemented and scheduled for completion by 2021. Reductions in constituents in storm flows and dry weather flows from the watershed to meet WLAs and LAs will be monitored by the Permitees to track progress toward these goals. Further discussion of sediment quality within the Ballona Estuary Channel is presented in the following section.

1.2.2 Ballona Estuary Creek Channel

Water Quality

In general the oceanic water quality is better than in Ballona Creek or Marina Del Rey. In Ballona Creek the tidal influence extends up to Centinela Creek and water quality reduces further away from the ocean as a result of less mixing (a function of tide and fresh water flow). As described above, water quality data indicate that flows from Ballona Creek are impacted by bacteria, metals, and pesticides, but the 2007 Bacteria TMDL and the combined Ballona Creek Metals and Ballona Estuary Toxic Pollutant TMDL will require reductions of these constituents by 2021.

Sediment Quality

Historical sediment quality data indicate that sediments within the tidal prism of Ballona Creek are impacted by metals, pesticides, PAHs, and other organic compounds (Stein and Tiefenthaler 2004, LARWQCB 2005). Sediments within the tidal prism of Ballona Creek (identified as the Ballona Estuary in the State Water Board documents) were 303d listed for cadmium, copper, lead, silver, zinc, chlordane, DDT, PCBs, PAHs and toxicity. The Ballona Estuary Toxics Pollutant TMDL (2006 Toxics TMDL) was developed to address impairments to designated beneficial uses due to concentrations of these metals and toxic pollutants in sediment and fish tissue above guidelines within the tidal prism of Ballona Creek. Toxicity testing of sediments within the tidal prism also indicated toxic responses to marine benthic organism. The Ballona Estuary Toxic Pollutant TMDL set numeric sediment targets based on effects range-low (ER-Ls) values, which are sediment quality guidelines compiled by the National Oceanic and Atmospheric Administration.

Recent monitoring of the sediments in Ballona Channel within the tidal prism indicate toxicity of sediments to marine benthic organisms continues to be observed, but the contribution of DDT, PCBs and PAHs to the sediment toxicity was not significant. While DDT, PCBs and PAHs were not found to be contributors to toxicity, concentrations of these toxic pollutant and metals were detected above 2006 Toxics TMDL targets. Metals in sediments were responsible for some toxicity to sea urchins. The results of toxicity identification evaluation testing (TIE) indicated that synthetic pyrethroid pesticides were the major contributor to toxicity in estuary sediments.

As discussed above, the 2006 Toxics TMDL (Ballona Estuary) was revised and combined with the 2008 Metals TMDL for Ballona Creek in 2013. The LARWQCB staff recommended removing the DDT, PCBs, and chlordane targets, WLAs, and LAs from the TMDL based on this recent sediment quality monitoring. PAHs targets, WLAs, and LAs were also recommended for removal from the TMDL, but monitoring requirements for PAHs were maintained. The sediment targets, WLAs, and LAs for the 303d listed metals and DDT were updated based on the current sediment quality data.

Reductions in toxic pollutants in sediment within the tidal prism of the Ballona Creek will be monitored by the Permitees and will include chemical, toxicity and benthic assessments that will be used to compare with the Sediment Quality Objectives (SQO) required under the State’s Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality (EB&E Plan Part 1) adopted in 2009. The EB&E Plan Part 1 requires this multiple line of evidence or “triad” approach to determining the protection of benthic communities. The revised 2005 Toxics TMDL requires that the results of the SQO analysis of sediments in the Ballona Estuary demonstrate the attainment of the protective SQO categories of “Unimpacted,” or “Likely unimpacted.” The revised 2006 Toxics TMDLs also requires monitoring of fish tissue to protect human health beneficial uses as also required under the EB&E Plan Part 1. The revised TMDL requires attainment of target fish tissue concentrations for chlordane, total DDT, and total PCBs. The revised now combined Ballona Estuary Toxic Pollutant and Ballona Creek Metals TMDL (revised December 2103)requires attainment of protective SQOs and toxic pollutant concentration targets in the sediment within the tidal prism by 2021. Fish tissue targets for toxic pollutants are also to be attained by this date. WLAs for chlordane, DDT and PCBs in stormwater flows from the watershed have been revised and included in the combined 2006 Toxics and 2008 Metals TMDL. WLAs for metals in dry weather and stormwater from the watershed have also been established in the combined TMDL. Therefore, the combined TMDL addresses both metals and toxic pollutant loading reductions from the watershed in the water column of Ballona Creek (non-tidal) to reduce impacts to sediment within the tidal prism of Ballona Creek, and the attainment of protective targets for sediment and fish tissue in the Ballona Estuary.

1.2.3 Marina del Rey – Fiji Ditch

Water Quality

Like Ballona Creek, Marina del Rey also exceeds the water quality objectives for bacteria indicators, metals, and other constituents (ABC 2004). However, the magnitude and frequency of these exceedances are lower than in Ballona Creek. The main channel of Marina del Rey has better water quality than the back basins due to greater circulation, proximity to the ocean, and less direct input from urban runoff. During high discharges from Ballona Creek, flushing of the marina is inhibited, leading to an accumulation of chemicals in marina waters (Moffatt and Nichol 1994). Additionally, Ballona Creek is an important contributor of chemicals to the marina (Moffatt and Nichol 1994, Soule et al. 1996, ABC 2001).

Fiji Ditch is connected to Basin H in Marina del Rey, which has better water quality than the back basins due to its proximity to the ocean and tidal flushing. However, water samples collected by SMBRC (2011) indicate bacteria input from Marina del Rey to Fiji Ditch.

Sediment Quality

Marina del Rey has impacted sediments in the main channel, where vessels may be a major contributor of contaminants, and in several of the back basins, where water movement is low and fine sediments, which are more likely to have high levels of chemicals associated with them, settle (Moffatt and Nichol 1998, ABC 2001). The sources of the impacted sediments may include the Ballona estuary, resuspension of coastal sediments during storms, storm water discharges directly into Marina del Rey, and human activities within the Marina (Moffatt and Nichol 1998, ABC 2001).

1.2.4 The Freshwater Marsh

Water and sediment quality monitoring data collected by the Center for Natural Lands Management and Geosyntec indicate that the Freshwater Marsh is functioning as a biological system (2003, 2005). Nutrients, such as nitrates, are within ranges expected of natural wetlands and metals are low in concentration and below the Acute and Chronic Freshwater Toxicity Values in the California Toxics Rule. No pesticides have been detected. Across all parameters, water quality and sediment quality data do not show any trends of accumulation or build-up that would signal the need for sediment removal, or pose a threat to aquatic life.

1.2.5 Urban Runoff and Stormwater

Water Quality

Results of the analysis of stormwater samples entering the Freshwater Marsh from Jefferson Boulevard indicate the presence of constituents common to urban runoff, including metals, bacteriological indicators, and nutrients (Center for Natural Lands Management and Geosyntec 2003, 2005). Similar characteristics can be expected from runoff entering the tidal marsh from surrounding urbanized areas.

Sediment Quality

Suspended sediment and organic matter in urban runoff attract and provide the mechanism to transport constituents such as heavy metals (copper, lead, zinc), bacteria, pesticides, PAHs, and other organic compounds to receiving waters. These sediments then settle out as velocity decreases when storm flows meet tidal waters or enter into the wetlands. Sediment data in the existing Area B Marsh (see Section 1.1.1 [West Area B Existing Marsh]) indicate that runoff from adjacent residential communities and transportation corridors (Culver Boulevard) is impacting sediment quality in the marsh (Weston 2006).

1.2.6 Groundwater

Although the historic level of groundwater at the Ballona Wetlands was high, today it is much lower. Straw (1987) described a confined aquifer with artesian pressure under Area B. The groundwater is strongly controlled by the adjacent uplands, which act as recharge areas for the confined aquifers, and by Ballona Creek and the coast which are discharge areas. The water table, therefore, slopes from the Del Rey Bluffs towards Ballona Creek. The inflow of groundwater into Area B is indicated by the presence of willows (generally salt water intolerant) along the base of the bluff slope. However, the amount and characteristics of groundwater inflows to the project area has not been fully investigated to quantify or characterize at this time.

2. Potential Impacts from the Project

The water and sediment quality data summary presented in Section 1 (Existing Water and Sediment Quality Conditions) provides the basis to assess the potential impacts from the Project on the environment during and following construction of the restoration project. The assessment of these potential impacts is presented as responses to the specific assessment questions first listed in Section 1 and presented below. The assessment questions related to Project construction are first discussed followed by the assessment of potential impacts following restoration completion. Assessment questions that are associated with similar sources and issues are addressed under a combined response. The discussion following these related assessment questions include both identification of potential impacts and proposed project measures that address them. Where additional measures are needed to address the potential impacts for post construction operation and maintenance, the discussion references Section 4 (Adaptive Management and Monitoring).

During Construction

The following assessment discussion addresses the following related questions:

- ***Would the project violate any water quality standards or waste discharge requirements?***
- ***What are the potential impacts of sediment migration from the Project site during grading activities due to wind borne emissions and construction equipment that can then be carried by stormwater runoff to adjacent water bodies that include Ballona Creek, existing tidal marsh, and Marina del Rey?***
- ***What are the potential impacts of sediment migration from the Project site during construction from disturbed areas that can then be carried by stormwater runoff to adjacent water bodies that include Ballona Creek, existing tidal marsh, and Marina del Rey?***

There is a potential for violation of water quality standards or waste discharge requirements during construction from the migration of sediments and soils during excavation, grading and placement activities into receiving waters through dust emissions, construction equipment and stormwater runoff or direct discharge into receiving waters in the absence of required best management practices (BMPs). These measures include erosion and sediment controls, dust controls, off-site sediment migration from construction equipment controls, and stormwater pollution BMPs required under the 401 and General Construction Permits to prevent impacts to receiving waters from sediment migration and direct discharges.

During restoration activities management measures will be implemented to address potential violation of water quality standards or waste discharge requirements under the 401 Permit and General Construction Permit. Monitoring of the effectiveness of these measures to address these permit requirements will also be conducted. Both the protective measures and monitoring are defined in the Preliminary Stormwater Management Plan for the Ballona Restoration Project (SMP) (Psomas 2015).

Water quality standards will be protected with the implementation of erosion and sediment control, stormwater management BMPs, off-site sediment transport by vehicles, and dust control measures that will be implemented in accordance with the Final SMP prepared for the 401 Permit. The Final SMP will be prepared in accordance with the State-wide General Construction Permit that requires implementation of BMPs to control and manage on-site discharges that could impact receiving waters. The General Construction Permit has established water quality standards for discharges and receiving water that may be impacted by construction activities. The Final SMP will outline the type and performance requirements of the proposed BMPs that will be implemented during construction to meet the permit requirements.

The Final SMP will also require monitoring of receiving waters during construction to verify that grading activities and other construction activities are not resulting in the impact of the beneficial uses of adjacent receiving waters. This monitoring includes measurements of turbidity down-current (may vary due to tide cycles) of construction activities that disturb, excavate or place soils and sediments. BMPs for these activities in areas not subject to tidal waters include erosion control rolls, check dams, stabilized construction entrances, and stormwater capture and retention basins. Stabilization of disturbed areas to control erosion also includes temporary vegetative, application of binder material or placement of mulch. These types of BMPs and disturbed soil stabilization will be defined in the Final SMP. Soil and sediment disturbance within direct contact with tidal waters will be avoided to the extent feasible through the construction sequencing of the work in the existing creek channel. Where this work occurs in direct contact with tidal waters, control measures such as sediment curtains, minimal disturbance and continuous construction monitoring will be implemented in accordance with the construction phase permits.

The following assessment discussion addresses the following related question:

- **What are the potential impacts from on-site sediments that are excavated and placed in a permitted marine placement site?**

Sediments excavated from Area A and Area B to establish final restoration grading will be used for beneficial use on-site to the extent feasible. On-site sediment that is not used for on-site beneficial use may be designated for alternative placement depending on final cut and fill balance quantities. Previous and recent investigations provide geotechnical, chemical and toxicity testing results for assessment as summarized above. The testing results to date do not preclude this placement option. A presentation of the sediment testing results from samples collected from Area A and Area B that may be placed in an approved marine placement site was given to the Southern California Dredge Material Management Team (DMMT) on January 28, 2015. The DMMT includes the USACE Los Angeles District and the Los Angeles Regional Water Quality Control Board. The presentation included the results of the Preliminary Geotechnical Investigation (Weston 2009) and the Sediment Quality Study (ESA 2014) that is detailed in the Sediment Investigation Report (ESA 2015, May). The results indicate no toxic response to three marine species due to any constituents detected in the sediment samples collected from both Area A and Area B. The DMMT recommended further testing of the sediments as part of the final permitting for off-site disposal in accordance with the USACE guidelines. These guidelines require additional sample testing that includes bioaccumulation studies. Based on the current set of results, potential impacts from placement of on-site sediment at a permitted site are not anticipated.

Post Construction

The following assessment discussion addresses the following related question:

- **What is the potential impact of site sediments on water quality and biological resources within the created and existing tidal wetlands and uplands?**

Previous and recent sediment quality investigations provide geotechnical, chemical, and toxicity testing results on the potential impact of the use of on-site sediments on water quality and biological resources. Results from the Preliminary Geotechnical Investigation (Weston 2009) and the Sediment Quality Study (ESA 2014) are summarized above and more detailed discussion presented in the Sediment Quality Investigation Report (ESA 2015, May). Samples were collected throughout Area A and Area B at various depths to represent materials that would be used for site grading for wetlands and upland habitats and sediments that would be re-exposed for channels, marsh and upland habitat. Geotechnical and chemical testing were performed on these representative samples. The results of the chemistry analysis indicated concentrations of several metals and legacy pesticides were above the most conservative effects range low (ERL), but none were above the effects range –medium (ERM). Comparison of these concentrations to Beneficial Reuse criteria for wetland restoration, developed by the San Francisco Regional Water Quality Control Board (2000) and refined for use outside of San Francisco Bay by Germano & Associates (2004) for use as wetland surface (more conservative) and wetland foundation material (less conservative), indicate only silver concentrations in limited samples were above the criteria for wetland surfaces and none above for wetland foundation. In addition, toxicity and toxicity investigation evaluation (TIE) testing indicated no toxic response from three marine species due to constituents (metals or pesticides) detected in on-site sediment samples. These results indicate no anticipated impact from site sediments used for wetland surface or foundation on water quality and the biological resources.

The result of the sediment quality analysis summarized in the Sediment Quality Investigation Report (ESA 2015, May) of the analytical analysis of samples taken within the depths that will be excavated and used for predominantly upland placement, indicate the concentration of silver and total DDT are above the most stringent ER-L guidelines and similar TMDL goals in two of nine and three of nine samples, respectively. No bioassay testing was performed on this material. As material use for uplands, the biological resources will be terrestrial and not wetland/marine species that have a greater exposure risk from constituents that can migrate through interstitial water and the sediment/water interface. Based on the results of toxicity and TIE testing of on-site sediments with similar metals and pesticides concentrations for use in more restrictive tidal wetlands, potential impact on water quality and biological resources from these sediment used for upland habitat is not likely. Migration of these sediments to receiving water from stormwater runoff will be addressed through post-construction erosion and sediment controls. Upland areas will be stabilized with established native vegetation to minimize erosion during storm events and minimize migration of on-site soils/sediments that may impact adjacent receiving waters.

The following assessment discussion addresses the following related question:

- **What is the potential impact of site sediments on groundwater below the site?**

Although there were multiple detections of TPH as diesel, TPH as Heavy Hydrocarbons, and Total Recoverable Petroleum Hydrocarbons, none of the concentrations were above the residential soil screening criteria for surface or deep soils for the protection of groundwater (Screening Criteria for Environmental Concerns at Sites with Contaminated Soils and Groundwater – SFBRWQCB, 2007 and revised May 2008). Residual concentrations of petroleum products were anticipated in soils within Area A and Area B based on the historical uses of the property which was used for oil and gas extraction. Gas production wells remain active on the site. The soils in the areas around the existing gas wells were inspected and only minor surface staining was observed and did not extend below the surface of the soil (area less than 1 foot squared and only in three to four places). Shallow 10-foot boreholes were advanced around the existing well heads, but due to the lack of evidence of sediment impacts, no sampling was collected for analysis. Other constituents that were detected in on-site are less mobile metals and pesticides. All samples were screened in the field using an organic vapor head space analysis. Samples that indicated reading above background were selected for TPH analysis. These analyses reflect the historical and current industrial uses of the site and address potential contamination from these activities. Based on these results, impact to groundwater below the site from existing soils is not likely.

Furthermore, the groundwater elevations below the site correspond to the tidally influenced creek elevations and therefore are also likely tidally influenced. It is not likely the sites groundwater will be used for direct potable use due to the tidal connection and salt water intrusion.

The following assessment discussion addresses the following related question:

- **What is the potential impact of site sediments on the public that may visit the site?**

The results of the analytical analysis, compared to residential California Human Health Screening Levels (CHHSL) indicated arsenic concentrations are above these criteria in all samples that were collected and analyzed in the Sediment Quality Stud. Iron also exceeded the CHHSL in many samples. As reported in the Sediment Quality Investigation Report (ESA 2015, May), these concentrations are characteristic of marine sediments. One sample out of twenty samples from the Preliminary Sediment Investigation (2008) had concentrations of the PAH benzo(a)pyrene above the residential criteria. As residential criteria, these thresholds are more conservative to actual site usage. Potential impact to visitors at the site is only possible in areas of high public use and access where direct exposure to on-site sediments at the surface is possible. As most of the site will be restricted to public access as a wetland preserve, areas of potential impact are very limited. Measures to fully address potential impact due to direct exposure of site sediments in these limited areas of high public access may include covering on-site sediments in these higher public access areas with a 6- to 8-inch layer (loose thickness) of clean soil, top soil or mulch, and restrict activities that would disturbed this cover and expose these sediments.

The following assessment discussion addresses the following related question:

- **Are the requirements of the Ballona Wetland TMDL achieved by the Project?**

The TMDL for Sediment and Invasive Exotic Vegetation for the Ballona Creek Wetlands (US EPA, March 2012) establishing a load allocations for legacy sediment removal for Area A, Area B, and Area C. The Ballona Creek Wetlands TMDL also includes alternative load allocations for sediment based on the restoration of historical marsh habitats. Table 2 (
Ballona Creek Wetlands TMDL Waste Load Allocations and
Estimated Sediment Removal Quantities) presents the TMDL load allocations for sediment and anticipated sediment removal for the three alternatives for the Project. As summarized in Table 2, the proposed sediment removal quantities for the three alternatives do not reach the load allocations under the TMDL. However, the TMDL allows for the use of an alternative load allocation based on the acres of historical salt marsh habitats restored.

TABLE 2
BALLONA CREEK WETLANDS TMDL WASTE LOAD ALLOCATIONS AND ESTIMATED SEDIMENT REMOVAL QUANTITIES

	TMDL Load Allocation – Sediment Removal(cy)	Alt 1 – Estimated Sediment Removal (cy)	Alt 2 – Estimated Sediment Removal (cy)	Alt 3 – Estimated Sediment Removal (cy)
Area A	2,100,000	1,730,000	1,730,000	1,420,000
Area B	700,000	310,000	310,000	-
Area C	300,000	-	-	-

Table 3 (
Alternative Load Allocations for Ballona Wetland TMDL and
Estimated Project Habitat Acreage) provides a summary of the TMDL alternative load allocations based on attainment of beneficial uses for Ballona Creek Wetlands through habitat restoration. These alternative load allocations may supersede the sediment load allocations in Table 1, if the proposal to use these alternative allocations is submitted to USEPA and the Los Angeles Regional Water Quality Control Board, and approved by the Executive Officer of the Regional Board with no objections from USEPA. As summarized in Table 3, the alternative load allocations under the TMDL for acreage of specific habitat types based on the lesser of historical elevation ranges in Ballona Creek Wetlands and similar marsh-tidal flat dominant wetland

systems in Southern California are above and below the TMDL load allocation. As both sediment removal and tidal wetland habitats are achieved under the Project, but not in accordance with the TMDL load allocations, a proposal to use alternative load allocation for the Project is anticipated for submittal to EPA and the Regional Board.

TABLE 3
ALTERNATIVE LOAD ALLOCATIONS FOR BALLONA WETLAND TMDL AND ESTIMATED PROJECT HABITAT ACREAGE

Elevation Range (ft NAVD)	TMDL Load Allocation (ac)	Alt 1 habitats (ac)	Alt 2 habitats (ac)	Alt 3 habitats (ac)	Assumptions
-3 to -0.2 (subtidal)	22	62.97	63.14	62.53	Subtidal
-0.2 to 3.6 (intertidal)	87	19.96	13.74	2.81	Mudflat and low marsh
3.6 to 9.6 (vegetated wetland)	346	195.29	186.64	85.28	Mid and high marsh, transition zone, and muted-tidal
6.3 to 9.6 (salt flat)	5	26.25	26.69	22.81	Salt Pan

3. Potential Impacts on the Project

The following discussion focuses on the potential impacts from water and sediment quality originated not from the site, but from upstream Ballona Creek and other inputs to the Project as listed in Section 1. Based on the existing and applicable water and sediment quality data summarized in Section 1, a set of potential impact questions were developed for each of the following inputs to the Project that may impact the Project:

- Upstream Ballona Creek Water
- Existing Ballona Estuary Creek Channel Sediment
- Marina del Rey – Tidal Flow into Fiji Ditch
- Discharges from the Freshwater Marsh
- Urban Runoff and Stormwater from Adjacent Properties to the Project
- Groundwater Seepage from Adjacent Properties to the Project

The water and sediment quality data summary presented in Section 1 provides the basis to assess the potential impacts from Ballona Creek and adjacent properties on the Project. The assessment of these potential impacts is presented as responses to the specific assessment questions for the listed inputs presented below. The discussion following these related assessment questions include both identification of potential impacts to the Project and proposed Project design and implementation measures to minimize these impacts. Where additional measures are needed to address the potential impacts to the Project for post construction operation and maintenance, the discussion references Section 4.

3.1 Impacts from Ballona Creek

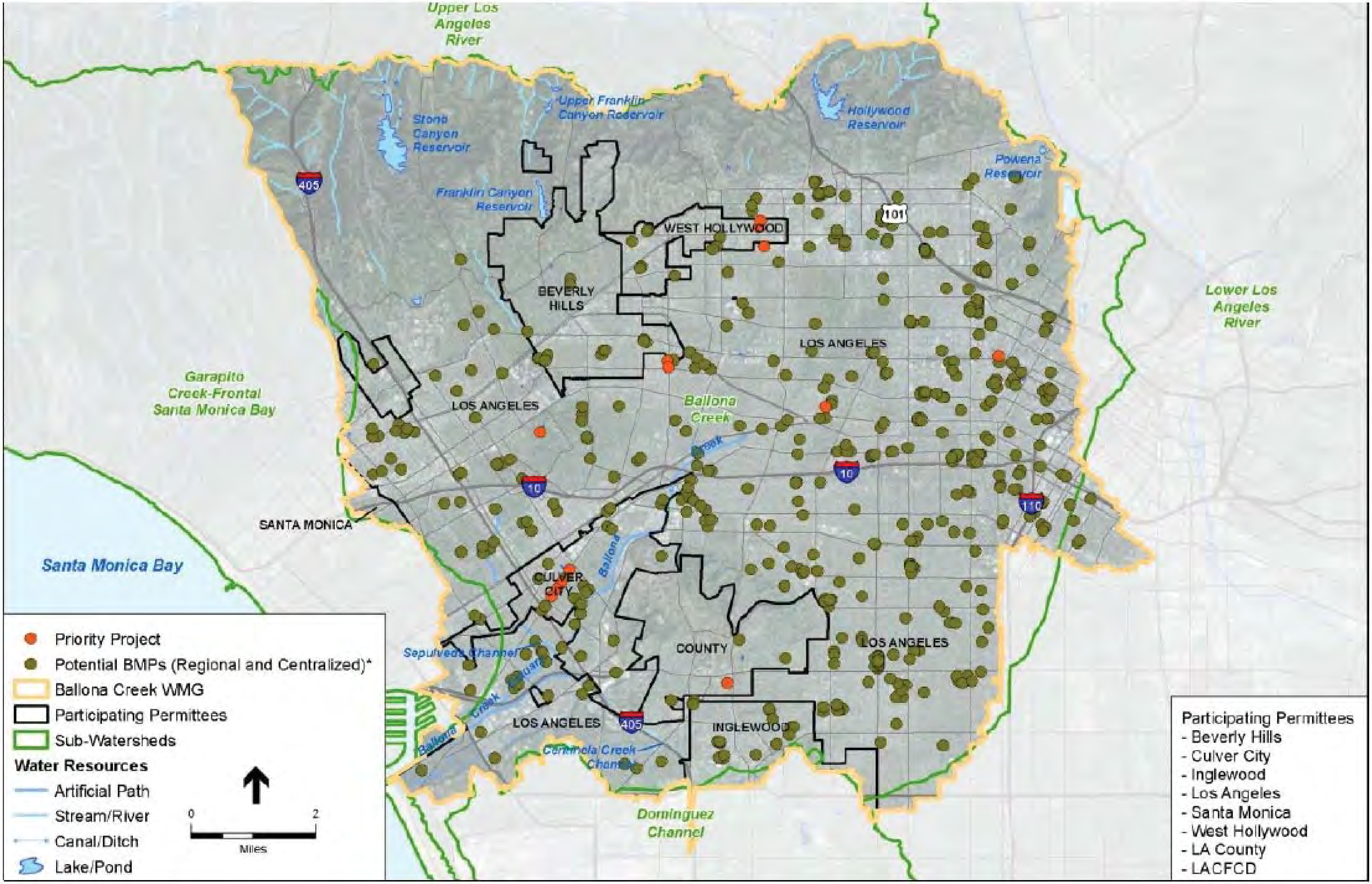
Based on the existing and applicable water and sediment quality data summarized in Section 1, the following potential impact questions will be assessed:

- **Ballona Creek Water Quality – What are the potential impacts of water quality from dry and wet weather flows (including dissolved and solid fraction constituents and sediment) in Ballona Creek on the restoration project, based on existing water and transported sediment quality data, anticipated pollutant reductions required under the TMDLs, and estimated project implementation schedule?**

As summarized in Section 1 under the water quality for Ballona Creek (Section 1.2.1 [Ballona Creek]), historical and current water quality data indicate that dry weather flows from Ballona Creek exceed water quality objectives for bacteria indicators, metals, and other constituents (Stein and Tiefenthaler 2004, Weston 2005, LARWQCB 2003, 2005, 2007). Storm water flows frequently exceed water quality objectives for bacteria, metals, PAHs, and pesticides in the creek as well. TMDLs for bacteria and metals in the water column and metals and toxics in sediment for Ballona Creek have been developed. Waste load allocations and implementation timelines to meet these goals are defined in these TMDLs. Waste load allocations are the allowable amount of constituents that may be discharged to receiving waters, such as Ballona Creek, that will not result in impairment of designated beneficial uses often based on water quality objectives and defined as receiving water limitations. The Los Angeles Regional Water Quality Control Board has incorporated these TMDL waste load allocations and timelines into the reissued municipal separate storm sewer system (MS4) permit. The MS4 Permit requires municipalities and agencies that discharge stormwater and non-storm runoff from an MS4 to Ballona Creek to reduce pollutant concentrations and loading to achieve these waste load allocations and meet the receiving water limitations to restore and protect the designated beneficial uses of Ballona Creek. Compliance with the MS4 permit is an enforceable action subject to fines under the Clean Water Act and California Porter Cologne legislation. The current reissued MS4 permit allows permittees to meet compliance with receiving water limitations through the implementation of the Enhanced Watershed Management Plan (EWMP).

EWMPs vary for each watershed, but generally provide the opportunity for Permittees to customize their stormwater programs to achieve compliance with applicable receiving water limitations (RWLs) and water-quality-based effluent limits (WQBELs) in accordance with the MS4 Permit through implementation of stormwater best management practices (BMPs) or watershed control measures. BMPs vary in function and type, with each BMP providing unique design characteristics and benefits from implementation. The overarching goal of BMPs in the EWMP is to reduce the impact of stormwater and non-stormwater on receiving water quality and address the water quality priorities as defined by the MS4 Permit. The development of each EWMP involves the evaluation and selection of multiple BMP types, including nonstructural (institutional) and distributed, centralized, and regional structural watershed control measures, that will be implemented to meet compliance goals and strategies under the 2012 MS4 Permit.

An EWMP has been developed for Ballona Creek with specific prioritized BMPs to be implemented within the timelines needed to achieve the RWLs and WQBELs. Figure 2 (Location of Priority and Planned BMPs for Ballona Creek Watershed) presents the preliminary location and type of BMPs that are planned throughout the Ballona Creek Watershed to meet the water quality goals. Figure 2 demonstrates the watershed-wide efforts that are proposed to reduce pollutant loading to Ballona Creek that will have benefits to the Restoration Project through improved water quality entering the wetland.



* Potential Distributed BMP not shown - predominantly located in urbanized areas

Ballona Wetlands Restoration Project

Figure 2
Location of Priority and Planned BMPs for Ballona Creek Watershed

Priority and planned structural BMPs to reduce the impact of stormwater and non-stormwater on receiving water quality, include the following types:

- **Distributed Structural BMPs** – Treat runoff close to the source and typically implemented at a single- or few-parcel level (e.g., facilities typically serving a contributing area less than one acre). Because of their nature (intended to treat runoff at the parcel-scale), distributed BMPs are most likely to be implemented in high-density urban, commercial, industrial, and transportation areas, where they will either replace or improve upon existing stormwater infrastructure. These types of BMPs are generally "retrofit" type projects that replace existing impervious surfaces with pervious surfaces such as bioinfiltration cells, bioswales, porous pavement, and filter strips that tie into existing stormwater management systems as part of the MS4. These projects may also augment the existing MS4 with additional inlet screens, filter media systems, sediment removal systems, and diversions to sanitary sewer lines.
- **Centralized Structural BMPs** – Centralized structural BMPs use similar elements to the low impact development (LID), infiltration and biofiltration type BMP used in distributed structural BMPs, but collect, store, treat and filter stormwater from multiple parcels and much larger drainage areas. Centralized BMPs also include diversion and treatment type BMPs that use similar technologies for these types of BMPs under distributed BMPs, but can be implemented on a much larger scale collecting, diverting, and treating urban runoff (dry-weather flows) or limited stormwater flows from multiple parcels and large drainage areas. Therefore, centralized structural BMPs require greater footprints for construction and implementation, but provide a greater potential for water quality improvement through the filtering, treatment and/or infiltration of greater volume and rates of stormwater and urban runoff. Finally, centralized BMPs include two unique BMP types, treatment wetlands, and stream/creek restoration projects. Unlike the other structural BMP types described, these BMPs use natural systems to filter and clean the water. Treatment wetlands are typically off-line treatment systems that are not in the receiving waters, but may have habitat benefits through the establishment of more native plants and ecosystems. Creek, river, and estuary restoration projects provide a unique opportunity to restore natural cleansing processes, reestablish habitats, and address impacts from hydromodification and urban runoff.
- **Regional Structural BMPs** – Centralized BMPs that include storage and infiltration or storage and use have similar functions and construction methods to regional BMPs using the same stormwater management elements. However, regional BMPs have the distinct requirement per the Permit to retain on-site the 85th percentile 24-hour storm event for the drainage area served by the BMP (i.e., in the Los Angeles area, the 85th percentile storm is around 0.75 inch of rain in a 24-hour period), which are meant to retain the 85th percentile storm over 24 hours from a contributing area. Generally, the 85^{th} percentile storm is approximately 0.75 inch over 24 hours

The implementation of distributed, centralized, and regional BMPs within the Ballona Creek Watershed will begin with the priority BMPs that have undergone a greater level of site evaluation, design, and permitting. The planned BMPs will be implemented based on further site assessment and planning. Compliance with the MS4 Permit requires implementation of the number and pollutant removal capacity of BMPs that is needed to meet the RWL and WQBELs within the required timelines of the current TMDLs. As presented in Section 1.2.1, the compliance data for meeting these water quality goals and objective under the metals and toxics TMDLs is 2021. The anticipated schedule for the Project includes breaching the levies to allow

Ballona Creek to enter Area A in 2021 – the same time as the TMDL timeline to meet the water quality goals. Phase 2 of the Project will not be completed until 2025.

Based on the historical water quality data for Ballona Creek, there is a potential for impact to the Project from metals, pesticides and PAH concentrations that are above the water quality objectives. However, the concentration and loading of these constituents from the watershed will be reduced to comply with the re-issued MS4 Permit and EWMP that includes the attainment of water quality goals that meet the RWL and WQBELs within a timeline that proceeds the completion of the Project. Progress toward meeting these water quality goals has been challenging in the past due to the resources needed to implement BMPs on the scale and magnitude needed as presented in the EWMP. As compliance is now directly linked to progress in implementing the EWMP, greater progress in meeting the pollutant reduction goals is anticipated over the next 5 to 10 years. The potential for impacts to the Project from Ballona Creek will therefore be significantly reduced with the implementation of the EWMP given that attainment of the goals are achieved with the current timelines that correspond to the construction of the initial phase of the Project. ***Implementation of Phase 1 of the Project (i.e., breaching and connecting restored wetland areas to Ballona Creek) is therefore recommended to be completed on the same schedule or after successful implementation of the EWMP.***

Recent water quality and sediment toxicity testing (SCCRWP, 2014) have indicated that synthetic pyrethroid pesticides were the cause of the toxicity to benthic macro-invertebrates in sediments in the Ballona Creek Channel at the base of the watershed adjacent to Area A, Area B, and Area C. Synthetic pyrethroids are new emerging water quality issue that has been identified throughout urban areas in California. Synthetic pyrethroid pesticides are now widely available and used to replace banned pesticides such as chlordane. These and other emerging water and sediment quality issues have the potential to impact the Project. The continued implementation of structural and non-structural BMPs in the watershed will address these emerging issues. For example, the implementation of infiltration and bio-filtration distributed, centralized and regional structural BMPs will also reduce the concentrations and loading of synthetic pyrethroids and other pesticides. Synthetic pesticides and many pesticides are hydro-phobic and are more prone to adsorbed to sediment particles in stormwater runoff than remain in the water column. Infiltration and bio-filtration type BMPs filter out sediments and the pollutant that are adsorbed to these sediments. Non-structural BMPs are also being implemented such as requirements for training of pesticide applications and certification of commercial pest control appliers to reduce over spraying and applying these pesticides before a rain event. Continue monitoring of receiving water and sediment quality remains a requirement of the MS4 permit. The identification of emerging pollutants s and potential impacts will continue through MS4 Permit monitoring by the permittees and other parties.

In addition to the significant reduction in the potential for impacts to the Project from Ballona Creek water and sediment through the implementation of the Ballona EWMP, the Project alternatives have considered these potential impacts in the design of the restoration. The Project alternatives allow for full tidal flows into the wetlands to the extent possible while protecting existing important habitat. Full tidal exchange creates more favorable water quality conditions by reducing retention times of potentially impacted stormwater and non-storm flows and increased flushing of the wetlands with much higher water quality of the ocean. Sediment carried from the watershed during storm flows that may contain pollutants such as metals, pesticides and PAHs may accumulate in portions of the restored channel and some areas of the wetland floodplain. These areas of sediment accumulation are identified in the Sediment Dynamics and Sediment Budget Analysis (ESA 2015) and will be open to full tidal flow and periodic flushing during high tide events.

To fully address the potential of impact of sediments carried by storm flows from the urbanized watershed to the Project, a monitoring and adaptive management program will be implemented after construction as discussed in Section 4.

Based on the existing and applicable water and sediment quality data summarized in Section 1, the following potential impact questions will be assessed:

- **Ballona Creek Channel Sediment Quality – What are the potential impacts of sediment quality from sediments within the Ballona Creek Channel on the restoration project based on existing sediment quality data?**

The results of historical and recent sediment quality sampling and testing within the tidally influence segment of Ballona Creek that will be within the Project boundaries, have indicated these sediment contain metals, PAHs, and pesticides that are above the ER-L and show a toxic response to marine species. Recent TIE studies (SCCWRP, 2014) have indicated that the toxicity is due to concentration of synthetic pyrethroid pesticides as discussed above. These sediments within the tidally-influenced segment of Ballona are likely impacted from sediment carried from the watershed during storm events that are deposited when fresh water storm flows are slowed by tidal flow and changes in geochemistry within this segment. As discussed in the previous assessment question on water quality of Ballona Creek, significant reduction of these impacted sediments and overall pollutant loading from the watershed is anticipated through the implementation of the Ballona EWMP in accordance with the MS4 Permit. The existing sediments, however, remain a potential source of impact to the Project.

The proposed Project alternatives include the re-alignment of Ballona Creek within the tidally influenced segment (Figure 3 [Fill and Excavation in Alternative 1]). The Project would have the beneficial effect of covering impacted sediments within the existing channel per the restoration design. For the sections of the creek channel that will remain and contain the existing impacted sediment, the existing sediments have the potential to impact the Project and the environment in reaches of the channel that are erosional.

Consideration of sediment management measures to reduce the potential for increased mobilization of existing impacted sediment within the existing channel is recommended. For example, impacted sediments could be removed and replaced with clean material. Impacted sediment could be placed as wetland foundation in the sections of the existing channel to be filled at a depth that would not be subject to scour. Alternatively, impacted sediment could be undercut and buried with underlying clean sediment. The depth of excavation could be based on the constituents concentrations compared to the TMDL cleanup requirements (ER-L) or to a depth that is not subject to exposure due to scouring.

3.2 Impacts from Adjacent Properties

Based on the existing and applicable water and sediment quality data summarized in Section 1, the following potential impact questions will be assessed:

- **Marina del Rey – Fiji Ditch – What are the potential impacts of water quality from tidal flows (including dissolved and solid fraction constituents and sediment) from Marina del Rey on the restoration project based on existing water quality data, anticipated pollutant reductions required under the TMDLs, and estimated project implementation schedule?**

Ballona Wetlands Restoration Project

Figure 3
Fill and Excavation in Alternative 1

The results of water quality monitoring in Marina del Rey indicate the water quality is of much higher quality than Ballona Creek due to the greater tidal exchange and flux with the ocean, and not anticipated to impact the Project. Further the Project is not changing the tidal portion of Fiji Ditch, so the same flow and extent of tidal influence will remain the same.

Based on the existing and applicable water and sediment quality data summarized in Section 1, the following potential impact questions will be assessed:

- **Freshwater Marsh – What are the potential impacts of water quality from dry and wet weather flows (including dissolved and solid fraction constituents and sediment) from the Freshwater Marsh on the restoration project based on existing water quality data?**

The results of water quality monitoring of the Fresh Water Marsh indicate the water quality is good and not anticipated to impact the Project.

Based on the existing and applicable water and sediment quality data summarized in Section 1, the following potential impact questions will be assessed:

- **Urban Runoff and Stormwater – What are the potential impacts of water quality from urban runoff and stormwater flows from adjacent urbanized areas and roadways on the restoration project based on existing water quality data and anticipated pollutant reductions from the best management practices (BMPs) proposed in the Stormwater Management Plan (Psomas 2015)?**

Stormwater inputs to the Project were investigated during the Baseline Study for the Ballona Wetlands Restoration Feasibility Report (PWA 2008) and through continued monitoring by the The Bay Foundation. The results of these investigations indicated that stormwater runoff from adjacent roadways and urbanized area of Playa del Rey to the west of Area B has impacted sediments in existing marsh channels. Higher concentrations of metals were detected sediments closed to stormwater outfalls that discharge urban runoff into the marsh. Several metals concentrations were above the ER-L. Based on these results, there is a potential for stormwater from adjacent roadways and urbanized areas that include Playa del Rey to impact the water and sediment quality of the Project (as is currently the case under existing conditions), unless measures are implemented to reduce pollutant loading and concentrations of metals, pesticides and PAH form stormwater discharges to the Project.

The Preliminary Stormwater Management Plan (Psomas, 2015) provides a conceptual plan to address these impacts. The planned measures include the construction of bioswales along the existing roadways and stormwater retention facilities at the stormwater outfalls that discharge directly into the marsh. The BMPs will provide for the capture and reduction of sediment carried in stormwater flows that can also contain metals, PAH and pesticides. The Preliminary SMP will be further developed to provide more detail on the planned BMPs that balance the need to reduce impacts from these storm flows on the wetlands with the area needed to capture and treat these flows effectively. More detail on the specific capture and treatment BMPs that address the metals, PAH and pesticides that are known to be in urban stormwater flows will be provided in the Final SMP. With these details on the types of BMPs will also be the anticipated design storm and pollutant removal efficiencies of the BMPs for the constituents that are indicated to exceed the sediment quality guidelines in the previous sediment studies in Area B. BMPs will therefore be designed to remove pollutants in stormwater from adjacent properties to concentrations that will not impact the water and sediment quality of the Project.

4. Adaptive Management and Monitoring

As discussed in the assessment of potential impacts to the Project, there may be the potential for impact from the watershed during storm events depending on the effectiveness of the implementation of BMPs under the EWMP. As stated, the timeline for meeting TMDL waste load allocations for metals and toxics from the watershed is 2021, which corresponds with the implementation schedule for the initial phase of the Project. No potential impact is anticipated if these pollutant reductions are achieved in accordance with the MS4 Permit. A sediment and water quality monitoring and adaptive management plan is recommended to address the potential impact if these reductions are not made or potential new emerging water quality issues occurs that are not fully addressed by the BMPs implemented under the EWMP. The monitoring will focus on sediment quality in areas subject to the greatest deposited form storm events and that are also not subject to regular tidal flushing, for example the Area A meander bend. The sediment quality monitoring would be performed at a frequency that would capture the build-up of contaminants in the deposited sediment before concentration are reached that would impact benthic macro-invertebrates and other sensitive species. A Sediment and Water Quality Adaptive Management Plan is recommended in which sediment management measures would be specified and triggered if impacted sediment is identified. Protocols would be established in the Sediment and Water Quality Adaptive Management Plan for the detection of impacted accumulated sediments that may pose an impact to the biological resources of the Project. These measures may include additional sampling and analysis, additional testing to determine the risk of impact based on toxicity and where applicable bioaccumulation. Depending on the concentrations and results of follow-up testing, additional measures may be taken to partially remove impacted sediments. These measures will balance the potential impact from the constituents in the sediment with the impact of temporary disturbance of sediments and habitat. More detailed monitoring and adaptive management procedures will be developed subsequent to this Administrative Draft for use in the Project EIR/S.

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APPENDIX F7
Hydraulics and Hydrology Report

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Draft

BALLONA WETLANDS RESTORATION PROJECT

Preliminary Hydrology and Hydraulics Report

Prepared for
California State Coastal Conservancy

May 8, 2013

ESA PWA

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BALLONA WETLANDS RESTORATION PROJECT

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May 8, 2013

Mr. Richard Leifield
Chief of Engineering and Levee Safety Officer
U.S. Army Corps of Engineers, Los Angeles District
P.O. Box 532711
Los Angeles, CA 90053-2325

Subject: Ballona Wetlands Restoration Project Preliminary Hydrology and Hydraulics Report

Dear : Mr. Leifield

Please find enclosed the Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report (H&H Report) as part of the Section 408 Initial Submittal A to the U.S. Army Corps of Engineers for the Ballona Wetlands Restoration Project.

This H&H Report documents preliminary hydrology and hydraulics technical analyses including the hydrology of Ballona Creek and local tributaries, a hydraulic analysis using the 1-D HEC-RAS model, a hydrodynamic analysis using the 2-D EFDC model, a preliminary sediment transport analysis, a geomorphology analysis, and tsunami and coastal sediment assessments.

The following additional analyses will be completed subsequent to Submittal A for CEQA/NEPA review and detailed analysis and design for Submittal B:

1. This H&H Report includes a preliminary analysis of sediment transport. Additional sediment transport analysis will be performed to further assess potential changes in sediment transport
2. A channel dynamics assessment will be conducted to further evaluate the dynamics and erosion potential of the realigned Ballona Creek, including a long-term sediment budget analysis.

The sediment transport, channel dynamics, and sediment budget analyses will be submitted as addenda to the H&H Report during Summer/Fall 2013.

Please note that this H&H Report assesses a prior iteration of the Project design that is similar to the current design presented in the Ballona Wetlands Restoration Project Preliminary Design Report (PDR) (ESA PWA 2013). Since the completion of analyses in the H&H Report, the preliminary design has been updated. The key differences between the design in this H&H Report and the PDR are the treatment of the existing natural gas wells in west Area A and West Area B. Section 1.2 of the PDR describes these differences. Refinements to the hydraulic analyses will evaluate the current design in greater detail and will be included in Submittal B.

Sincerely,

Nicholas Garrity, P.E.
Southern California Manager / Project Manager
ESA PWA | Environmental Hydrology

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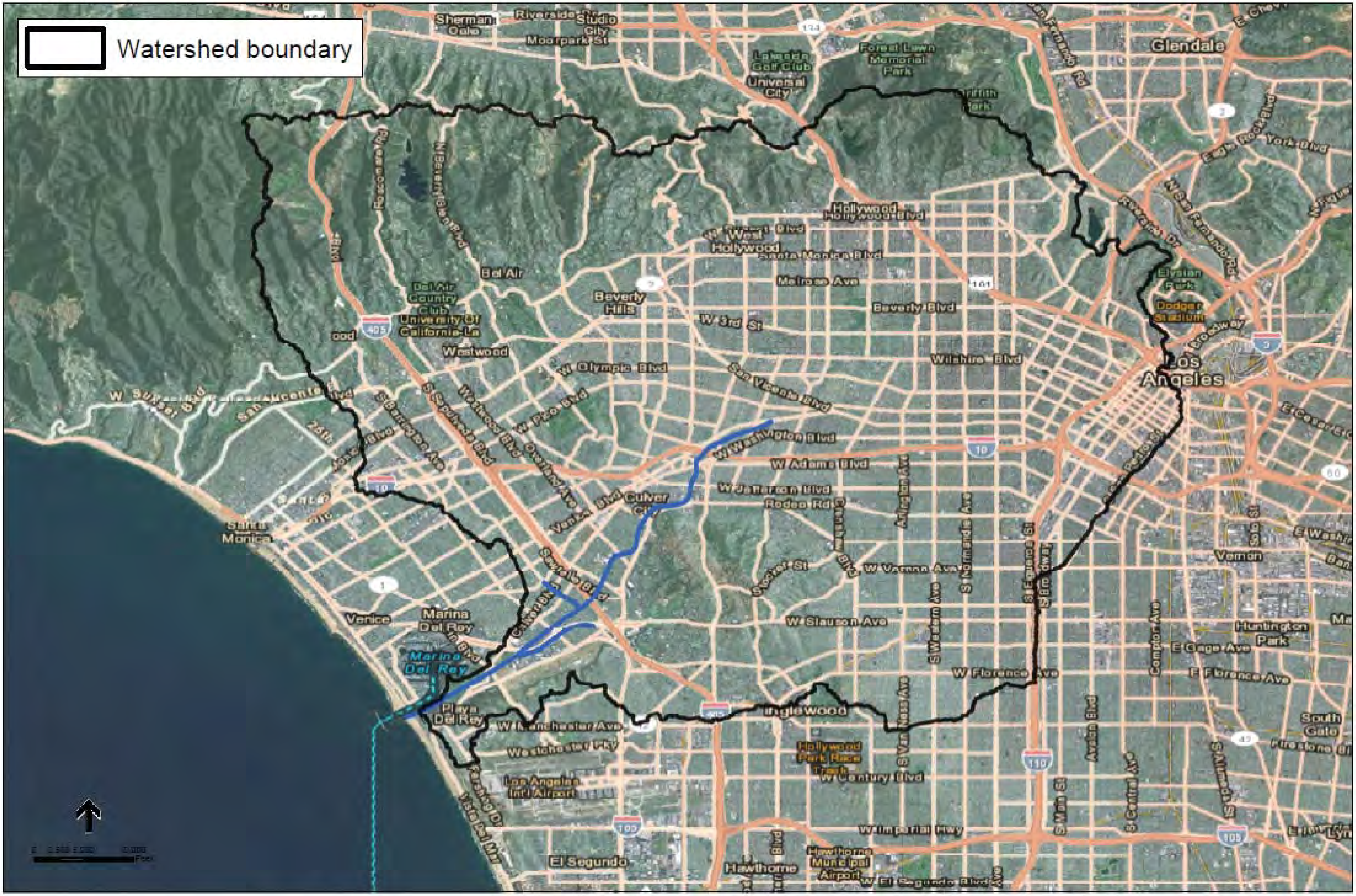
1. INTRODUCTION

ESA PWA has conducted analysis of the hydraulic behavior of flood discharges in Ballona Creek under existing conditions and a proposed project to create several hundred acres of tidal marsh along the lower reaches of the channel. Ballona Creek is currently a channelized trapezoidal flood control channel that collects surface runoff and concentrated storm drainage from canyons in the Santa Monica Mountains and the heavily urbanized areas of Beverly Hills, Culver City, Hollywood, and a western portion of the City of Los Angeles. The watershed drains approximately 130 square miles, of which 20% is undeveloped foothill and canyon area while the remaining 80% is highly urbanized coastal plain (USACE 2010a).The watershed location is shown in Figure 1.

This report summarizes the results of preliminary hydrologic, hydraulic, hydrodynamic, sediment transport, and geomorphic analyses that were used to inform the development of the preliminary restoration design for the Ballona Wetlands Ecological Reserve (Ballona Wetlands), including a reach of Ballona Creek. The Preliminary Design Report (PDR) describes the proposed project conditions that were analyzed for this report in more detail.

The purpose of the Preliminary Hydrology and Hydraulics study was to evaluate the preliminary project design relative to current flood management and sediment transport conditions, and inform design development to accommodate geomorphic processes and future sea level rise (SLR). ESA PWA reviewed prior studies to identify appropriate design flows for use in the hydraulic analysis. In addition, tidal conditions in Santa Monica Bay were assessed to develop representative starting water levels at the downstream end of Ballona Creek.

The primary hydraulic and sediment transport analyses were conducted using a one-dimensional (1-d), steady-state HEC RAS model. Because of the spatial complexity of the proposed project, a two-dimensional (2-d) hydrodynamic model was also developed to simulate both flood flows and tidal conditions on the site. Results from the 2-d model were used to inform the set up of the 1-d model to appropriately simulate 2-d processes and flow expansion and contraction and to verify 1-d model results. Preliminary sediment transport analyses were conducted to verify that sediment continuity will be maintained under the preliminary project design conditions without excessive sedimentation or erosion, and to inform preliminary design development.



SOURCE:ESRI ArcGIS Online (basemap)

ESA PWA

Ballona Wetlands. D120367

Figure 1
Ballona Creek Watershed

2. HYDROLOGY

The Ballona Creek watershed encompasses 130 square miles of western Los Angeles County. Mean annual precipitation in the watershed ranges from just over 13 inches in the southwest, to more than 19 inches in the higher portions of the Santa Monica Mountains. The headwaters of Ballona Creek originate on the southern slopes of the Santa Monica Mountains which are characterized by gently sloping terrain dissected by steep canyons. Approximately 20% of the drainage area is located in this environment, which is the least developed portion of the watershed. The remaining 80% of the watershed includes the densely developed communities of Beverly Hills, Culver City, Hollywood and a portion of the City of Los Angeles. The urbanized portions of the watershed drain to Ballona Creek and its tributaries via streets and storm drains. (USACE 2010b)

2.1 DESIGN FLOWS

USACE 2010a provides the following description of flow rates used in the design of the Ballona Creek flood protection channel:

> "(1) The design and construction history of Ballona Creek channel is somewhat obscure. The original set of design discharges for the channel was developed in the mid-1930's using a form of the rational method. At that time, the unit-hydrograph procedure was not used and the standard project flood had not yet been conceived. A modified rational method (ultimate Q) was adopted as the best method by which the runoff hydrographs could be computed that would compensate for (expected) ultimate development. Optimized 24-hour-50 year rainfall was used to develop these design discharges. Channel and possibly bridge construction based on these values followed.
>
> "(2) In 1949, the Los Angeles County Flood Control District (LAFCD) prepared a set of "Capitol Q's" (design discharges) for Ballona Creek. These discharges were also based on 24-hour-50 year rainfall. They are compared favorably with the previous design discharges. It is not certain if these Capitol Q's were used as a basis for any design.
>
> "(3) In 1954, the Los Angeles District (LAD) computed standard project flood [SPF] design discharges for expected future conditions on Ballona Creek. These discharges were significantly greater than the previous design discharges and 1949 Capitol Q's in the upper reach (drainage less than about 50 square miles). For the larger drainage areas, all three studies resulted in similar discharges. Additional channel construction followed in the 1960's to increase channel capacities. It is believed that 1954 SPF discharges are the design discharges used to upgrade the conveyance capabilities of the Ballona Creek channel."

After reviewing numerous documents provided by LA County and Corps staff, ESA PWA has identified flow rates believed to correspond to those described in items (1) and (3) above. The LA District Corps maintenance manual (USACE 1999) identifies a design flow rate of 46,000 cfs for lower Ballona Creek, which is believed to reflect the original Corps design flow (item (1) above). LA County FCD as-built drawings for lower Ballona Creek channel and levee improvements constructed in 1959 show a design flow rate of 51,240 cfs for lower Ballona Creek, which may reflect the 1954 SPF discharge (item (3) above). Table 1 summarizes design flow estimates for Ballona Creek from these sources as well as USACE 2010b (Corps feasibility study Hydrology report).

Table 1 Summary of Ballona Creek Design Flow Rates (Project Reach)

	Q cfs	**Source**
Q100	44,270	USACE 2010b
Design Q (USACE)	46,000	LA District Corps 1999
Design Q (LA County FCD)	51,240	LA County FCD 1959

Based on preliminary direction from Corps staff, the preliminary hydraulic analysis described in this report is based on the design flow rate from USACE 1999 of 46,000 cfs (Renee Vermeeren, pers. comm. 8/22/12).

2.2 N-YEAR HYDROGRAPHS AND PEAK FLOWS

The USACE conducted a feasibility study for Ballona Creek ecosystem restoration in 2010. As part of this study, a HEC-HMS rainfall-runoff model was developed to estimate discharge hydrographs for multiple runoff events (2-, 5-, 10-, 25-, 50-, 100-, 150-, 100-, 200- and 500-year) (USACE 2010b). The USACE conducted a flood frequency analysis on data collected by the stream gage currently located approximately 500 feet upstream of Sawtelle Boulevard (LA County F38C-R Ballona Creek above Sawtelle) and used the results to calibrate the hydrologic model. The USACE conducted the frequency analysis using methods outlined in Bulletin 17B (IACW 1982) for 75 peak annual flows from 1928-2005. Gaged flows were adjusted for urbanization. The results of the flood frequency analysis were compared to peak discharges estimated in the HMS model for a given flood discharge and the model was adjusted to more closely match the flood frequency at the gage.

ESA PWA used the results of the calibrated HEC-HMS model as a source for n-year hydrographs and peak discharges for Ballona Creek. Model results for n-year peak flows at various model nodes in the Ballona Creek watershed are summarized in Table 2. The node that represents flows in the project area is at the confluence between Centinela Channel and Ballona Creek. Peak flow for the 100-year event at this location is 44,270 cfs, which is somewhat lower than the project reach design flow of 46,000 cfs described above.

Table 2 Flood Frequency on Ballona Creek Estimated by the USACE Using HEC-HMS

	Peak Discharge								
Location	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**	**Q150**	**Q200**	**Q500**
0.14 mile South of Venice Blvd on the Pickford Street	3800	5390	6460	7620	8930	10050	10692	11089	12494
Ballona Creek Cross with I-10	8350	11930	14280	16710	19610	22020	23426	24297	27376
Ballona Creek Cross with Jacob Street	11830	16900	20220	23560	27610	30990	32967	34192	38524
0.09 Mile North of Higuera Street on the Ballona Creek	11970	17120	20470	23820	27930	31320	33316	34553	38932
Ballona Creek Cross with Sepulveda Blvd	12610	18070	21600	25040	29420	32900	35000	36300	40900
At confluence between Sepulveda Channel and Ballona Creek	15700	22690	27130	31160	36740	40960	43577	45195	50922
At confluence between Centinela Channel and Ballona Creek	16980	24530	29320	33690	39720	44270	43577	45195	50922
Ballona Creek at Pacific Ave	17170	24840	29690	34020	40150	44690	47097	48846	55036

2.3 COASTAL HYDROLOGY AND FLOODING

2.3.1 Tidal Datums

The tidal hydrology of Santa Monica Bay was used to inform the starting downstream water surface elevation for hydraulic, hydrodynamic and sediment transport analyses. Water surface elevations describing tidal conditions are measured relative to a fixed elevation datum, and several different datums have been used in prior studies. Table 3 lists tide levels relative to The North American Vertical Datum of 1988 (NAVD), the mean lower low water tidal datum (MLLW), and the National Geodetic Vertical Datum of 1929 (NGVD). MLLW is the average lower low tide elevation, and the MLLW datum is commonly used for marine projects. NAVD is the national datum, which replaced NGVD (also referred to as the Sea level Datum of 1929 or “Mean Sea Level”) in 1988. In Santa Monica Bay and at the Ballona Wetlands Restoration site, NAVD is similar to MLLW. Elevations in this report are presented in the NAVD.

Table 3 Tidal Datums at the Ballona Wetlands Restoration Site in MLLW, NAVD, and NGVD.

	MLLW (ft)	NAVD (ft)	NGVD (ft)
100-year tide (FEMA)	9.1	8.9	6.5
Max. observed (11/30/1982 7:54)	8.5	8.3	5.9
HAT (12/2/1990 16:12)	7.3	7.1	4.6
MHHW	5.4	5.2	2.8
MHW	4.7	4.5	2.1
MTL	2.8	2.6	0.2
MSL	2.8	2.6	0.2
NGVD	2.6	2.4	0.0
MLW	0.9	0.7	-1.7
NAVD	0.2	0.0	-2.4
MLLW	0.0	-0.2	-2.6
LAT (1/1/87 0:00)	-2.0	-2.2	-4.6
Min. observed (12/17/1933 15:42)	-2.8	-3.0	-5.5

Notes: Tidal datums from NOAA/NOS Santa Monica Tide Station 9410840, 1983-2001 Epoch
NAVD to NGVD conversion from NOAA/NGS
100-year tide from FEMA (2008) Flood Insurance Study for Los Angeles County (based on studies completed in 1984)
HAT = highest astronomical tide
MHHW = mean higher high water
MHW = mean high water
MTL = mean tide level
MSL = mean sea level
MLW = mean low water
MLLW = mean lower low water
LAT = lowest astronomical tide
NAVD = North American Vertical Datum of 1988
NGVD = National Geodetic Vertical Datum of 1929

2.3.2 Sea Level Rise

Estimates of SLR were used in the hydraulic analysis to evaluate potential future flooding conditions. In 2010, the Ocean Protection Council released a draft resolution which revised previous global sea-level rise projections. The resolution advises California state agencies to consider 10-17 inches of SLR by 2050 and 31-69 inches by 2100 (measured from a 2000 baseline) (OPC, 2010). The 2100 estimates reflect the range in greenhouse gas emission scenarios, with low emissions resulting in 31-50 inches of sea-level rise and high emissions resulting in 43-69 inches. To date, emissions have been tracking on the high scenario. Assuming continuation of the high emissions trajectory, the higher range of SLR projections would apply. The high estimate is similar to the Army Corp of Engineers' Modified NRC-III curve which predicts 59 inches by 2100 (from a 1992 baseline) (USACE, 2011). Therefore, 59 inches by 2100 was selected as the SLR scenario for this analysis.

As global water levels increase, land elevations may also be changing. Land subsidence in the project area has not been quantified for this planning effort, but is likely much less than projected sea-level rise rates.

2.3.3 Coastal Flooding

Coastal flood hazards result from extreme tides, with water levels further raised by storm surge and waves. Planning for coastal floods take into account existing flood hazards, as well as recognize evolving conditions including SLR and local subsidence. Tsunami are also considered a source of coastal flooding, but are treated as separate events (see next section).

The Federal Emergency Management Agency (FEMA) publishes flood maps that indicate the likely extent of the 100-year coastal flood. The minimum flood level is the 100-year high Pacific Ocean water level, often evaluated by extreme value analysis of tide gage records. The effects of waves are additive to the ocean water levels. Waves are incorporated in multiple ways:

- The erosion during the flood event, called "Event-based Erosion" to distinguish from long-term erosion which is not considered by FEMA;
- The elevation of the wave crests;
- The potential vertical extent of wave runup projected on and potentially above the highest coastal barrier, usually a dune or bluff; and,
- The depth, extent and volume of overtopping waters in the lee of coastal barriers.

At Ballona, the project site is well inland of the beach and remaining dunes (mostly developed) and is therefore not expected to be flooded by direct wave action under existing conditions. While waves can propagate up the Ballona Creek channel, the rock breakwater offshore of the creek mouth and the rock jetties along both creek banks limit wave exposure.

The most recent coastal flood analysis by FEMA was completed in the 1980s (Dames and Moore, 1984 as referenced in FEMA, 2008a), with updated mapping in the 2000s to account for existing topography and datums (FEMA, 2008b). Ballona Channel is mapped within the 100-year coastal flood plain, without velocity wave action (called an "A Zone") and without an elevation specified. The rest of the project site is characterized as being subject to flooding of less than one foot at the 100-year recurrence (called an "X Zone) with no specific elevations, depths or frequencies defined. The flood elevation within the adjacent Marina Del Rey is 9 feet NAVD. Higher flood risk is identified for the beaches and nearshore areas due to exposure to ocean waves, with flood elevations of 14 feet NAVD and high velocity wave action (called "V Zone").

FEMA will accomplish new studies (called "re-studies") and update maps of the area within the next decade. The new maps are likely to show increased flood elevations and inland extents owing to the statistical effect of storm events observed since the 1980s, as well as updates in methodology and SLR over the last 30 years. Based on a review the existing FEMA reports, we estimate that the 100-year coastal flood elevation for levee design is roughly equivalent to the 100-year ocean water level, plus an allowance for local wave action, and elevated slightly with distance upstream due to creek discharge likely to occur during the coastal flood. Wave effects are likely to be small due to the protection afforded by the jetties and breakwaters, and the limited fetches available for local wind wave generation.

The effect of creek flows on water levels during the 100-year coastal flood event are expected to be small given the flat gradient. The limited wave and fluvial effects indicate a condition similar to that in Marina Del Rey, for which FEMA has established an elevation of 9 feet NAVD. The preliminary coastal flood level in the Ballona Creek channel is therefore estimated by adding to the Marina Del Rey elevation as follows: two feet for wave action, one foot of sloping water surface profile (due to creek flow), and one foot of freeboard[1], for a total additive amount of four feet. The corresponding minimum levee crest elevation is therefore 9 feet NAVD plus 4 feet or 13 feet NAVD. SLR would add to this water level, resulting in a required crest elevation of 17.9 feet NAVD by year 2100 for the anticipated 59 inches of SLR. These estimated elevations are below the conceptual design levee crest elevations of 20.5 feet NAVD. The conceptual design levee elevations allows for approximately 4 ft of freeboard above the estimated total coastal water level above. The design levee elevations will be refined in future phases based on further consideration of coastal and fluvial flood levels.

2.3.4 Tsunami Risk

ESA PWA reviewed existing tsunami research in the project vicinity. These results are presented in Appendix **1**. Further assessment will be conducted in later analyses.

[1] One foot of freeboard is used in this discussion to approximate a minimum levee height elevation above the 100-year total coastal water level including waves and creek flow.

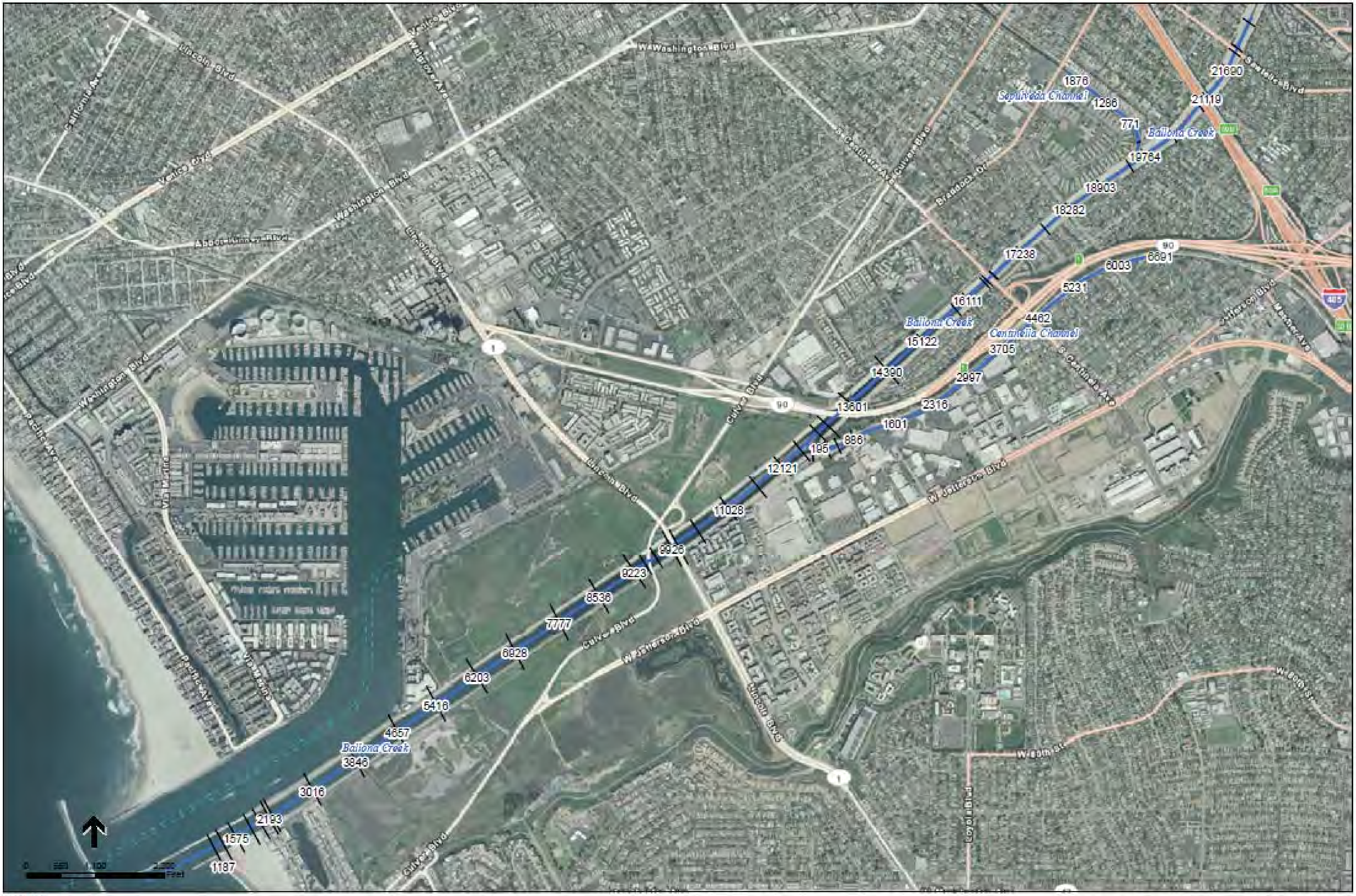
3. HYDRAULIC ANALYSIS

Ballona Creek is a nine mile long flood protection channel that drains the watershed described in Section 2. The major tributaries include Centinela Creek, Sepulveda Canyon Channel, Benedict Canyon Channel, and numerous storm drain outfalls. Figure 2 provides an overview of the Ballona Creek channel layout and location.

The Ballona Wetlands Restoration Project area includes about 600 acres between Marina Del Rey (to the north) and Playa Del Rey (to the south), and about 10,500 feet of the Ballona Creek channel between approximately Lincoln Boulevard and Pacific Avenue. Within the project site, the existing Ballona Creek flood control channel and levees, constructed in the 1930s by the USACE (USACE 1999), provide flood protection for surrounding areas. The existing channel is about 250 feet wide (width of the potential flow area between the levees), with a total corridor width (including the levees slopes) of about 320 feet. The channel and levees provide flood protection from the 100-year flood event (100-year discharge) in Ballona Creek according to the effective FEMA Flood Insurance Study (FEMA 2008).

The project entails expansion and enhancement of wetlands surrounding lower Ballona Creek and associated site modifications necessary to avoid increasing the flood risk to surrounding property and infrastructure. The project will include removing existing levees, reconfiguring the Ballona Creek channel within the project reach, and constructing new flood protection levees around the perimeter of the project area. Figure 3 shows the conceptual layout of the proposed project which is further described in the PDR.

ESA PWA constructed a hydraulic model of Ballona Creek using the HEC-RAS v4.1 software to evaluate existing and proposed project conditions. HEC-RAS is a one-dimensional step-backwater modeling program used extensively in flood and sediment transport analysis applications. The model was developed in a georeferenced framework using the GeoRAS toolbar in ArcGIS to enable geospatially oriented transfer of information between GIS and HEC-RAS. Based on preliminary direction from Corps staff, analyses of flood performance were based on the design flow rate of 46,000 cfs (Renee Vermeeren, pers. comm. 8/22/12).



FILENAME

SOURCE:ESRI ArcGIS Online (aerial)

Existing conditions model cross-sections

Existing conditions model channel alignment

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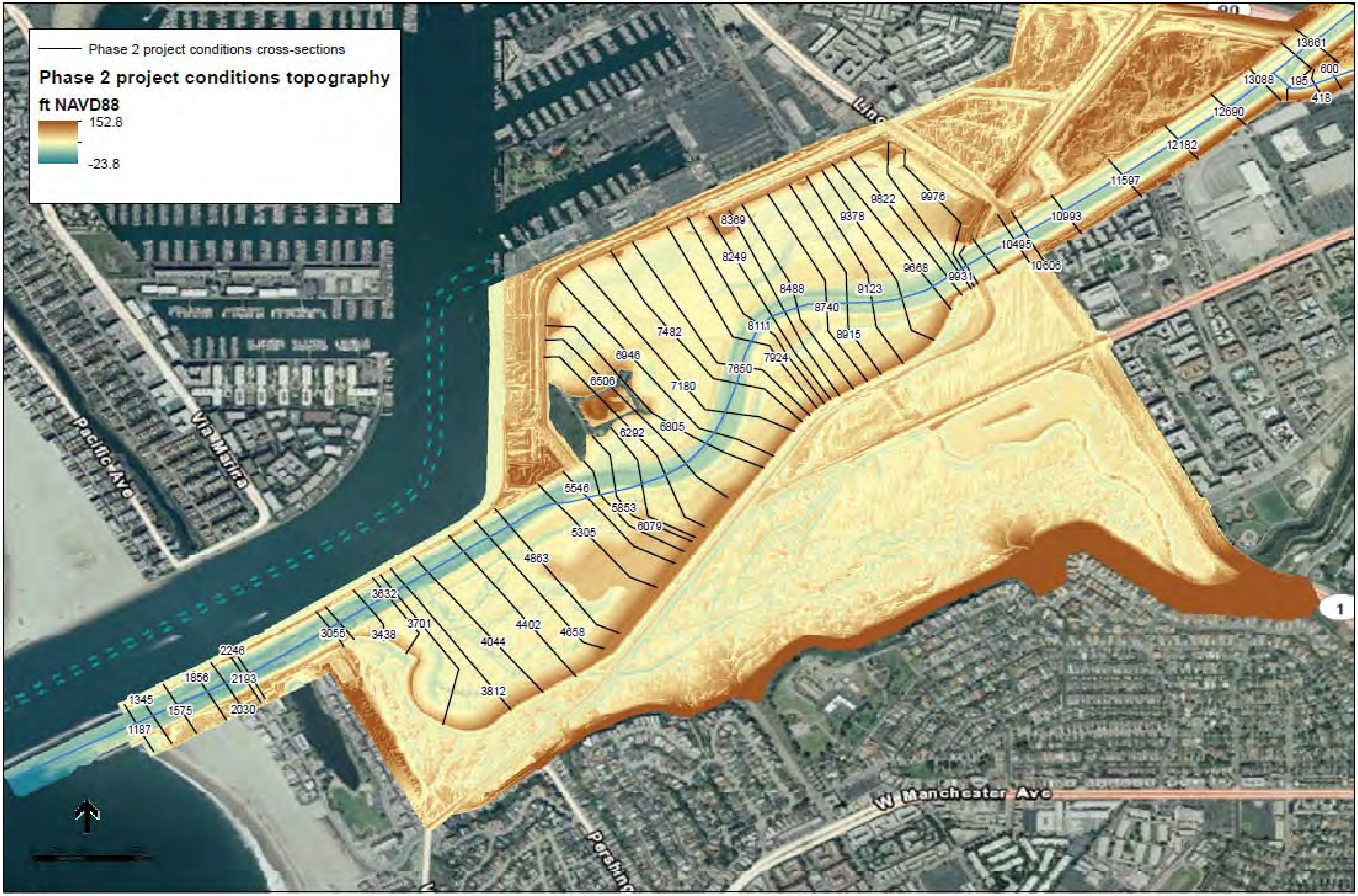
Figure 2

Ballona Creek Channel



FILENAME

SOURCE:ESRI ArcGIS Online (aerial), PSOMAS (existing condition topography), ESA (conceptual topography)

NOTE: River station shown on cross-sections in feet upstream of pacific ocean

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Figure 3

Ballona Project Plan

3.1 PREVIOUS HYDRAULIC MODELING

The USACE constructed a HEC-RAS hydraulic model of the Ballona Creek drainage system (USACE 2010a). To characterize channel and bridge geometry, the USACE used a series of as-built plans from LACFCD. Overbank areas beyond the extents of the as-built plans were extracted from a 10-meter USGS DTM (digital terrain model). All input data and results from the USACE model are vertically referenced to NGVD29. Table 4 summarizes the model reaches and Manning's roughness values from this model.

Table 4 USACE 2010a Model Reaches and "n" Values

		Manning's Roughness		
Reach	**Extent**	**Left Overbank**	**Main Channel**	**Right Overbank**
Ballona Creek	- Approximately 850-feet upstream of Burnside Avenue to the Sepulveda Channel	0.05	0.013 - 0.017	0.05
	- Between the Sepulveda Channel and the Centinela Channel	0.05	0.017 - 0.018	0.05
	- From the Centinela Channel to the Pacific Ocean	0.05	0.019 - 0.02	0.05
Sepulveda Channel	Ballona Creek to W Washington Blvd	0.05	0.015	0.05
Centinela Channel	From Ballona Creek to Margaret Avenue	0.05	0.015	0.05

ESA PWA used elements of the Corps' model to build the existing conditions model for Ballona Creek; we updated or revised a number of the model COE model parameters based on the most recent available information. The revised parameters used in the ESA PWA model of Existing Conditions and the basis for the revision are documented below.

- **Horizontal projection of geometry data** – The horizontal coordinate system used in the HEC-GeoRAS analysis conducted by the corps was not identified however the x, and y coordinate values in the model indicate that the model was projected using NAD83/California State Plane Zone VI. Los Angeles County and Ballona Creek are located in NAD83/California State Plane Zone V.
- **Channel stationing** – The channel station for each cross-section represents the cumulative distance in feet from the downstream node of the channel centerline. As such, the main channel distance input for each cross section should correspond to the difference in the cross-section stations. Some discrepancies exist between the channel stationing and the defined channel lengths at the cross-sections.
- **Contraction and expansion coefficients –** The coefficients used to define the head loss incurred by velocity differences caused by expanding or contracting cross-sectional area are typically defined as 0.1 and 0.3 for contraction and expansion respectively. Effectively, these values define the fraction of velocity head difference between sections that is converted to head loss. The values in the corps model were set at 0.01 and 0.03—an order of magnitude below the default

values. This has a significant impact on the water surface profiles calculated by the model particularly in the vicinity of the multiple bridge crossings.

3.2 MODEL SETUP

3.2.1 Geometry

3.2.1.1 Existing Conditions

The existing conditions model extent includes the Ballona Creek channel from the Pacific Ocean to the streamflow gage approximately 500 feet upstream of Sawtelle Boulevard, the Centinela Channel from Ballona Creek to Margaret Avenue, and the Sepulveda Channel from Ballona Creek to Braddock Drive. The model structures include: Sawtelle Blvd, I-405, Inglewood Blvd, S Centinela Ave, CA-90, Lincoln Blvd, Culver Blvd, and Pacific Highway.

Topography

Topographic data obtained for modeling existing conditions for the Ballona Creek system is a combination of as-built structure data from the USACE model and a DTM constructed by PSOMAS engineering. All elevations are vertically referenced to NAVD88.

In 2012 PSOMAS constructed a DTM of the Ballona Creek channel and overbank areas from the following datasets:

1. Bathymetric surveys of the lower reaches of Ballona Creek
2. Cross-sectional surveys of Ballona Creek
3. Photogrammetric data
4. LiDAR data

A detailed description of the methods used to construct the topography is provided in the PDR.

Cross-sections for the hydraulic model were extracted from the DTM and imported into HEC-RAS using the GIS based HEC-GeoRAS tool. HEC-GeoRAS enables the transfer of data from GIS to HEC-RAS including cross-section topography, river stationing, downstream reach lengths, bank station locations, roughness limits, and ineffective flow areas, and allows for the transfer of HEC-RAS results to GIS for a quasi-two-dimensional depiction of modeled flow depth, velocity, and shear stress. Cross-section alignments were laid out in GIS, intersected with the DTM to extract the topographic profile, and imported into HEC-RAS for the existing and project conditions models.

Structures

Topographic data for the existing structures included in the model was obtained from structure information extracted from the USACE HEC-RAS model. Our understanding is that the original source for these data was as-build drawings of the bridge structures. The elevations for the structures, vertically referenced to NGVD29 in the USACE model, were converted to NAVD88 by adding a constant of 2.4-feet.

In HEC-RAS, two approaches are available for modeling high flows through bridges. The approaches are:

1. **Energy Flow** – This method balances the energy equation by assuming open channel flow with flow area limited to the bridge opening through the bridge. Friction losses are calculated using the manning's equation and bridge piers and abutments are subtracted from the available flow area. This approach is most appropriate when the bridge is either highly submerged or in cases where the bridge does not provide a substantial barrier to flow.
2. **Pressure and/or Weir Flow** – Bridge hydraulics computed using this method assumes that flow through the bridge opening can be represented using orifice flow equations while overtopping flows are computed separately using weir flow equations. This approach is most appropriate where a bridge crossing provides a substantial barrier to flow generating appreciable backwater and where flow through the bridge opening is expected to be similar to orifice flow.

In general, the bridges over the Ballona Creek channel have relatively large openings that would not be expected to reflect orifice conditions or introduce large backwater effects. The energy flow approach was therefore selected as the most appropriate method for modeling the bridges for this system.

As described above, the expansion and contraction coefficients used for typical cross sections are 0.1 and 0.3 respectively. Contraction and expansion losses at hydraulic structures are greater than typical channel sections and the HEC RAS Hydraulic Reference Manual recommends the use of 0.3 and 0.5 for "typical bridge sections" (USACE, 2010c). Therefore, contraction and expansion coefficients of 0.3 and 0.5 were applied to the nearest upstream and downstream sections.

Hydraulic Roughness

The hydraulic roughness values used in the USACE model were reviewed and verified relative to typical values for similar hydraulic channel features. The values were maintained for existing conditions in the modeled reaches.

3.2.1.2 Project Conditions

The project conditions model covers the same extents as the Existing Conditions model, but incorporates proposed changes to the project site reflecting the preliminary project design (Figure 3).

Topography

ESA PWA developed a surface representing the proposed project using AutoCAD, using the existing conditions DTM as a base. Cross-sections for the hydraulic model were extracted from AutoCAD and imported into HEC-RAS using the GIS based HEC-GeoRAS tool, similar to the method described for Existing Conditions above. Cross-section alignments were laid out in GIS, intersected with the DTM to extract the topographic profile, and imported into HEC-RAS for both existing and project conditions models. Details of the preliminary project design are provided in the PDR.

Structures

Existing bridge structures will not be affected by the proposed project reflected in the PDR. Therefore, bridge geometry, modeling approach and expansion and contraction coefficients were unchanged from Existing Conditions. Future runs may include a new bridge if included in the project design.

Hydraulic Roughness

The floodplain roughness for the overbank areas under project conditions was estimated using the methods outlined in the USGS Water-supply Paper 2339 (WSP2339) derived by Arcement *et al* (1989). A USACE document (EM 1110-2-1601) identifies this approach among a list of acceptable methods in Chapter 5 (USACE 1994, pg. 5-1). The method involves calculating a bare soil base roughness (n_b) which is then increased using adjustment factors for surface irregularities (n_1), floodplain obstructions (n_3), and floodplain vegetation (n_4)[2]. The composite roughness value is computed using the following equation:

$$n = n_b + n_1 + n_3 + n_4$$

A relationship between hydraulic radius (R_h), intermediate particle size (d_{84}), and roughness (n) developed by Limerinos (1970) was used to estimate the base roughness of the floodplain. This relationship is expressed in the following equation:

$$n_b = \frac{0.1129 {R_h}^{1/6}}{1.16 + 2.0 \log_{10}\left(\frac{R_h}{d_{84}}\right)}$$

Based on the HEC-RAS results the average hydraulic radius of cross-sections through the project reach is approximately 8 feet (2.44 meters). Sediment grain size distributions (GSD) for floodplain sediment were not available for this report thus it was assumed that the intermediate particle diameter was equal to the d_{84} of the composite GSD of from channel sediment samples collected by the USACE (USACE 2003). Based on floodplain core data presented in the preliminary geotechnical memo (GDC 2012), the floodplain surface sediment is composed primarily of sand and silt with some locations containing gravel sized sediment classes. This is consistent with the sediment composition in the channel which contains approximately 15% gravel, 60% sand, and 20% silt. Thus the d_{84} from the channel samples of approximately 2 mm (.002 meters) was used to estimate the base roughness. Using the values of R_h and d_{84} in meters, the Limerinos relationship yields a base roughness value of 0.018.

Typical roughness adjustment factors for floodplains are provided in Table 3 of WSP2339. For surface irregularities, the adjustment factor varies from 0.0 for the smoothest possible floodplain area, to 0.02 for a severe degree of irregularities including sloughs, rises, and dips in the floodplain. Based on the proposed floodplain contouring and natural evolution of tidal channels and seasonal wetlands in the floodplains, it was assumed that the surface irregularities could be characterized as moderate to severe,

[2] Note: the ordering of the correction factors comes from the equation for estimating channel roughness which contains factors not relevant for computing floodplain roughness

requiring a roughness adjustment of 0.01 for n_1. The adjustment factor for floodplain obstructions including debris, stumps, and isolated boulders varies from 0.0-0.004 for a negligible coverage, reflecting obstructions covering less than 5% of the cross-sectional area, to 0.02-0.03 for appreciable coverage described as 15-50% of the cross-sectional area obstructed. It was assumed that obstructions in the graded floodplains would be relatively negligible corresponding to a roughness adjustment factor of 0.004 for n_3. The adjustment factor for vegetation coverage varies from 0.001 to 0.2 depending on the degree of vegetation coverage and the type of vegetation present. For the project conditions it was assumed that the vegetation coverage in the salt marshes will contain primarily cord grass and pickleweed, with some larger stemmed vegetation along the upland transitions. An adjustment factor of 0.025 for n_4 was assumed for floodplain vegetation coverage corresponding to the high end of the medium coverage category. By adding the adjustment factors to the base roughness estimate, we derived a composite floodplain roughness of 0.057.

Other floodplain roughness references considered in this analysis include a USACE publication (ERDC/CHL TR-00-25) on the *Determination of Resistance Due to Shrubs and Woody Vegetation* (USACE, 2000), and the textbook *Sediment Transport Technology* (Simons and Senturk, 1992). The USACE publication from 2000 suggests that floodplain roughness values for Mulefat, a typical southern California riparian wetland plant that, of the categories considered in this publication, most closely resembles the type of vegetation expected in the salt marsh floodplains for project conditions, range from 0.051 to 0.059 for high velocity flow. Simons and Senturk suggest floodplain roughness values varying from 0.05 to 0.07 for medium brush vegetation. Based on the value derived through the methods outlined in WSP2339, and the supporting references described above, a floodplain roughness value of 0.06 was selected for the project conditions overbank areas.

Ineffective Flow Areas

Under project conditions, high flows will encounter an expansion in channel area at the upstream end of the project site where the existing trapezoidal channel section transitions to a reduced trapezoidal area with a large overbank floodplain. Similarly, flows will contract back into the existing channel shape at the downstream end of the restored floodplain. At abrupt transitions in channel area, the rate at which flow can expand and contract can be less than the rate at which the channel area expands or contracts. As a result, the portion of the wetted cross-section that is outside the expansion or contraction zone does not contribute to the overall conveyance of flow through that cross-section. To simulate this two-dimensional phenomenon within the one-dimensional framework of HEC-RAS, the channel areas where significant downstream flow does not occur are defined explicitly as “ineffective” flow area within the model geometry. Defining the ineffective flow area in HEC-RAS forces the model to route all conveyance through the effective area of the cross-section, more accurately simulating both velocity and water depths.

Ineffective flow area is frequently encountered at bridge constrictions and the length over which flow expands and contracts has been studied to aid in defining these regions in a one-dimensional model. In Technical Paper 151 (TP-151, USACE 1996) the USACE summarized research conducted by Hunt (1995) who utilized two-dimensional models of idealized bridge cross-sections for a total of 76 cases to estimate expansion and contraction reach lengths and coefficients. For flow expansion the mean and median of the ratio of distance in the direction of flow over distance perpendicular to flow was estimated to be approximately 1.5:1. The ratio derived for flow contraction had a range of 0.7:1 to 2.3:1 with a mean and median of around 1.1 to 1.

As described in Chapter 4 of this report, a 2-d hydrodynamic model of Ballona Creek was developed to inform the hydraulic analysis and project design. As illustrated in Figure 4 velocity vectors from the 2-d model results for the 100-year flood were used to identify ineffective flow areas at the upstream and downstream project limits. Flow expanding onto the floodplain in Area A creates a vortex of slow-moving water in the northeast corner of the project site which does not contribute to downstream conveyance. Additionally, much of the water near the levees on West Area B is stagnant and does not contribute to the total flow conveyance. The ineffective flow areas suggested by these results represent a flow expansion ratio of 1.7:1 for flow expanding at the upstream entrance to the project site, and a flow contraction ratio of 2.0:1 for flow contracting from West Area B back to the existing flood control channel downstream. The transition lengths are consistent with the findings outlined in TP-151.

3.2.2 Hydrology

As described in Section 2, the design flood flow rate for the project reach used in this analysis is 46,000 cfs; the source for project reach n-year peak flows and hydrographs is USACE 2010b (model results for Ballona Creek at confluence between Centinela Channel and Ballona Creek).

3.2.3 Downstream Boundary Conditions

Under subcritical flow conditions, HEC RAS computes water surface elevations for each cross section working upstream from a known water surface elevation. The downstream boundary condition (water level) is therefore an important input to the model. For this study, the downstream boundary of the HEC RAS model is Santa Monica Bay where Ballona Creek discharges to the Pacific Ocean. Downstream boundary conditions representing a range of tidal conditions were therefore used in the hydraulic analysis of Ballona Creek.

3.2.3.1 Design Flood Boundary Condition

As described in Section 2.1, little information is available regarding the hydraulic assumptions used in the original channel design for Ballona Creek. LA County staff provided a sheet of hydraulic calculations dated 1/3/1940 which indicates a downstream water level of 5.23 ft NGVD (7.63 ft NAVD) was used in the channel design hydraulic analysis for Ballona Creek. This water level is referred to as the "highest tide of record." We were not able to verify the highest tide of record as of the date of the calculation sheet, and the source of the calculation sheet is unknown. Nonetheless, this water level represents best available information on the downstream water level used in the original channel design analysis and was therefore selected as the downstream boundary condition for design flood analyses. Further discussion of tidal boundary conditions is provided in Section 3.2.3.2 below.

SOURCE: ESRI Online (aerials), ESA PWA EFDC model (2D velocity vectors)

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Figure 4

Plan View of Modeled Velocity Vectors and Ineffective Flow Areas

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3.2.3.2 Tidal Boundary Conditions

In addition to the design event described above, other scenarios were modeled to reflect a range of flow and tide conditions. Water levels selected to represent tidal conditions were based on the NOAA/NOS Santa Monica Tide Station (9410840). MHHW, MTL and MLLW were used in sensitivity runs to test the sensitivity of water levels to the downstream boundary condition. In addition, MHHW was used to represent typical high tide conditions for n-year flood runs.

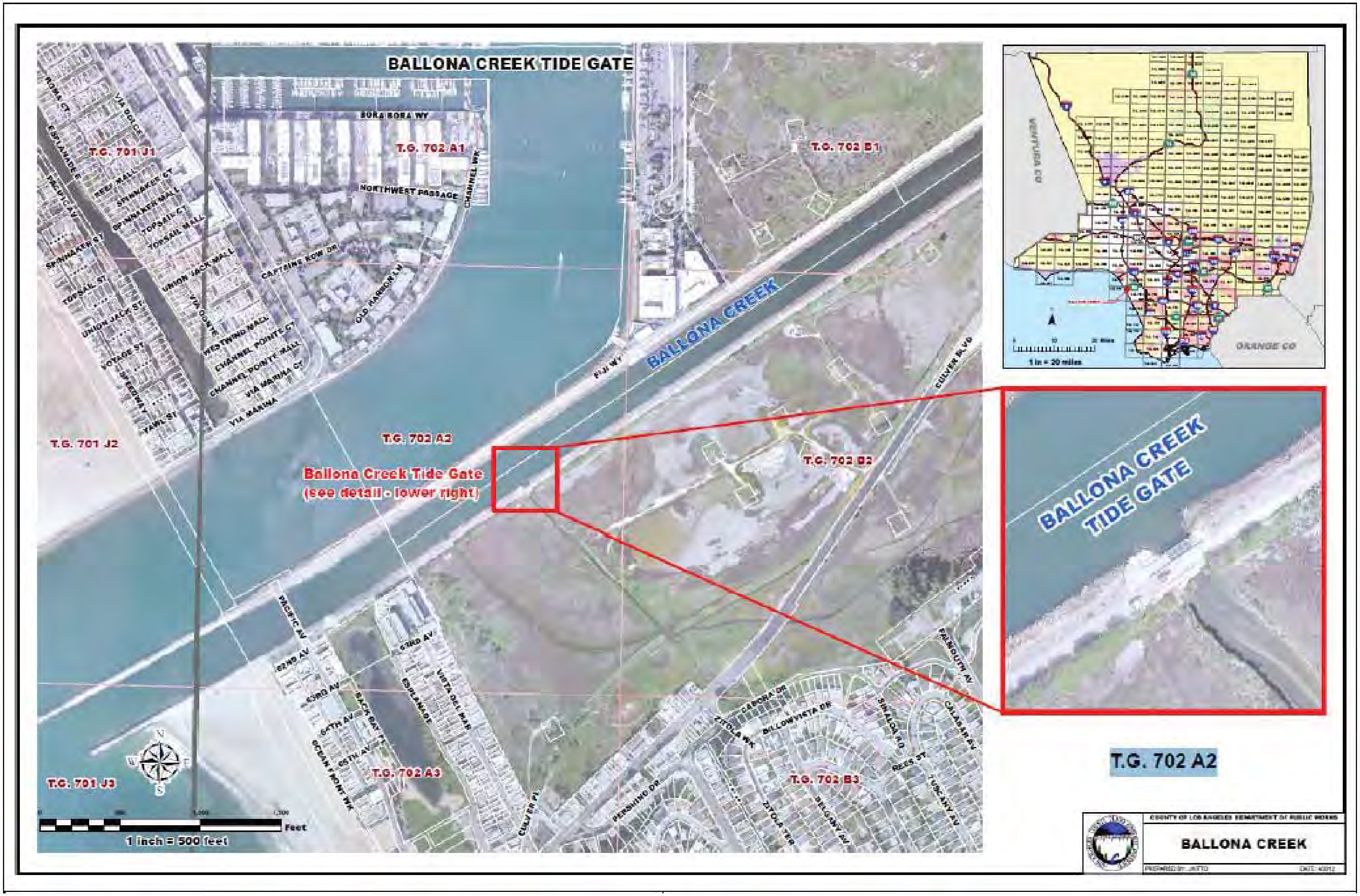
Table 5 summarizes the tidal conditions in Santa Monica Bay. In addition to the design flood boundary condition, MHHW, MTL and MLLW used in the hydraulic analysis (shown in **bold**), the Highest Astronomical (HAT) and Maximum Observed tides for the Santa Monica Tide Station and the FEMA 100-year tide level for this location are also shown for comparison. The design flood boundary condition of 7.63 ft NAVD represents an extreme high tide condition, approximately midway between the HAT and Maximum Observed tide for the Santa Monica Bay.

Table 5 Summary of Downstream Boundary Conditions

Description	Water level (ft NAVD)	Source
Design flood boundary condition	**7.6**	**1940 Hydraulic Calculation Sheet**
Mean Higher High Water (MHHW)	**5.2**	**NOAA/NOS Santa Monica Tide Sta**
Mean Tide Level (MTL)	**2.6**	**NOAA/NOS Santa Monica Tide Sta**
Mean Lower Low Water (MLLW)	**-0.2**	**NOAA/NOS Santa Monica Tide Sta**
FEMA 100-year tide	8.9	FEMA (2008)
Highest Astronomical Tide (HAT)	7.1	NOAA/NOS Santa Monica Tide Sta
Maximum Observed Tide (11/30/82)	8.3	NOAA/NOS Santa Monica Tide Sta

3.2.3.3 Tidal Time Series

To conduct unsteady flow analysis for model verification, ESA PWA used observed water level data provided by the Los Angeles County Department of Public Works (LACDPW; Tide Gate 702 A2) for a gage in Ballona Creek approximately 3,000 feet upstream of the mouth (Figure 5). Water level readings recorded at this gage extend from 2008 to the present during which time six events occurred with flows equal or greater than 7,000 cfs with the largest event having a peak flow of 14,000 cfs. A review of the tidal time series during these significant flow events indicates that the watershed flow input has little to no impact on the water levels this far downstream. This is described further in Section 3.3.1.



Source: LACDPW (2012)

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Figure 5
LACDPW Tide Gauge Location

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3.2.3.4 Sea Level Rise

ESA PWA applied an adjustment of 59 inches to downstream water levels to reflect a conservative estimate of SLR by 2100 (Section 2.3.2). In addition to adjusting the downstream water levels, model runs were conducted incorporating an assumption for bed aggradation under a long period of rising sea levels. For these runs, it was assumed that the amount of bed aggradation would match SLR at the mouth of Ballona Creek (i.e. 59 inches of aggradation) and the aggradation would project linearly back to meet the existing channel bed elevation at approximately Lincoln Boulevard. It is not clear whether there is sufficient sediment supply to realize this amount of aggradation by 2100 but this condition was selected as a conservative assumption pending refinements in modeling and design.

3.3 RESULTS AND DISCUSSION

Table 6 provides a summary of hydraulic model runs used in the analyses described in this section.

Table 6 HEC RAS Model Run Catalog

	model name	geometry source	flow inputs (Q)	d/s boundary	sediment data	description
Without Project Conditions	HEC RAS Updated Existing	as-builts & new survey	46,000 cfs	7.63 ft NAVD, MHHW, MTL, MLLW		Corps (1930's) design capacity
	HEC RAS Updated Existing	as-builts & new survey	Q2, 5, 10, 25, 50, 100, 200, 500	MHHW		flood frequency (Qn)
	HEC RAS (or HEC 6T) Sediment Transport	HEC RAS Updated Existing	1993-2003 composite gage record (all flows >200cfs)	MTL (2.6 ft NAVD)	BC: suspended sed data + assumption for total load based on % SL / BL, Grain sizes: Corps average grain size, Transport function&Cohesive options: TBD	sediment transport
	HEC RAS model verification	HEC RAS Updated Existing	Unsteady flow record (adjusted from Sawtelle)	tidal time series (observed)		model verification
Future Without Project Conditions	HEC RAS Future Existing	HEC RAS updated existing plus bed aggradation	46,000 cfs	7.63 ft NAVD+SLR, MHHW+SLR		future no project
With Project Conditions	HEC RAS With Project	design plan as of 10/17/12	46,000 cfs	7.63 ft NAVD, MHHW, MTL, MLLW		future design capacity
		design plan as of 10/17/12 plus bed aggradation	46,000 cfs	7.63 ft NAVD+SLR, MHHW+SLR		future design with SLR
			Q2, 5, 10, 25, 50, 100, 200, 500	MHHW		future flood frequency (Qn)
	HEC RAS Interim Project	Phase I plan as of 10/17/12	46,000 cfs	7.63 ft NAVD		Interim design capacity
	HEC RAS Sediment Transport With Project	design plan as of 10/17/12 plus bed aggradation	Unsteady Q100 hydrograph	MTL + SLR (59")	BC: suspended sed data + assumption for total load based on % SL / BL, Grain sizes: Corps average grain size, Transport function&Cohesive options: TBD	future sediment transport

3.3.1 Model Verification

LA County has operated a water level recording station at a tide gate located on the south bank of Ballona Creek between the Culver Boulevard and Pacific Avenue bridges since 2008. ESA PWA reviewed flow records from the Sawtelle gage and identified the highest flow rates recorded during this time period. We then attempted to correlate peak flows at Sawtelle with corresponding peaks in the recorded water level. However, even the largest flow recorded during that time period (14,000 cfs) did not influence high water levels in the Ballona Creek channel, as recorded at the water level station, apparently due to the strong influence of the tides at this location.

We ran the recorded event through the unsteady HEC RAS model to verify that the model results represented the water level conditions recorded at the tide gate. To represent inflow from the Sepulveda and Centinela tributaries ESA PWA scaled the gage readings using relationships between discharge at the Sawtelle gage and discharge estimates for flow contributed by the tributaries from HEC HMS model results (USACE 2010a) (Table 7). HEC HMS model results showed a consistent ratio of approximately 0.25 for the Sepulveda tributary ($Q_{Sepulveda}/Q_{Sawtelle}$), and 0.10 for the Centinela tributary ($Q_{Centinela}/Q_{Sawtelle}$) across a range of design flood events. The downstream boundary for the model verification run was a tidal time series from the LACDPW tide gage.

Table 7 Model Verification Run

Date	Peak Q Sawtelle (recorded) cfs	Peak Q Sepulveda (scaled) cfs	Peak Q Centinela (scaled) cfs
1/18/10	14,000	3,500	1,400

As shown in Figure 6, the HEC-RAS model results are similar to recorded water surface elevations at the location of the tide gate. Both modeled and recorded water levels reflect the dominance of tidal water surface elevations at this location and flow rate.

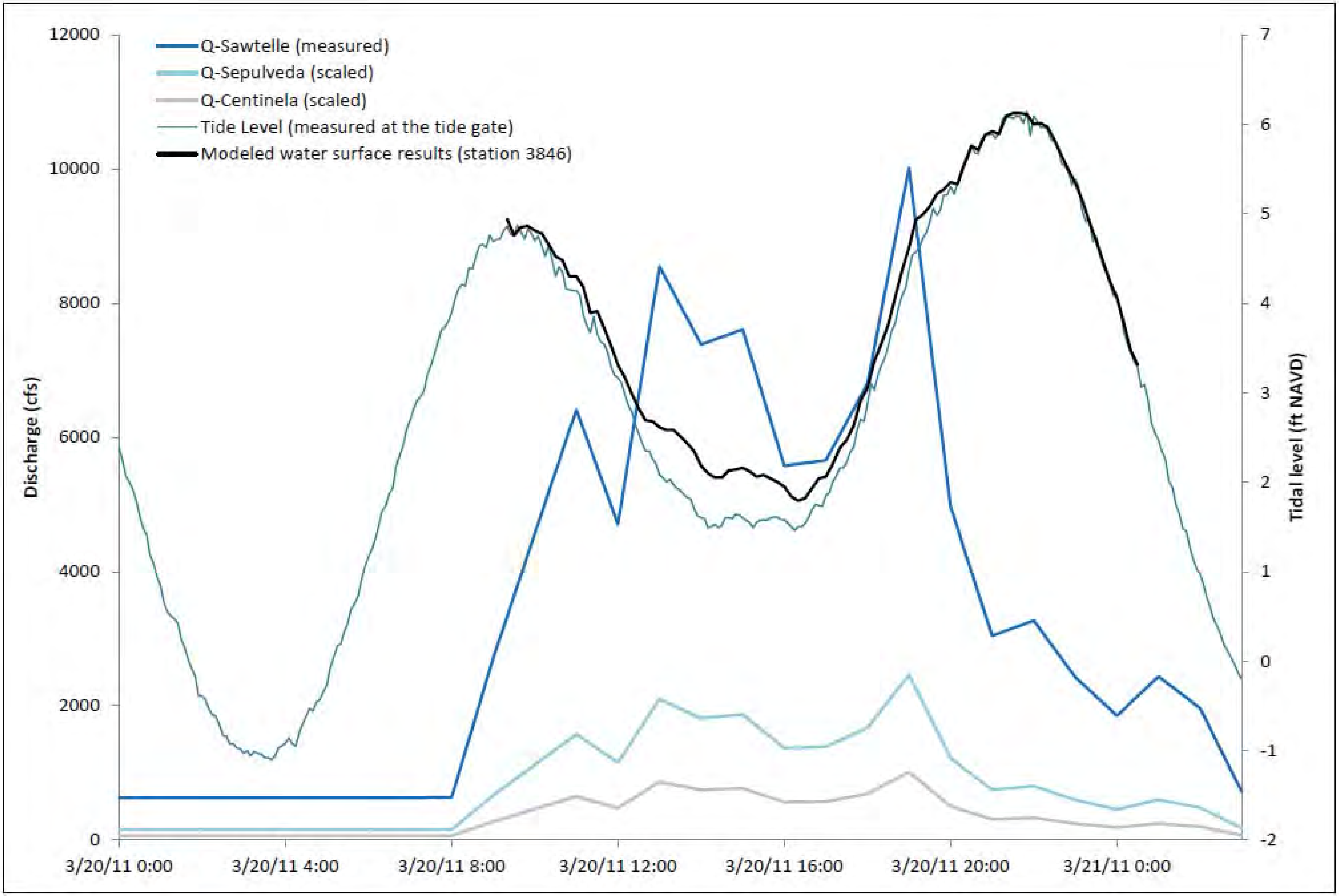

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Figure 6

Model Verification Results - Time Series

3.3.2 Existing Conditions Model Results

A variety of discharge rates and boundary conditions were simulated for Existing Conditions to characterize the hydraulic behavior of Ballona Creek in the project reach under existing conditions.

Figure 7 shows HEC RAS water surface profile results for the design flow of 46,000 cfs with a downstream boundary of 7.6 ft NAVD along with the channel thalweg (the line following the lowest point of the channel). Under existing conditions, model results indicate that the design flow is contained in the channel throughout the project reach with approximately five to seven feet of freeboard below the existing levee crests. Modeled flow velocity is approximately ten feet per second within the project reach.

Figure 8 shows HEC RAS water surface profile results for the design flow of 46,000 cfs with a range of downstream boundary conditions. These results indicate that under existing conditions, flood levels are moderately sensitive to the downstream water level throughout the project reach. Upstream of Culver Blvd, the flood level is not sensitive to the downstream boundary condition for the simulated range of water levels (-0.2 to 7.6 feet NAVD).

Figure 9 shows HEC RAS water surface profile results for a range of peak flows representing n-year events (Q2,5,10,25,50,100,200,500), with a downstream boundary of MHHW. These results show the sensitivity of the water surface profile to discharge rate under existing conditions.

3.3.3 Future (without project) Conditions

The future (without project) condition was simulated using the Existing Conditions geometry in combination with a downstream boundary condition that reflects SLR (59-inches by 2100). In addition, the Existing Conditions channel geometry was modified to represent bed aggradation equal to SLR at the channel mouth and tapering off to zero at the upstream limit of tidal influence (approximately Culver Blvd). This scenario is considered a worst case condition for bed aggradation, since it could only occur if ample sediment supply were available to allow the channel to aggrade. See further discussion of the sediment budget in Chapter 5. Model results for the 100-year flood shown in Figure 10 indicate that, with the exception of the south jetty which would overtop onto the adjacent beach, flood flows would be contained within the existing channel under SLR conditions, but freeboard would be significantly reduced relative to existing conditions.

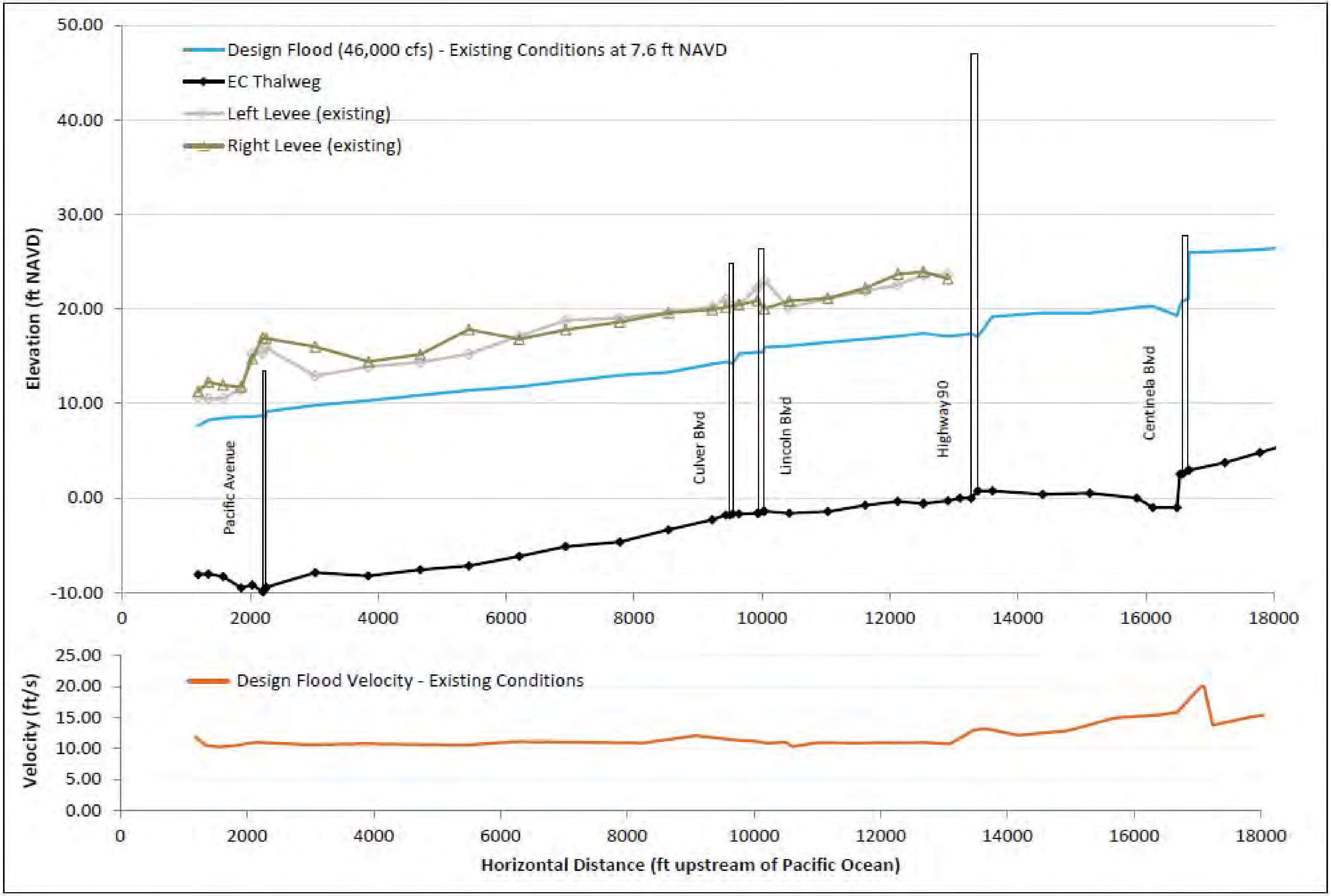

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Figure 7

Design Flood and Velocity Profiles
Existing Conditions

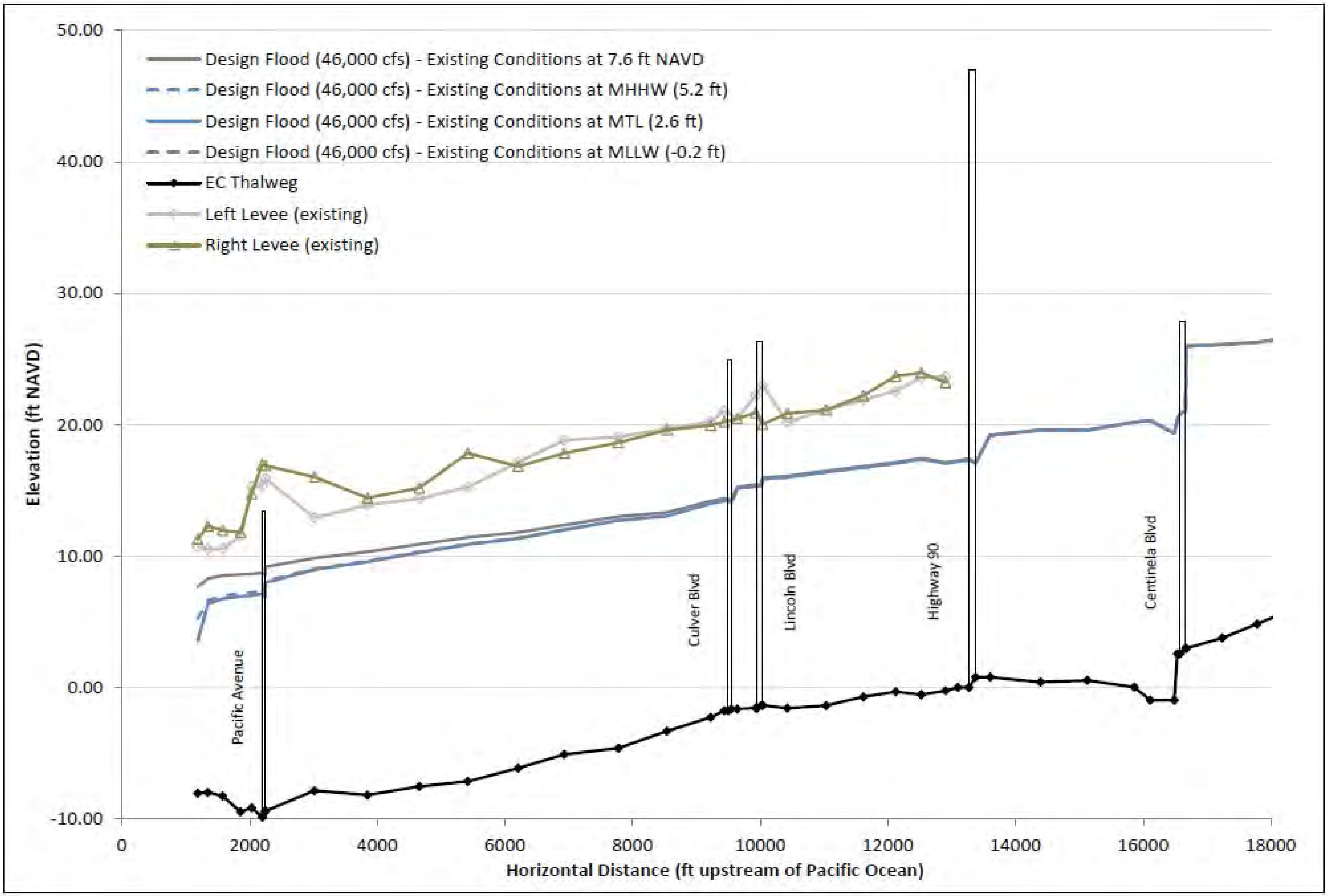

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Figure 8

Design Flood Profiles

Existing Conditions Downstream Boundary Sensitivity

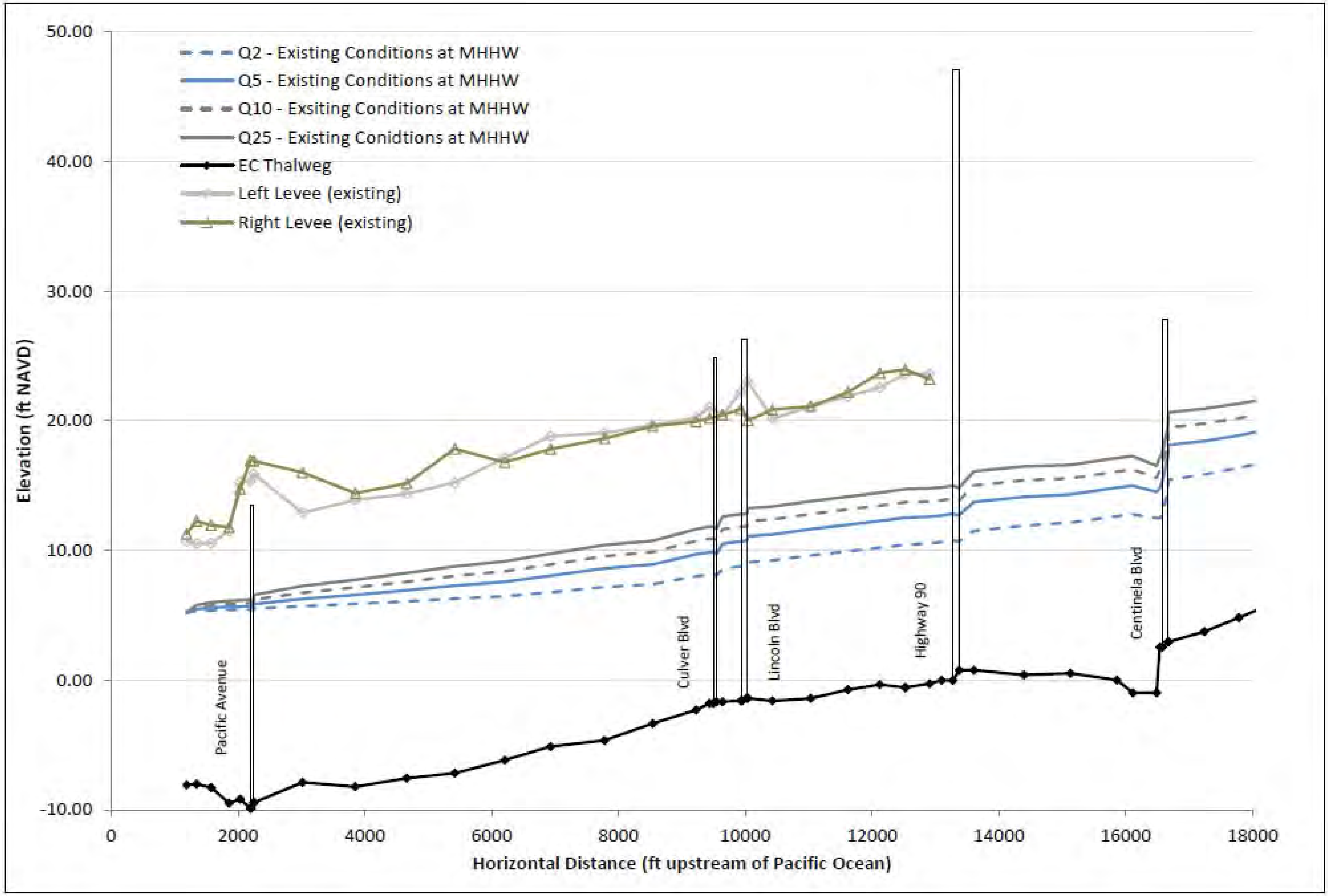

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Figure 9a

Q2 - Q25 Flood Profile
Existing Condtions

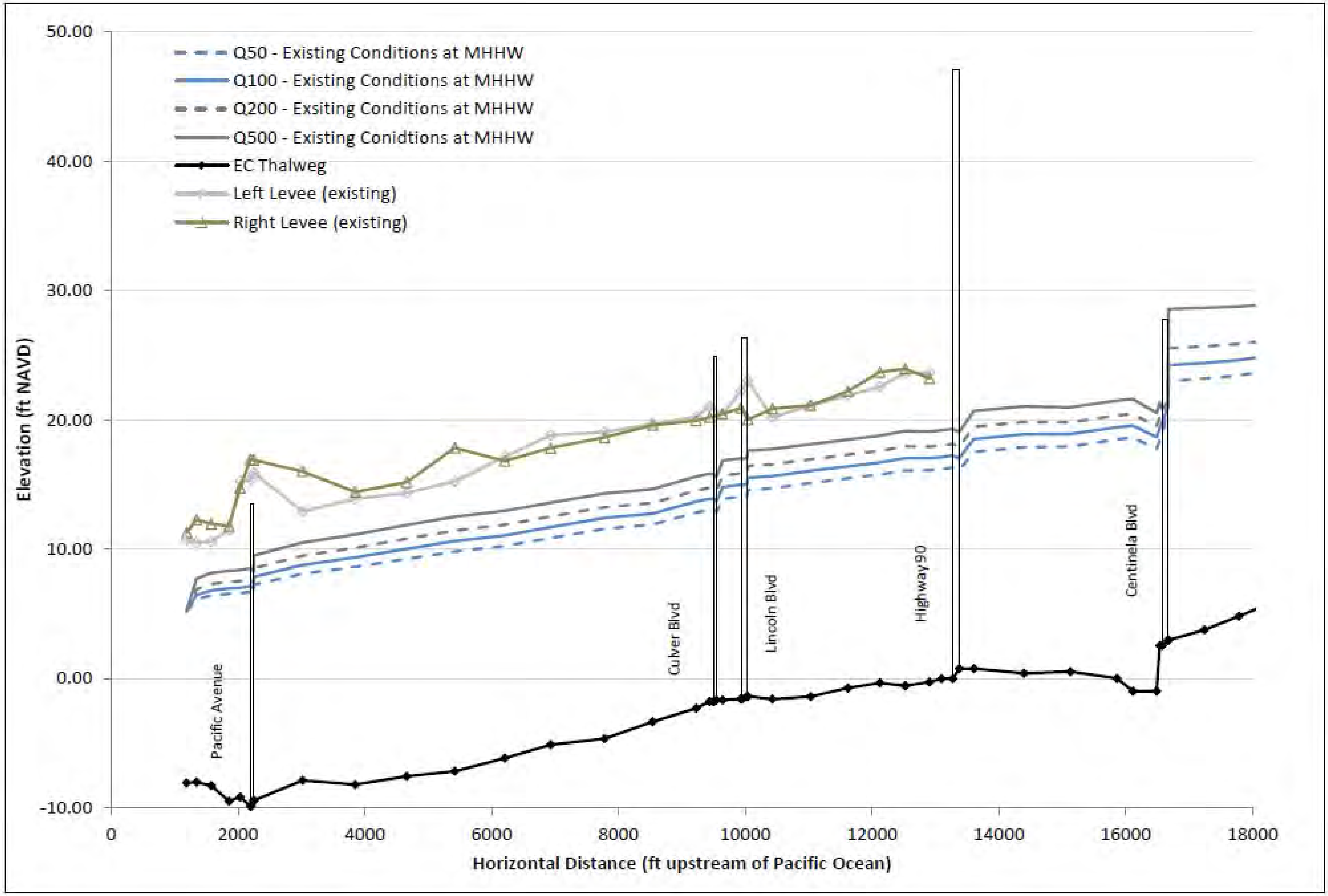

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Figure 9b

Q50 - Q500 Flood Profile
Existing Condtions

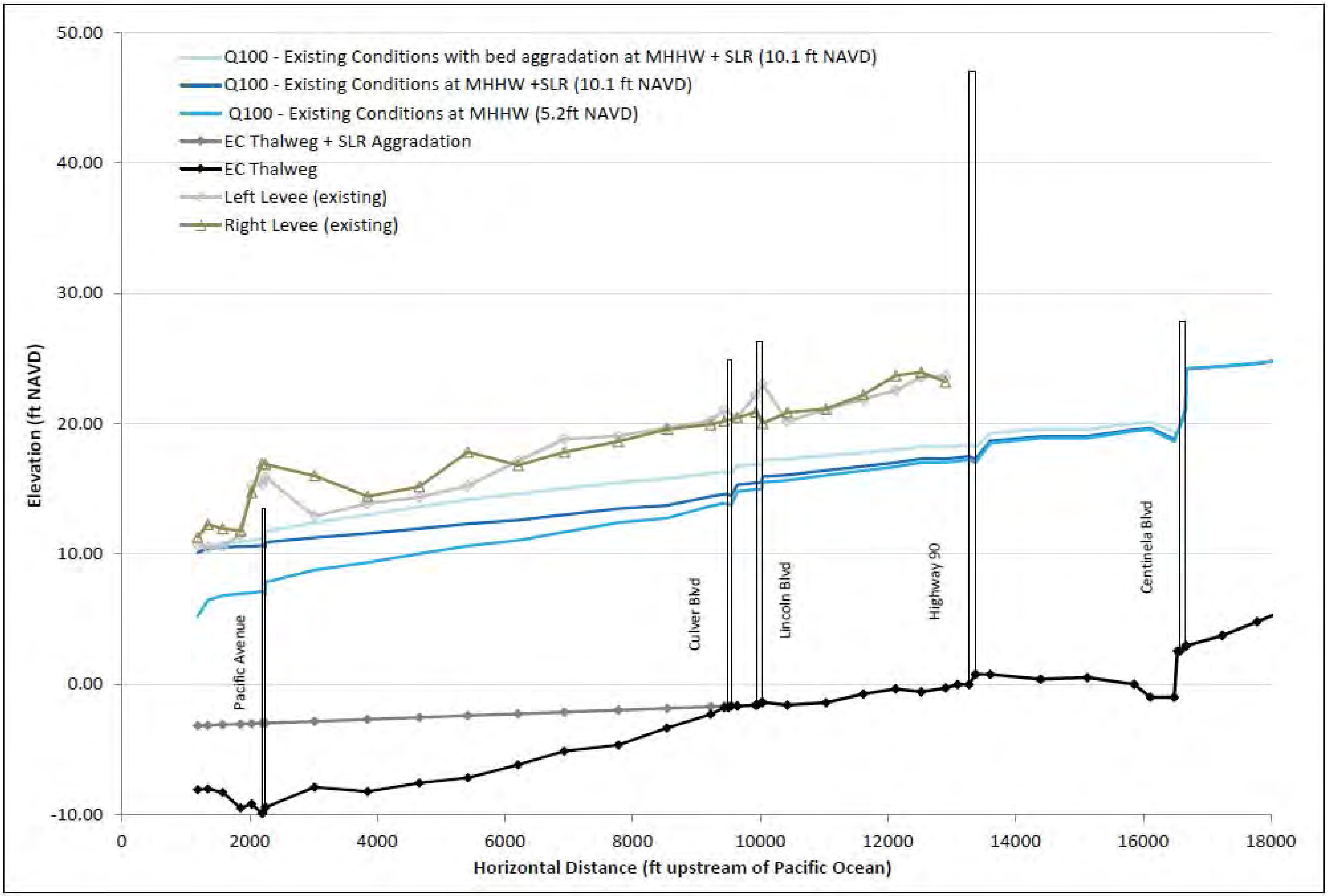

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Figure 10

Q100 Flood Profile

Existing vs. Future (without Project)

3.3.4 Project Conditions

A variety of discharge rates and boundary conditions were simulated for Project Conditions to evaluate the potential hydraulic effects of the project on Ballona Creek relative to existing conditions, and to inform restoration design development. For Project Conditions scenarios, the post-project levee crest is assumed to be at 20.5 feet NAVD based on the current preliminary project design (Figure 3).

Water surface and velocity profiles for project conditions relative to existing conditions are shown in Figure 11. This figure shows significant reduction in flow velocities through the project reach for the design flow of 46,000 cfs with a downstream boundary of 7.6 ft NAVD. Under project conditions, floodplain areas on the left and right banks of the channel provide increased conveyance capacity while also increasing roughness and wetted perimeter, which reduces flow velocities. This leads to a generally flatter water surface profile relative to the constrained existing conditions, resulting in slightly higher water surfaces through the project reach. Because the levee heights are increased under project conditions, freeboard through the project reach is increased as summarized in Table 8 and Table 9. The flattened water surface profile extends through the bridges at Culver and Lincoln boulevards resulting in less head loss through these bridges and slight reductions in water surface elevation extending upstream to Highway 90. Upstream of highway 90 the existing and project conditions water surface profiles converge.

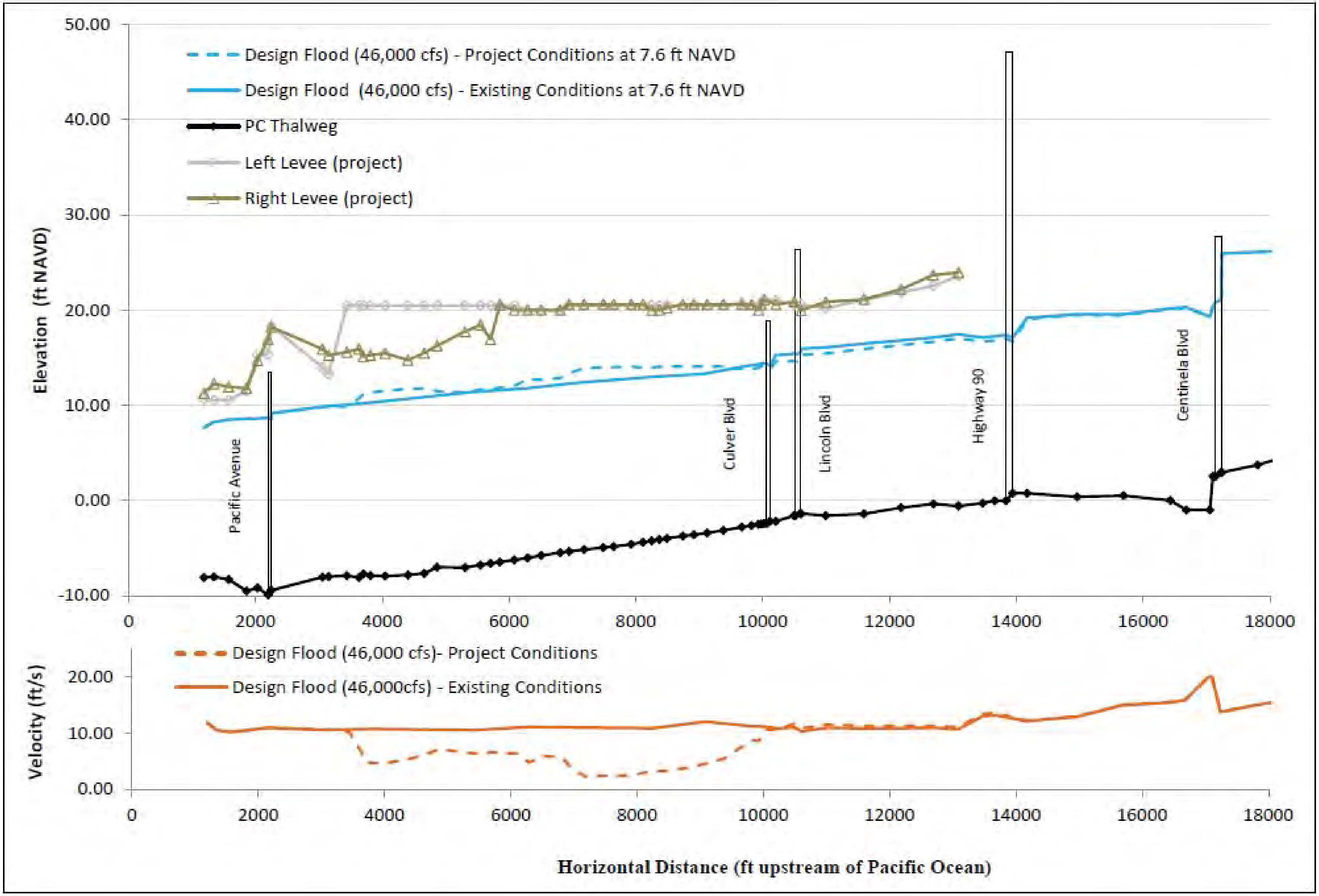
To evaluate the effects of SLR on the water surface elevations, model runs were conducted for project conditions with a downstream boundary of MHHW plus 59 inches of SLR with the current project thalweg. In addition, this tidal boundary was combined with a theoretical future geometry with the thalweg aggraded by 59 inches projecting linearly to Lincoln Boulevard. The results of these two runs compared to existing conditions for the 100-year flood are shown in Figure 12. As seen in these figures, the increase in the downstream water level under SLR scenarios increases water levels from the creek mouth to Centinela Boulevard. For the scenario including the aggraded channel bottom, the water surface is higher than without aggradation; however the change between these two profiles is mitigated by the fact that the bed aggradation represents a relatively small portion of the overall flow area in the cross-section.

To evaluate the sensitivity of the project conditions model results to the downstream tide level, the design flood was run under a series of tidal boundary conditions. Water surface profiles for the design flood with a tidal boundary at the design condition (7.6-feet NAVD), and at MHHW, MTL, and MLLW (5.2, 2.6, and -0.2-feet NAVD respectively) are shown in Figure 13. As seen in this figure, the tidal boundary condition has a moderate influence on the water surface profile from the downstream boundary up to Lincoln Boulevard. This influence dissipates between Lincoln and Highway 90, upstream of which all the project conditions profiles converge. The design tidal boundary results in a water surface profile above the lower tidal boundary profiles by a maximum of 1.1 feet near Pacific Highway, and an average of 0.6 feet between Pacific and Lincoln. Reducing the tidal boundary below MHHW has no significant impact on the water surface profiles, which are dominated by the fluvial input for low tide levels.

Water surface profiles under project conditions for the suite of n-year floods are shown in Figure 14. These profiles, discharging against a tidal boundary at MHHW, show that the project's effect on the water surface profile increases relative to existing conditions as discharge increases. The relative change in the flow hydraulics, including flow velocity and shear stress, between the existing channel and the project reach is more pronounced as an increasing portion of the flow overtops the banks and floods the floodplain areas created by the project.

3.3.4.1 Interim Project Conditions

Water surface and velocity profiles for project conditions under the interim construction phase (described in the PDR that accompanies this report) for the 46,000cfs design flow are shown in Figure 15. For this phase of the project, the existing levee separating West Area B is retained and flow is converged back into the existing channel approximately 1500 feet upstream of the convergence point for the full project. The velocity and water surface profiles for this scenario show similar patterns as for the full project through Area A and North Area B, and converge with existing conditions where the existing channel is retained. The average velocity through the interim project reach drops from 11.0 ft/s under existing conditions to 5.5 ft/s.



Ballona Wetland Restoration. D120367

Figure 11

Design Flood and Velocity Profiles
Existing vs. Project Conditions

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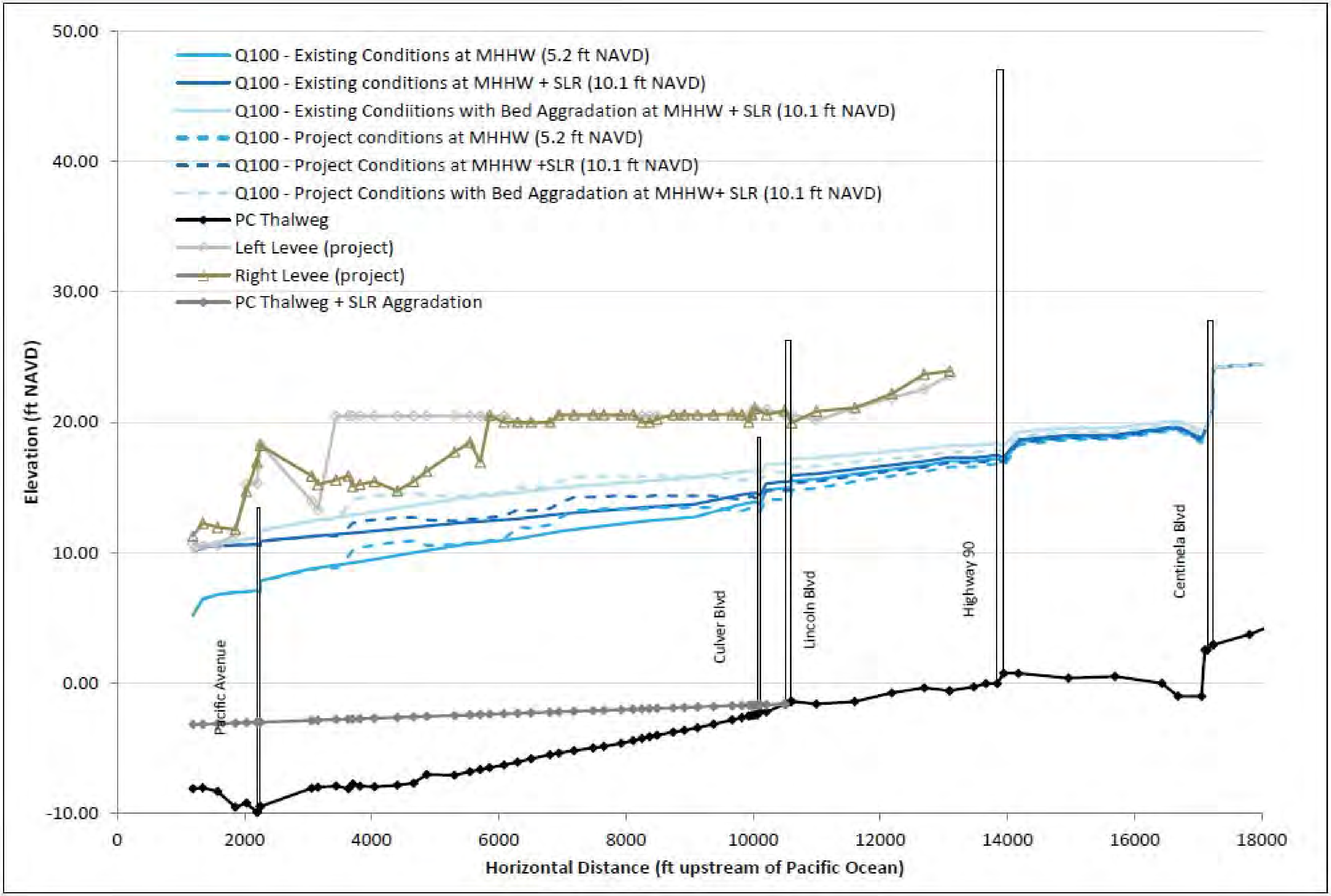

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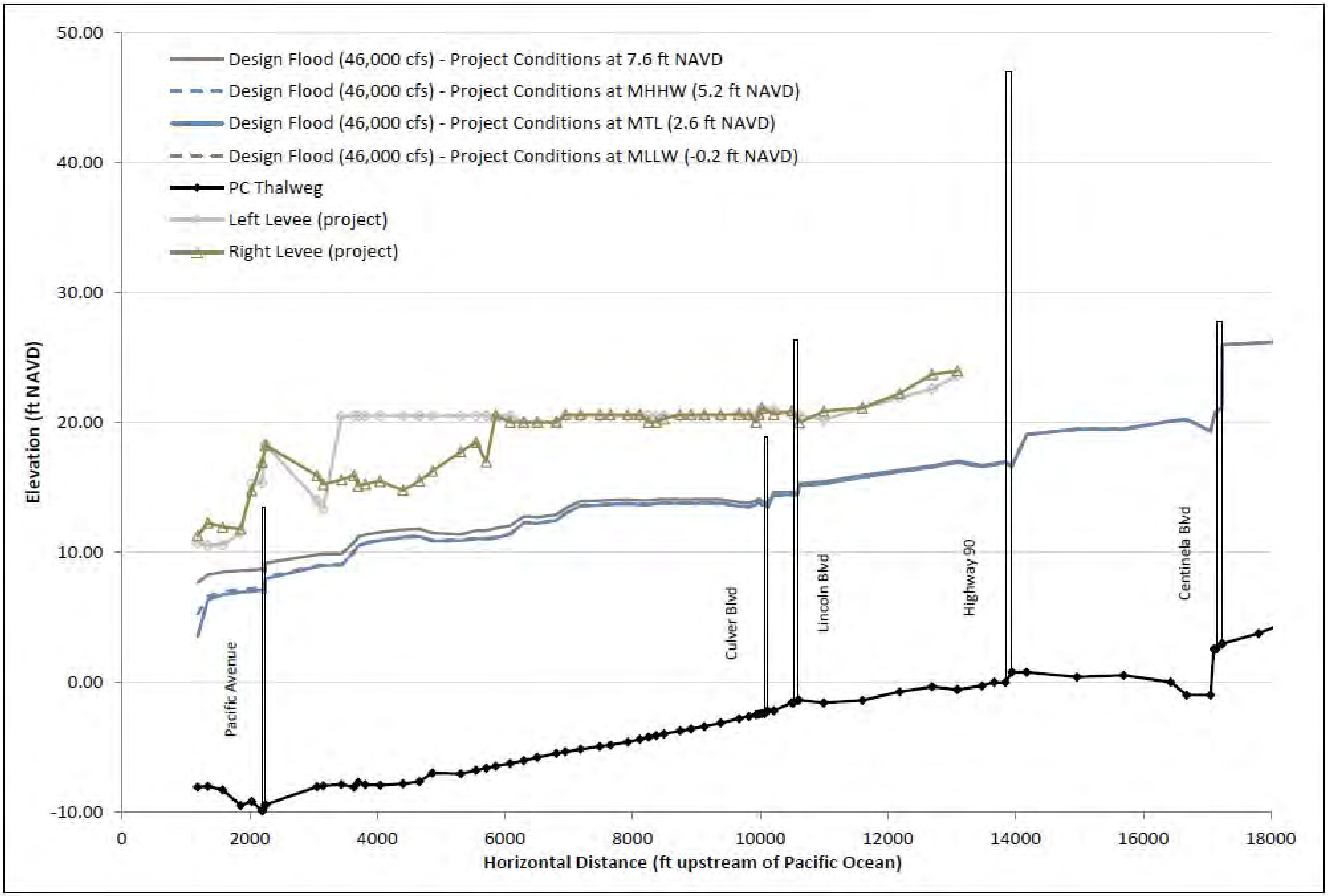
Ballona Wetland Restoration. D120367

Figure 12

Q100 Flood Profiles

Existing vs. Project with SLR Conditions



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Ballona Wetland Restoration. D120367

Figure 13

Design Flood Profiles

Project Conditions Downstream Boundary Sensitivity

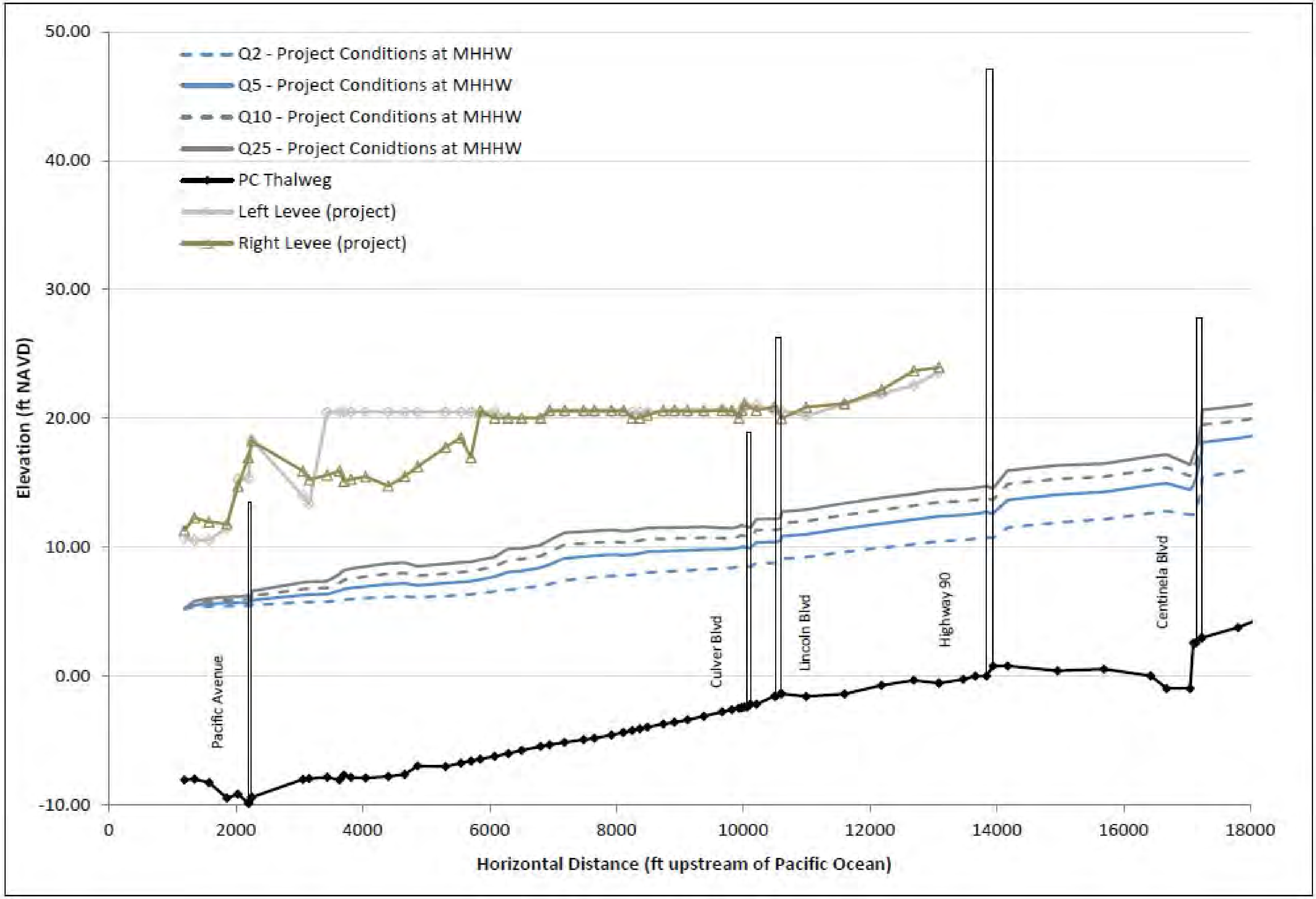

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Figure 14a

Q2 - Q25 Flood Profile
Project Conditions

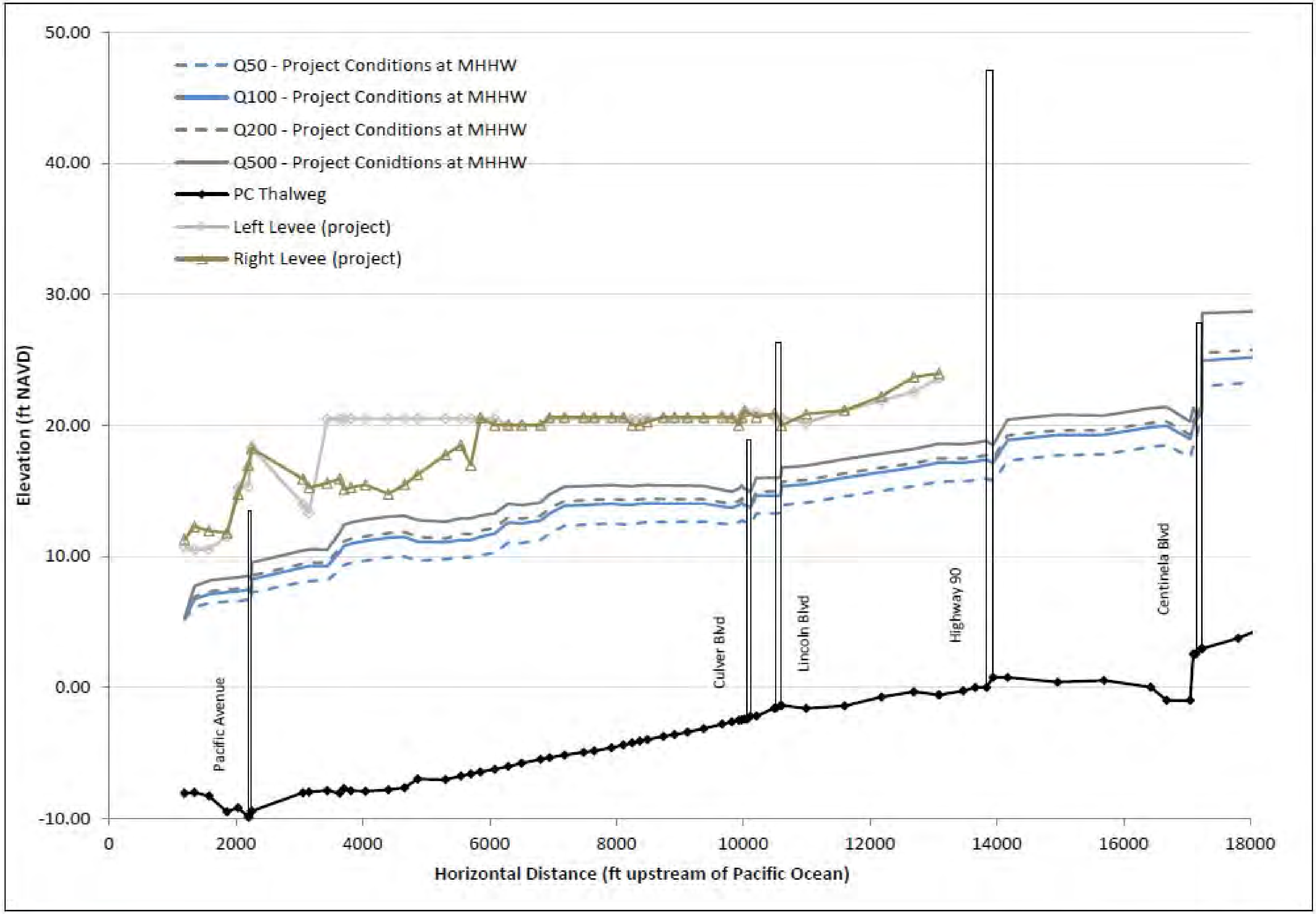

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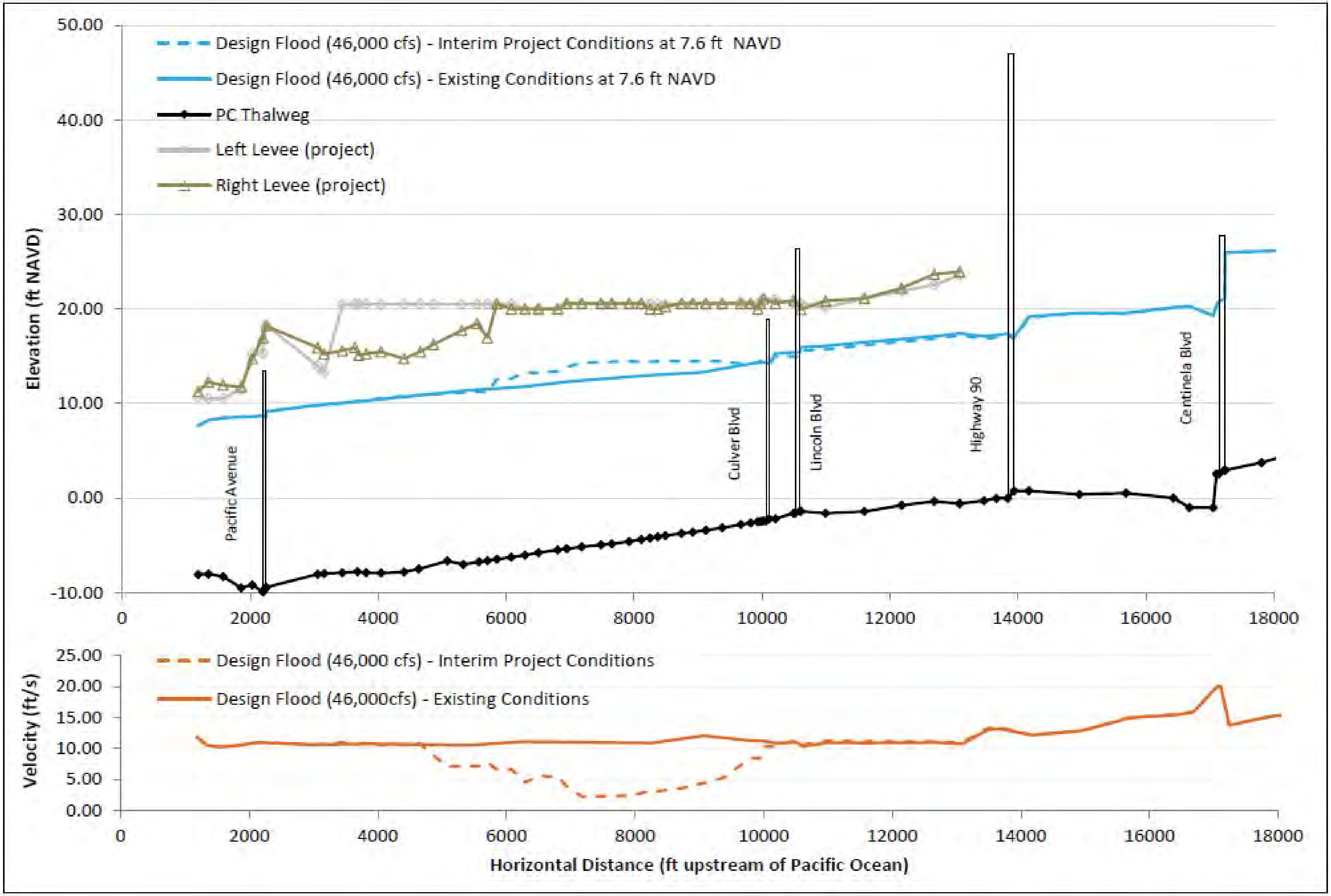
Figure 14b

Q50 - Q500 Flood Profile
Project Conditions



Ballona Wetland Restoration. D120367

Figure 15

Design Flood Velocity Profiles
Existing Conditions vs. Interim Project Conditions

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3.3.5 Discussion

Tables 8 and 9 summarize freeboard results from the HEC RAS model for the design flood of 46,000 cfs. Results for Area A and North Area B, shown in Table 8, indicate that the maximum, minimum and reach averaged freeboard are increased under both interim and full project conditions relative to existing conditions. Freeboard results for the Left (south) and Right (north) Bank levees are reported separately in the table.

Table 8 HEC RAS Results - Freeboard (Project Reach through Area A and North Area B)

	Freeboard (ft) Area A/North Area B (RS 6079 to 10019)					
	Left Bank			Right Bank		
Design Flood (46,000cfs)	Reach Average	Maximum	Minimum	Reach Average	Maximum	Minimum
Existing[1]	6.22	6.68	5.35	5.70	6.27	5.01
With interim project[2]	6.32	7.88	5.97	6.38	7.88	6.01
With project[2]	6.76	8.47	6.33	6.70	7.97	5.95

[1] Freeboard based on existing levee elevation

[2] Freeboard based on project levee elevation of 20.5 ft NAVD

Results for West Area B are shown separately in Table 9. Model results show significant increases in freeboard for the Left Bank under project conditions, reflecting the increased levee heights proposed for West Area B. Through most of this reach, however, the Right Bank consists of the existing levee/jetty that is not shown as being modified under the preliminary project design. Elevated water levels in the vicinity of Area B under project conditions reduce the amount of freeboard provided by the existing levee/jetty along the Right Bank by up to one foot. The majority of the Right Bank is formed by the jetty that separates Ballona Creek from the Marina Del Rey and a reduction in freeboard along the jetty may not represent a significant increase in flood risk. However, as discussed in the PDR, there is a section of the existing levee between the upstream end of the jetty and the downstream end of the new proposed North Area A levee that may need to be raised in order to maintain or improve the existing level of flood protection.

Table 10 shows velocity results from the HEC RAS model for the design flood of 46,000 cfs. Reach averaged and maximum velocities in the project reach are significantly reduced relative to existing conditions under both interim and project conditions.

Table 9 HEC-RAS Results – Freeboard (Project Reach through West Area B)

	Freeboard (ft) West Area B (RS 3055 to 5853)					
	Left Bank			Right Bank		
Design Flood (46,000cfs)	Reach Average	Maximum	Minimum	Reach Average	Maximum	Minimum
Existing[1]	3.63	3.84	3.48	4.94	6.43	4.11
With interim project[1]	3.63	3.84	3.48	5.99	9.35	3.91
With project[2]	9.15	10.60	8.65	5.11	8.70	3.01

[1] Freeboard based on existing levee elevation

[2] Freeboard based on project levee elevation of 20.5 ft NAVD

Table 10 HEC RAS Results - Velocity (Project Reach)

Velocity (feet/second)	Reach Average	Minimum	Maximum
Design Flood - 46,000 cfs			
Existing	11.0	10.51	12.02
With interim project	5.53	2.16	10.84
With project	5.83	2.27	10.66

4. HYDRODYNAMIC ANALYSIS

The two-dimensional (2D) hydrodynamic model results are used to provide insight into the 1-d hydraulic analysis, the preliminary restoration design (see PDR), and to more closely examine some of the 2D processes, such as flow area, velocity, and shear stress for Project Conditions.

4.1 PREVIOUS MODELING

ESA PWA previously constructed an EFDC hydrodynamic model for Ballona Wetlands to support the restoration planning process (PWA 2009). The EFDC model was selected for application by the Project Management Team, Science Advisory Committee, the USACE, and ESA PWA. The model was used to characterize the hydrodynamic response of various restoration alternatives.

4.2 MODEL DESCRIPTION

EFDC is a numerical model designed for simulating flows in open water systems. The model was originally developed at the Virginia Institute of Marine Science and receives continuing support from the U.S. EPA. A complete description of the model assumptions, governing equations and approximations, including the space discretization, time integration, and numerical solution methods, is presented in Hamrick (1992). Tetra Tech (2002) provides guidance in using the model as well as references to successful applications of EFDC for a variety of tidally-influenced systems.

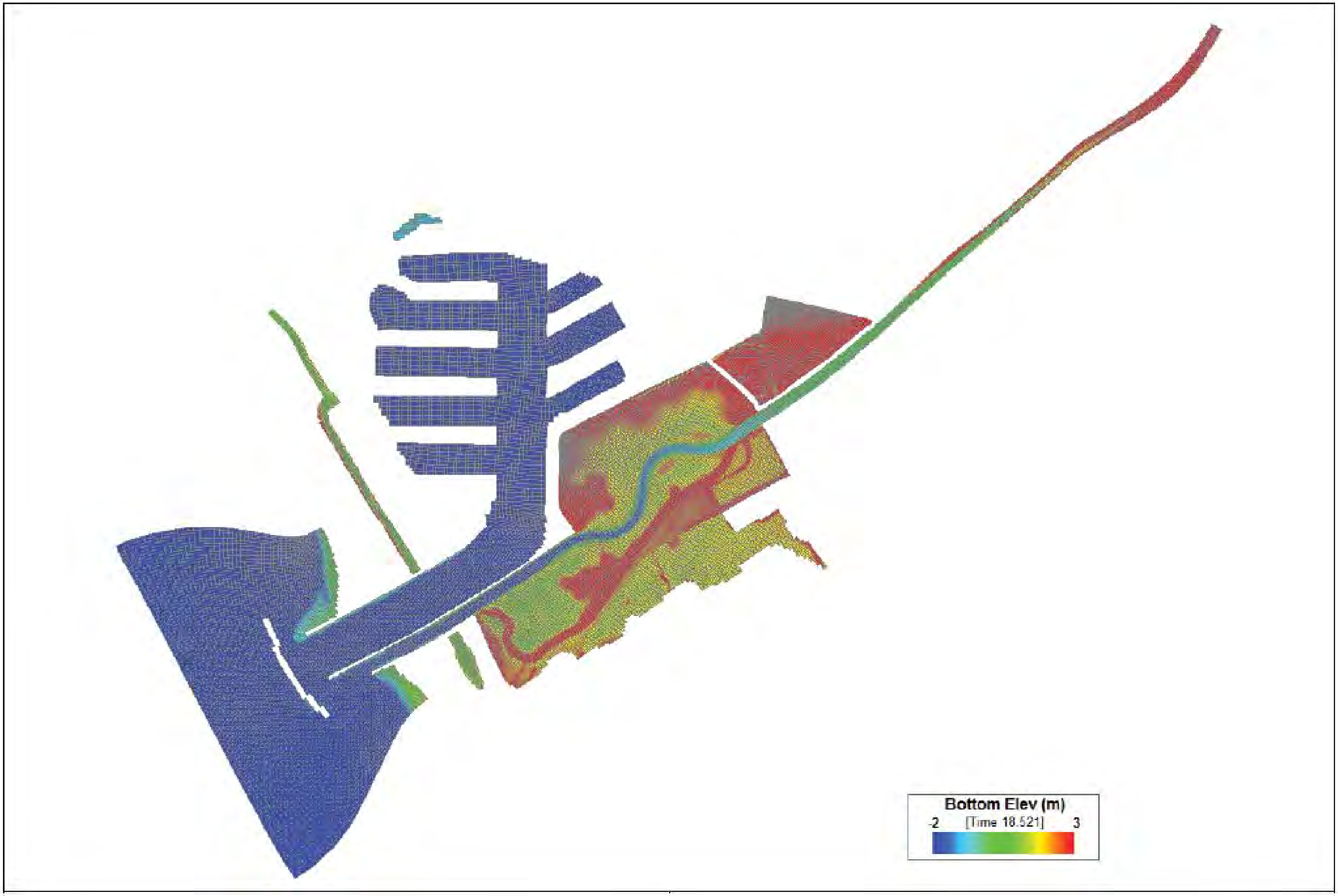
EFDC solves the physical equations for fluid flow on a staggered, finite-difference grid. The modeling domain is defined by a curvilinear flexible mesh, enabling the grid to follow dominant terrain features. At present, the model has been configured to predict 2D depth-averaged flow. Although not implemented for this study, the model can be extended to simulate three-dimensional (3D) flows and the transport of salt, sediment, and/or contaminants.

4.3 GEOMETRY

4.3.1 Existing Conditions

The model domain extends from where Ballona Creek passes under Sawtelle Boulevard to Santa Monica Bay, as shown in Figure 16. The upstream boundary is beyond the range of tidal influence and coincides with a discharge monitoring station. Placing the downstream boundary within Santa Monica Bay provides ample distance and tidal volume between the specified tidal boundary condition and the region of interest. Between the upstream and downstream boundaries, the model domain includes:

- Lower Ballona Creek;
- Ballona Wetland Restoration Areas A, B, and C;
- Marina Del Rey, including Oxford Basin;
- Del Rey Lagoon;
- Ballona Lagoon, including the Grand Canal downstream of Washington Boulevard; and
- A portion of Santa Monica Bay roughly 1.3 km by 2.5 km.



Ballona Wetlands . D120367

Figure 16
EFDC Project Conditions
Model Topography, Full Extent

ESA PWA

4.3.1.1 Topography and Bathymetry

The EFDC model represented the actual bathymetry as a single elevation value at the center of each 10 m grid cell. Multiple sources of bathymetric data were compiled to cover the entire model domain. The sources of bathymetry data for each region are listed below:

- *Ballona Creek and Ballona Wetland Areas A, B, and C:* Topographic and bathymetric surface from PSOMAS (2012).
- *Santa Monica Bay*: Bathymetric survey data from the National Oceanic and Atmospheric Administration (1997).
- *Marina Del Rey*: Elevations in the main stem of the marina from unpublished USACE dredging surveys in March 2006 and elevations in the mooring basins extrapolated from the adjacent main channel elevations.
- *Del Rey Lagoon:* Spot elevations from bathymetric survey drawings (City of Los Angeles, 2003) interpolated across the lagoon.
- *Ballona Lagoon and the Grand Canal*: Elevations from cross section surveys (Coastal Frontiers Corporation, 1989) and Ballona Lagoon Enhancement Project design drawings (City of Los Angeles, 1997).

All elevation data were converted to the same horizontal datum (UTM Zone 10N) and vertical datum (NAVD88). The data sets were then imported into the DELFT3D bathymetry generation software (WL | Delft Hydraulics, 2006a), checked for consistency where data sets overlap or adjoin, and smoothly interpolated at the boundaries between data sets. The compiled bathymetric surface was converted into EFDC-specific input files using the EFDC_Explorer graphical user interface (Craig, 2004). The compiled bathymetry for the model extent is shown in Figure 16.

4.3.1.2 Structures

Under existing conditions, culverts and gates regulate flow into and out of the Area B wetland, Del Rey Lagoon, and Ballona Lagoon. Culvert flow is represented in the model as water-level-dependent discharge between a pair of grid cells. Discharges through the culverts are implemented in the EFDC model through an input file that specifies the discharge as a function of the difference in water levels at the ends of each culvert.

Since Area B is managed and the culvert connecting Area B and Ballona Creek would be closed during flood events, the culvert is not open during flood model runs.

4.3.1.3 Bed Roughness

EFDC parameterizes the bed friction's effect on flow through a roughness height, z_0, based on the assumption of a logarithmic velocity profile. A typical, constant z_0 value of 0.02 m was applied across the entire domain (Blumberg and Mellor, 1987).

4.3.2 Project Conditions

4.3.2.1 Topography and Bathymetry

Topography and bathymetry for the Project Conditions includes the following changes from the Existing Conditions model (Section 4.3.1.1):

- New proposed setback levees around the north perimeter of Area A and in Area B along Culver Blvd. and the perimeter of West Area B.
- Ballona Creek channel realignment, including removal of the existing levees (existing north levee along Area A and south levee along Area B), creation of two new proposed channel meander bends within the restored site, and open connection between the realigned channel and adjacent restored wetlands.
- Area A: removal of fill to restore wetlands from the channel bank to the perimeter.
- Area B: wetland restoration along the south side of the realigned channel and fill to create an upland peninsula in West Area B around the existing gas wells.

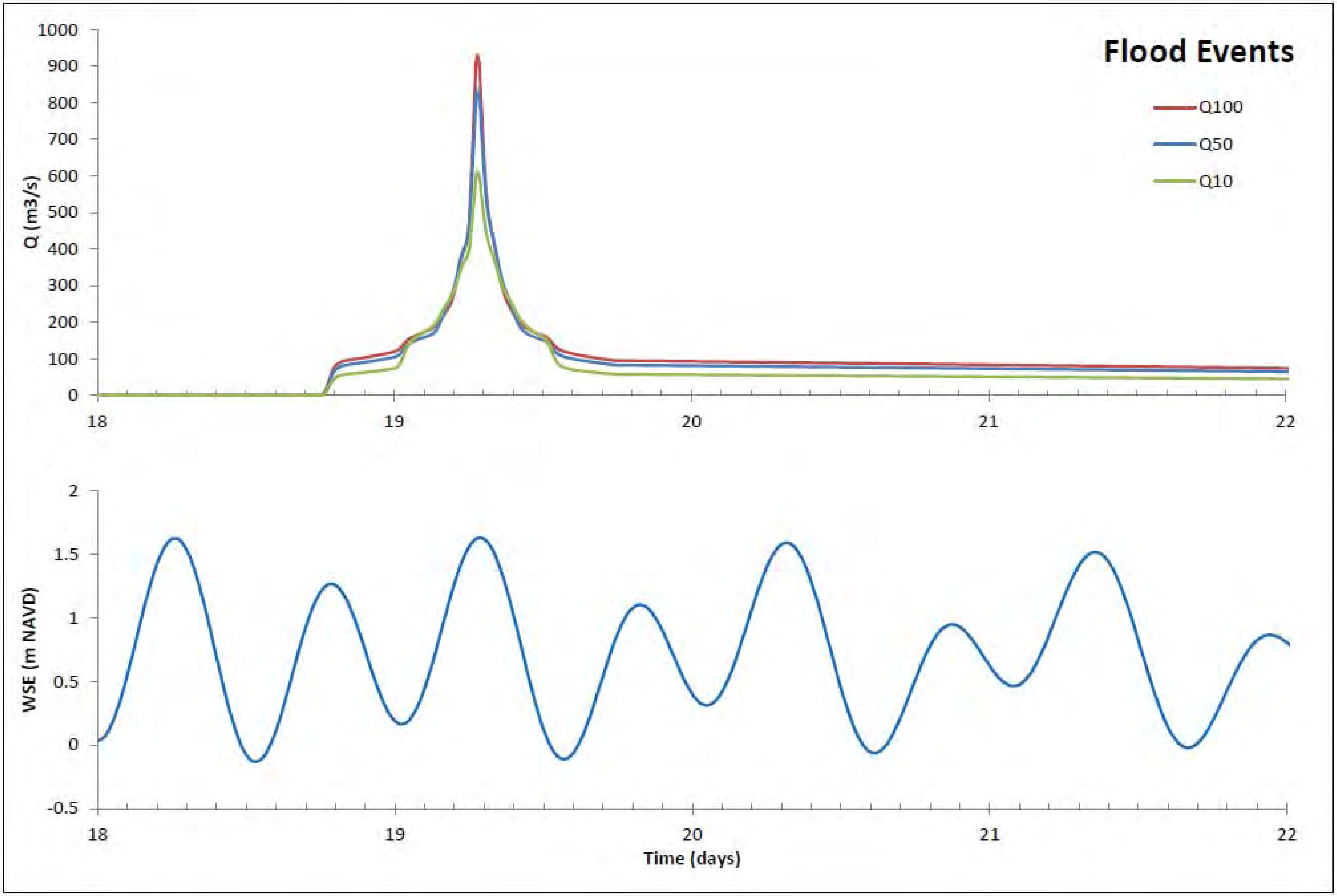
The project grading plan is presented in the PDR.

4.3.2.2 Structures

The existing levees and the West Area B tide gates are removed in the Project Conditions model. No changes from the Existing Conditions model were made to the other culverts for the Project Conditions model. The areas south of the new proposed Culver levee (South and East Area B) will be managed wetland, and the new proposed culvert connecting these areas to Ballona Creek would be designed to be closed during flood events. The new culverts are therefore not included in the Project Conditions model.

4.4 HYDROLOGY

As described in Section 2, the source for n-year peak flows and hydrographs is USACE 2010b (Table 2). The 10-, 50-, and 100-year hydrographs are shown in Figure 17 with the downstream tide boundary condition discussed below. These hydrographs are applied at the upstream boundary at Sawtelle Boulevard.



Source: Hydrograph data from USACE 2010b; Tide data from Santa Monica tide gage (Station ID 9410840) (NOAA 2012)

Ballona Wetlands. D120367

Figure 17

Hydrograph and Tide Boundary Conditions

4.5 TIDAL BOUNDARY CONDITIONS

Measured tide data at Santa Monica (Station ID 9410840) (Figure 17) was used as the downstream water level boundary condition in the model. The timing of the higher high tide and the hydrographs were adjusted so that the high tide and peak discharge are coincident within the restored site (Figure 17). The coincident high tide level is 5.4 ft NAVD (0.2 ft above MHHW).

4.6 RESULTS AND DISCUSSION

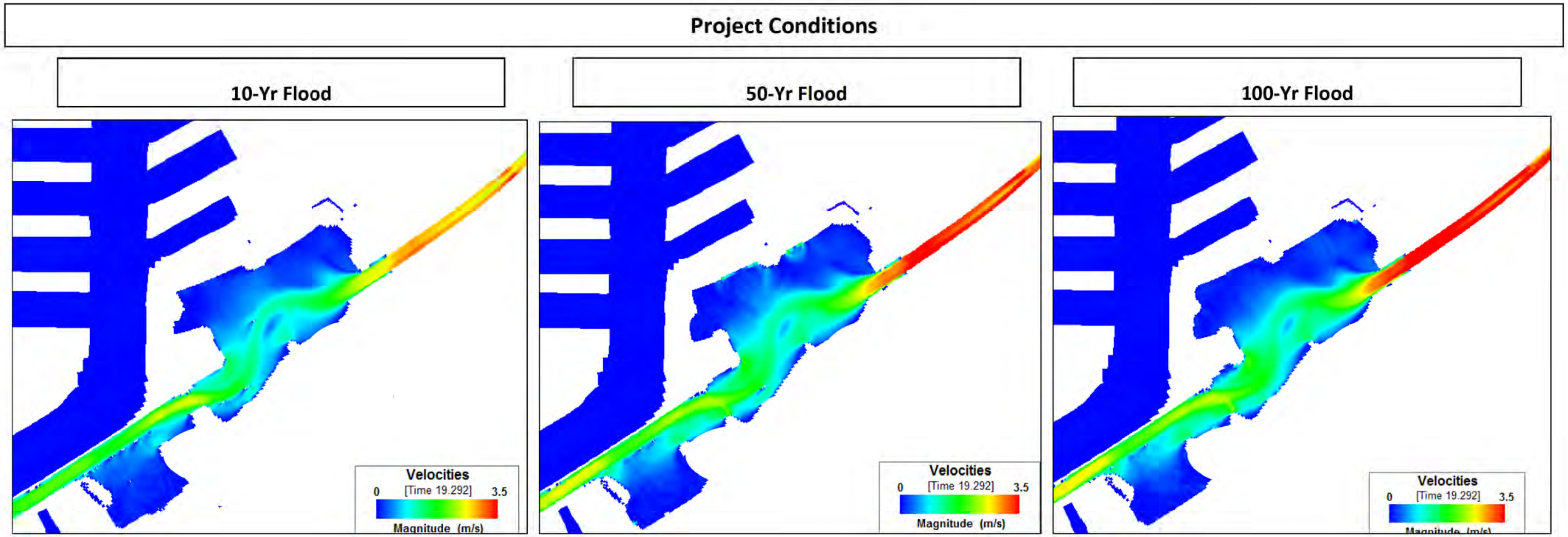
ESA PWA ran the 10-, 50-, and 100-year flood events through the EFDC existing conditions and project conditions models. Figure 18 shows the peak velocities across the site for the project condition. Figure 19 presents the direction of flow during the 100-year event under project conditions. The velocity vectors indicate that flow generally follows the realigned channel with some flow across the marsh. The velocity results show (from upstream to downstream):

- De-acceleration of flow as flow diverges onto the restored wetland floodplain downstream of Culver Blvd
- Low velocity flow and inundation in north Area A adjacent to the proposed Area A levee
- Low to medium velocity flow adjacent to the Culver levee on the south side of the realigned channel
- Flow acceleration as flow converges at the west end of Area A/Area B upland peninsula
- Medium velocity flow in West Area B adjacent to the channel
- Low velocity flow around the perimeter of West Area B and the proposed West Area B levee
- Flow acceleration at the downstream end of the project where flow re-converges into the channel downstream
- Downstream channel velocities comparable for existing and project conditions

Figure 20 presents peak velocities and shear at key locations across the site for the 100-year event under project conditions. Figure 20 also includes a table listing the permissible shear stress (i.e., critical shear stress above which erosion occurs) for a range of vegetation, soil, and armoring from the literature (Fishenich 2001). Peak modeled shear stresses for the 100-year event are generally within the range of permissible shear stress for native vegetation. The results indicate that vegetated wetland along the channel banks will experience some erosion. Peak shear stress in the channel and at the toe of the channel bank is generally at or above the critical shear for erosion of alluvial silt (colloidal). Some channel bed and bank erosion are therefore expected during the 100-year event.

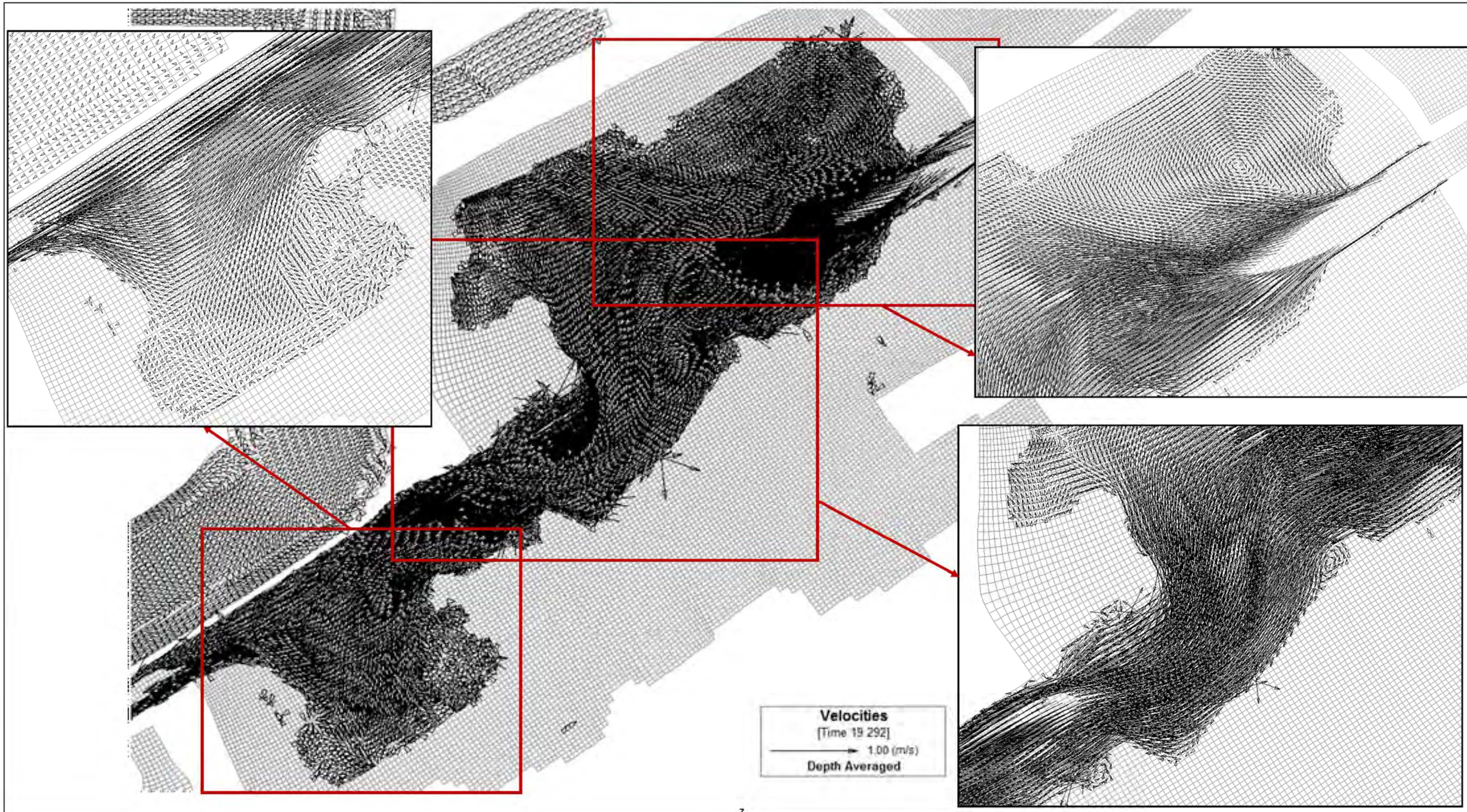
These results were used to develop the preliminary armoring plan included in the PDR. Soil samples and cores are being collected and analyzed for erosion properties. Further analysis of potential erosion rates and amounts will be performed in subsequent analyses based on soil erosion properties.

Figure 21 compares the peak water level profiles for the HEC-RAS and EFDC models for the 100-year event. The EFDC model does not include the bridges upstream of the site which are included in the HEC-RAS model, so the water levels do not agree upstream. Within the project reach, the water surface profiles generally agree.



SOURCE: EFDC model

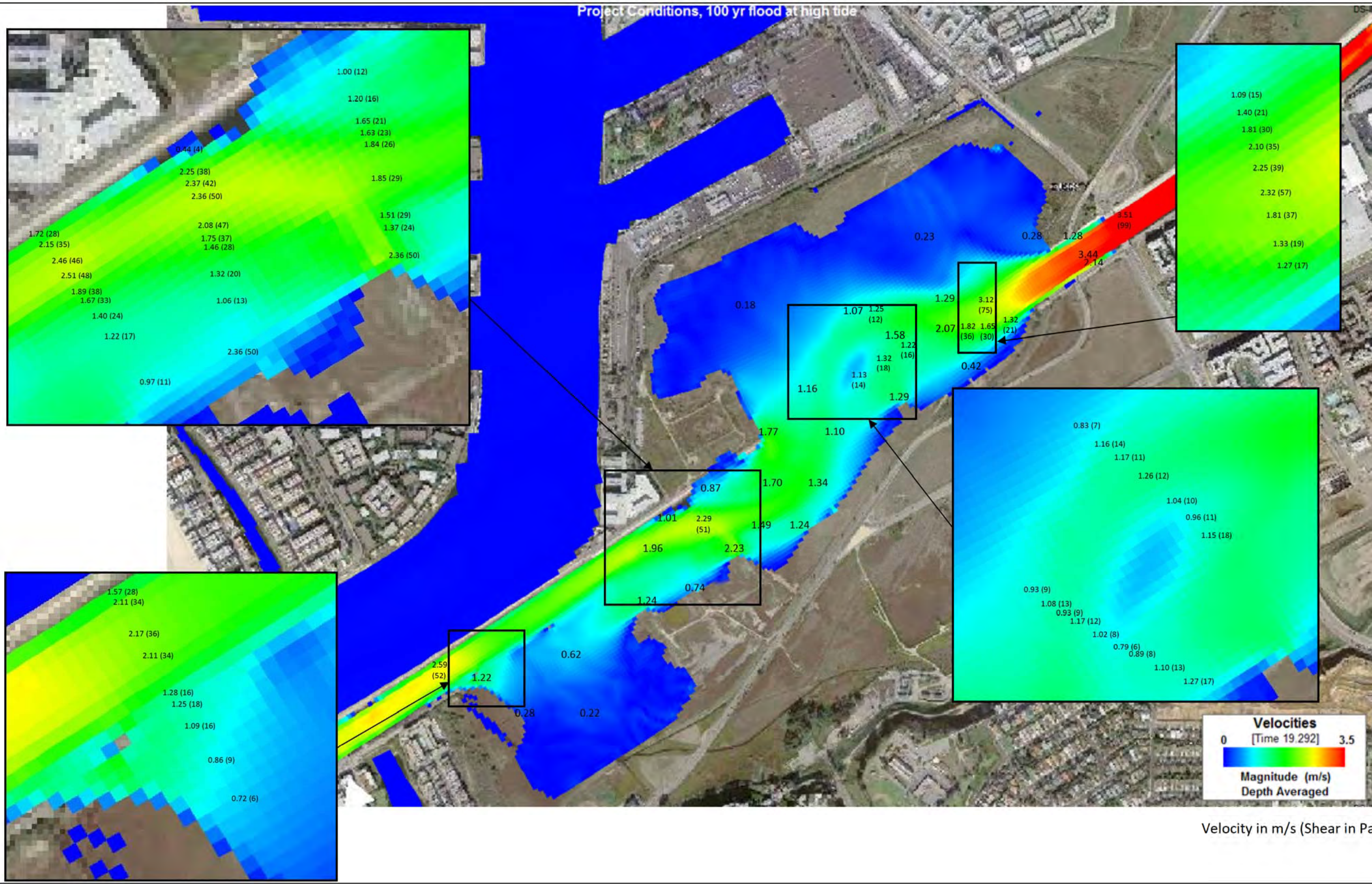
Ballona Wetlands . D120367
Figure 18
Project Conditions
Peak Velocities



SOURCE: EFDC model

Ballona Wetlands . D120367

Figure 19
Project Conditions, 100-Year Flood
Velocity Vectors at Peak Velocity



	Permissable Shear Stess in Pa (Fishenich 2001)
Alluvial silt (colloidal)	12
Reed plantings	5 - 29
Short native and bunch grasses	34 - 45
Long native grasses	57 - 81
Turf (Class A - C)	48 - 177
Rip rap - 6"	120
Rip rap - 24"	484

Velocity in m/s (Shear in Pa)

SOURCE: EFDC model

Ballona Wetlands . D120367

Figure 20
100-Yr Peak Velocity and Shear

ESA PWA

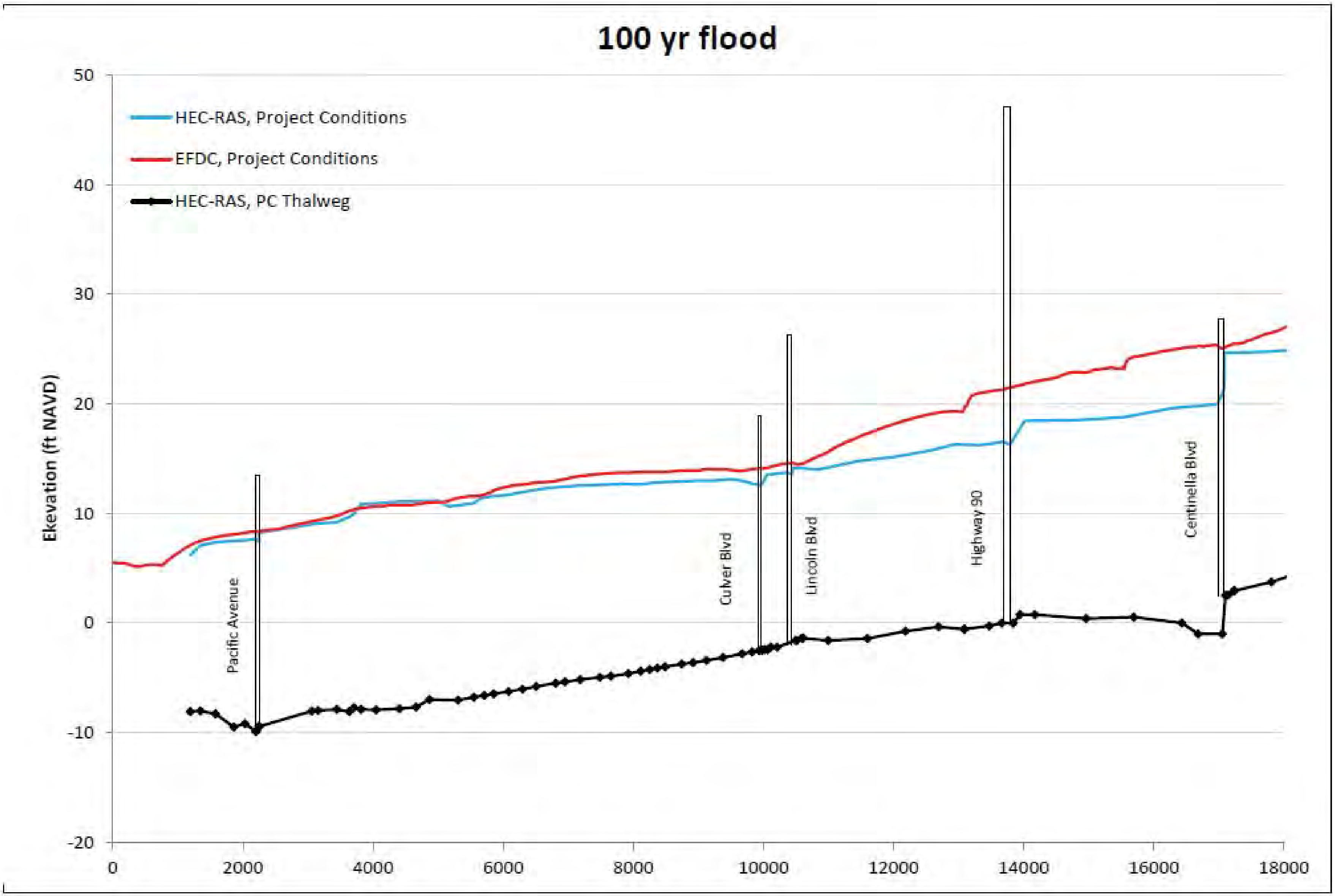


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Figure 21

HEC-RAS and EFDC 100-Yr Peak Water Level Profiles

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5. SEDIMENT TRANSPORT ANALYSIS

To evaluate sediment transport conditions in the project reach of Ballona Creek under existing and project conditions, we reviewed existing sediment data and studies for the channel and developed a sediment transport model based on the HEC RAS one-dimensional hydraulic model described above. For this preliminary evaluation, we ran the model for one representative flow event using available sediment data. Subsequent analyses will consider additional flow scenarios and incorporate additional sediment data based on recent sediment sampling from the project area.

Approximately 80% of the 130 square mile Ballona Creek watershed (Figure 1) is densely urbanized area with a high degree of impervious surfaces and low potential for sediment generation. The remaining 20% of the watershed is comprised of several steep headwater canyons on the southerly slopes of the Santa Monica Mountains with natural hillsides and urbanized valley bottoms. Many of the larger canyons contain debris and sediment collection basins which impound much of the sediment generated from the hillsides thus limiting the sediment supply to Ballona Creek as well as filtering out large diameter sediment. Samples collected by the USACE (2003) indicate that Ballona Creek sediments are primarily comprised of sand and silt (65% and 20% respectively) with small quantities of gravel (15%) based on a composite GSD. The size and quantity of sediment delivered to the Ballona Channel, along with the channel shape and profile slope, influences channel dynamics and flood performance for large, infrequent events, and governs the long term deposition and degradation regime in the channel.

Ballona Creek transitions from a concrete bottom channel to an earthen channel with concrete banks just downstream of Centinela Avenue. This location is also a major grade break in the channel profile, transitioning from a slope of 0.2% to a 0.09% slope. Based on a comparison of the channel profile between 1959 as-built plans from the Los Angeles County Flood Control District and topographic channel surveys conducted for this project (PSOMAS 2012), some sediment deposition has historically occurred in the channel downstream of this transition (Figure 22). This is likely due to the combination of the increase in channel roughness and the decrease in channel slope which decreases velocities in the channel thus reducing the channel's capacity to transport incoming and in-situ sediment. The proposed project is located downstream of this location in the low-energy, tidally-influenced zone of the Ballona Creek system.

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Ballona Wetlands. D120367

Figure 22
Bed Accretion in Ballona Creek (1959 and 2012)

5.1 SEDIMENT TRANSPORT MODEL

A preliminary sediment transport analysis was conducted using the sediment transport routines in HEC-RAS. The purpose of this analysis was to evaluate potential effects of the proposed Ballona Creek project on sediment transport within the project area and adjacent reaches of the channel based on a representative flow event. Potential impacts could include sediment deposition that could reduce flood conveyance capacity, or excessive scour that could cause channel and bank erosion. Subsequent analyses will evaluate these potential impacts in more detail for a broader range of flow conditions, including extreme flood events.

5.1.1 Sediment Data

Two primary forms of sediment play a large role in sediment transport processes in riverine systems: suspended sediment load, and bed sediment load or bedload. Respectively, these constituents represent the incoming sediment to a channel reach that remains in suspension (smaller particles), and the load of sediment that is mobilized along the channel bed by the incoming flow (larger particles). Together, these components comprise what is known as the total load of sediment being transported in the channel. Suspended sediment measurements are easy to obtain, and standard sampling methods have been widely applied in fluvial systems. However, bedload measurements are more difficult to obtain, and the techniques are generally less reliable than those used to sample suspended load. Therefore, bedload is often assumed to be a percentage, or range of percentages, of the total load. This percentage can be used to estimate total sediment load based on measured suspended sediment data (Turowski *et al* 2010). For this study, the fraction of bedload contributing to sediment transport was estimated to be about 10%, using documented values for California rivers as described in Section 5.1.1.3 below.

5.1.1.1 Grain size distribution

As part of the Ballona Creek Sediment Control Management Plan (USACE 2003a), the USACE collected a series of 20 sediment samples from Ballona Creek and its tributaries, and analyzed the samples for GSD. A composite GSD for the creek was derived for sediment transport analyses as summarized in Table 11.

Table 11 Representative Grain Size Distribution Curve for Sediment in Ballona Creek

Sediment Class	Grain size diameter range (mm)	Geometric mean diameter[1] (mm)	% Finer	% of Total
Silt	0.004 - 0.0625	0.02	20%	20%
Very fine sand	0.0625 - 0.125	0.09	25%	5%
Fine sand	0.125 - 0.25	0.18	40%	15%
Medium sand	0.25 - 0.5	0.35	56%	16%
Coarse sand	0.5 - 1	0.71	73%	17%
Very coarse sand	1 - 2	1.41	85%	13%
Very Fine Gravel	2 - 4	2.83	95%	10%
Fine Gravel	4 - 8	5.66	100%	5%

[1]Geometric mean represented by equation $\sqrt{(d_{max}*d_{min})}$

The composite GSD from the USACE data was used for the sediment transport analyses conducted in this study.

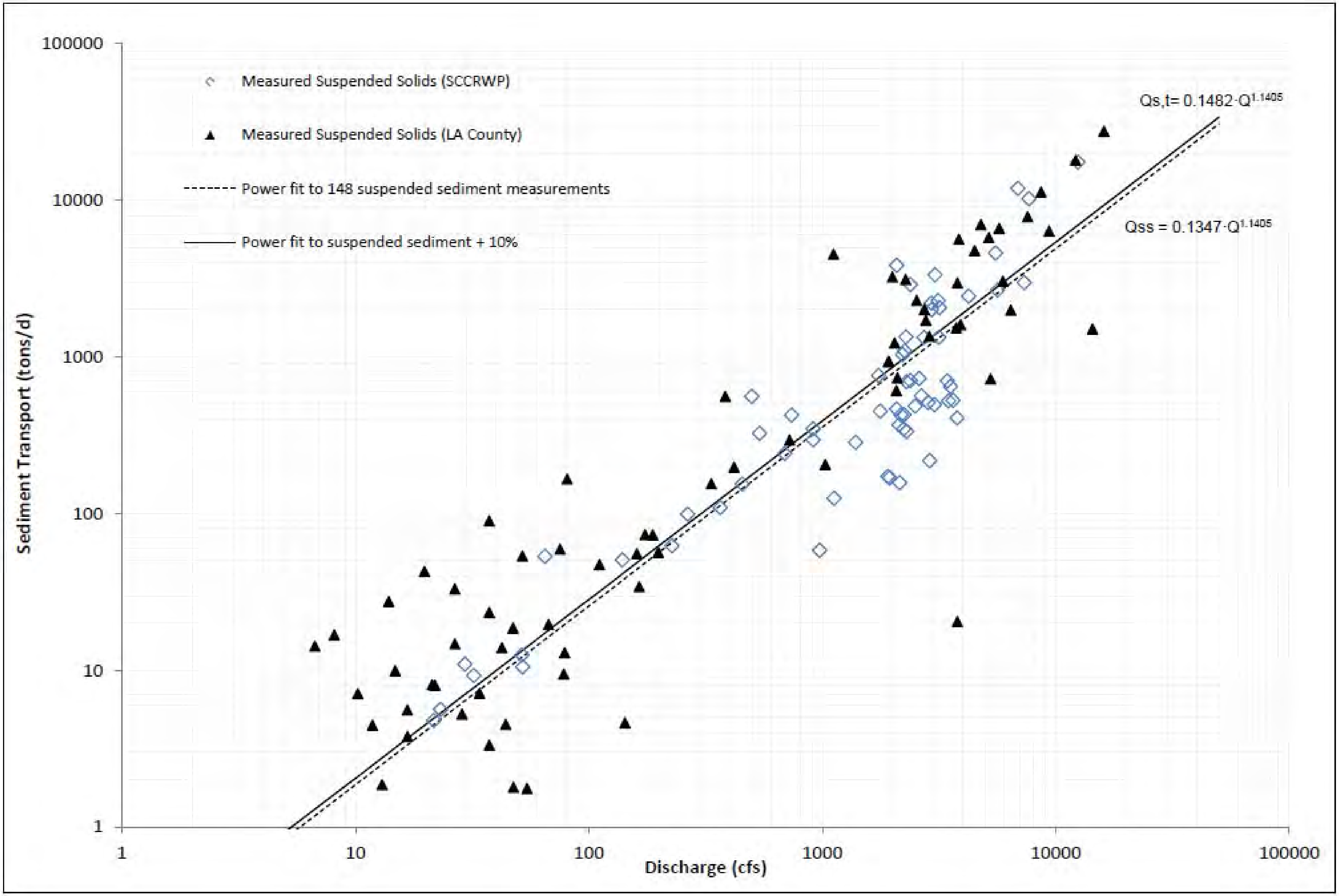
5.1.1.2 Suspended sediment data

Several water quality monitoring stations have been installed on Ballona Creek to evaluate total maximum daily loads (TMDLs) of various constituents affecting water quality in the Creek. The LACDPW has operated a monitoring station (S01) on Ballona Creek upstream of Sawtelle Boulevard since 1997 and the Southern California Coastal Water Research Project (SCCWRP) organization operated a mass emissions station (ME05) near the same location from 2001-2004. These monitoring stations were used to collect data for a number of water quality constituents including milligrams per liter (mg/L) of suspended sediment. Daily suspended sediment data in mg/L were provided by the LACDPW at S01 for 78 storm events from 1999-2011. These data did not include flow measurements at the time of the collected samples. For relating discharge to these suspended sediment data, it was assumed that the sample was collected near the peak daily flow measured at the LACDPW streamflow gage near Sawtelle (gage F38C-R). Additionally, data for 70 suspended sediment samples collected for 7 storm events at ME05 were provided along with measured flow data at the time of sampling. The total 148 samples were converted from a concentration (mg/L) to a loading rate (tons/day) by multiplying the discharge by the concentration and converting to the appropriate units. A suspended sediment rating curve relating suspended load (Q_{ss}) to discharge (Q) was created by fitting a power function to the measured data. The suspended sediment rating curve is shown in Figure 23

5.1.1.3 Bedload sediment fraction

In the absence of direct bedload measurements on Ballona Creek, the bedload fraction was estimated based on a review of typical values measured under similar hydrogeomorphic conditions. Several studies have been conducted to estimate the fraction of total load represented by bedload with estimates varying widely depending on characteristics of the river and sediment being analyzed. A commonly used ratio of bedload to suspended load of 10% has been assumed in several studies of coastal rivers in Central and Southern California (Willis and Griggs 2003, Warrick and Barnard 2012). Additional studies have been conducted using empirical and theoretical relationships as described in the following sections.

Based on previously collected data and existing studies for southern California rivers, it is apparent that for sand-bedded rivers with large watersheds, bedload fraction represents approximately 5-15% of suspended sediment load. For this analysis, it was assumed that the bedload fraction represents 10% of the suspended load and, therefore, that the total load supplied to the upper end of the channel is the suspended load yield plus 10%. The sediment rating curve representing the total load is presented in Figure 23.



SOURCE: LACDPW (S01 data), SCCWRP (ME05 data)
Note: Qss = suspended sediment load, Qs,t = total sediment load

Ballona Wetlands . D120367

Figure 23

Ballona Creek Sediment Rating Curves

ESA PWA

Inman and Jenkins 1999

Inman and Jenkins (1999) estimated streamflow and sediment characteristics in a study of the 20 largest rivers draining to the Pacific Ocean along the central and southern California coast including Ballona Creek. The study suggested that the fraction of the bedload component of total load is approximately 10% for rivers with watershed areas exceeding 500 km^2 (~190 square-miles), and approximately 15% for smaller rivers[3].

Brownlie and Taylor 1981

Brownlie and Taylor (1981) estimated the bedload fraction at the river mouth of the Santa Clara and Ventura rivers at 5.26%, and 13.6% respectively. Given suspended load measurements and particle size distribution of the bed material, the study applied the “modified Einstein” procedure of Colby and Hembree to estimate bedload fraction for 47 years of data from the Ventura River, and 25 years of data from the Santa Clara River. In the absence of GSD measurements, it was assumed, based on experience with Northern California rivers, that the bedload fraction for other rivers included in the study was 10%.

Turowski and others 2010

In a wide review studying the partitioning of sediment load between suspended and bedload, Turowski and others generated empirical relationships between bedload and suspended load transport rates using measured data reported by Nanson (1974), Williams and Rosgen (1989), Métivier *et al* (2004), and Meunier *et al* (2006). The relationship between bedload (G) and suspended load (L) in mg/s was described using the following equation:

$$G = \begin{cases} aL^b, & L \leq (a/c)^{1/(d-b)} \\ cL^d, & otherwise \end{cases}$$

By fitting this relationship to the suspended sediment data collected by the LACDPW and SCCWRP, using the range of values for parameters a, b, c, and d from the 25th percentile fit from the Turowski study, the average bedload fraction is estimated to be 9%.

5.1.1.4 Boundary Conditions

The following sections describe boundary conditions used in the HEC-RAS sediment transport model.

Sediment

Sediment boundary conditions are required at the upstream end of each reach included in the model characterize sediment discharge entering the system. In this case, the three reaches modeled are Ballona Creek and two tributaries: the Sepulveda and Centinela channels. No measured sediment data are available for the two tributaries and since the Sawtelle gage represents the majority of the watershed, it was assumed that only Ballona Creek upstream of the Sawtelle Gage delivers sediment to the lower reaches.

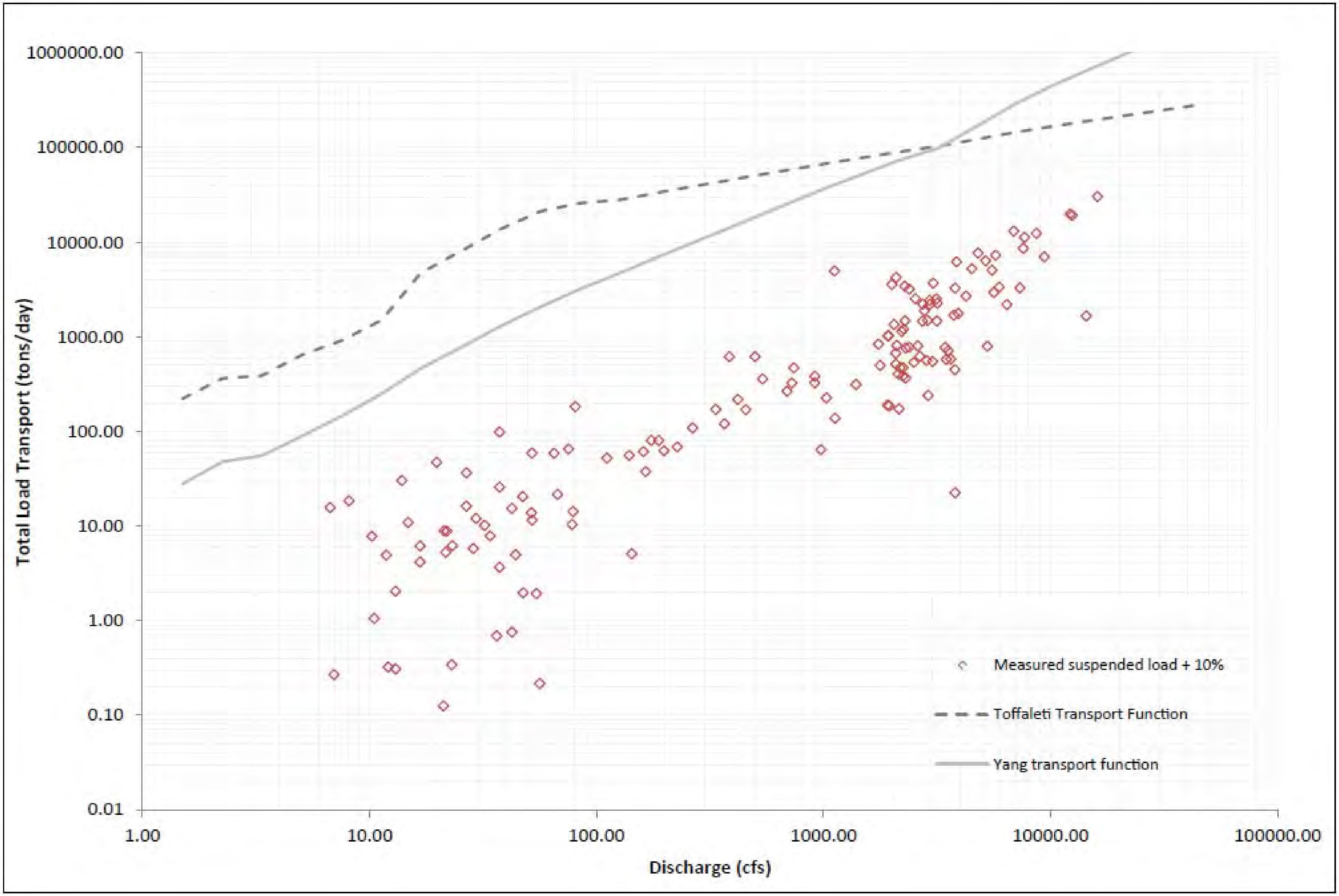
[3] The bedload fraction for smaller mountain streams has been seen to be considerably higher

For the sediment delivered by Ballona Creek, the sediment rating curve developed based on measured suspended sediment data at the Sawtelle gage was applied at the upstream end of the reach. The rating curve defines the total load in tons/day delivered for a given incoming flow rate. In addition to the total incoming load, each point on the rating curve requires an estimate of the GSD of the sediment load. To estimate the load composition, the sediment transport capacity tool in HEC-RAS was applied for the most upstream cross-section in the model. The transport capacity tool computes the hydraulics at a given cross section for a given flow rate or set of flow rates, then uses the hydraulic results to calculate sediment transport capacity and load composition for each flow rate profile in the model based on the GSD of the sediment at that cross section and a user-selected sediment transport function. The composite GSD from the USACE (2003a) was applied and two transport functions were selected to evaluate transport capacity: Yang, and Toffaleti. Of the transport functions available in HEC-RAS, these two methods were derived using sediment and hydraulic conditions that most closely resemble Ballona Creek. A comparison of the system parameters for the two transport functions used and corresponding features of Ballona Creek is summarized in Table 12.

Table 12 Ballona Creek Channel and Sediment Properties vs Those Used in Yang, Toffaleti

	Ballona Creek	Toffaleti (field)	Yang (field-sand)
Diameter range (mm)	0.004 - 8	0.062 - 4	0.15 - 1.7
D_{50} (mm)	0.5	0.095 - 0.76	N/A
Channel width (ft)	150 - 300	63 - 3640	0.44 - 1750
Channel Depth (ft)	22	N/A	0.04 - 50
Channel slope (ft)	.0009 - 0.002	0.000002 - 0.0011	0.000043 - 0.028
Velocity (ft/s)	5 - 20	0.7 - 7.8	0.8 - 6.4

As described above, the HEC-RAS transport capacity tool provides estimates of total transportable load at a given cross-section. This represents the total load that the reach would be capable of transmitting without any limitation on sediment delivery. A comparison of the total load capacity over a range of flows for the Yang and Toffaleti transport functions and the estimated total load transported near Sawtelle Boulevard (i.e. measured suspended load + 10% for bedload) is shown in Figure 24. This figure indicates that, based on the hydraulic conditions of Ballona Creek at Sawtelle including the channel shape and shear stresses and velocities incurred, the channel has substantially more transport capacity than the amount of incoming sediment. This condition is referred to as a “supply-limited” sediment regime. It is evident that the high degree of urbanization and the debris and sediment detention basins in the undeveloped segments of the watershed result in low sediment delivery rates in the Ballona Creek watershed.



SOURCE: LACDPW (S01 data), SCCWRP (ME05 data)

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Figure 24

Theoretical Sediment Transport Capacity (Yang, Toffaleti)
Compared to Measured Sediment Data

Discharge, Stage, and Temperature

For the discharge boundaries, one flow event was modeled to estimate scour and deposition behavior under a representative geomorphically-significant flood event. For southern California streams, Q_5 typically represents a channel forming discharge as it represents the combination of flow magnitude and frequency that make it most significant in affecting the long-term channel geometry (Coleman et al, 2005). Therefore, a Q5 event was selected as the representative event for preliminary sediment transport modeling.

To construct the quasi-unsteady hydrograph required for the HEC-RAS sediment transport routine, flow hydrographs were extracted from the HEC-HMS model developed by the USACE (2010a). Hydrographs were assembled for flow at the upper end of the three modeled reaches. The time steps for the hydrographs were revised from the raw output, which had a time step of 1-minute, to a more computationally efficient 30-minute time increment. Basins in the HEC-HMS model that add flow to Ballona Creek at the tributary confluences were added to the upstream end of their respective tributary to simplify the number of boundary conditions required and remain consistent with the total flow generated by the watershed model. A summary of the HEC-HMS basins used to develop the quasi-unsteady hydrograph for the 5-year flood is included in Table 13.

Table 13 HEC-HMS Basins Used to Construct Q_{100} Hydrographs for Sediment Transport Analysis

HEC-RAS Boundary	HEC-HMS Basins used	Description
Ballona Creek at Sawtelle Boulevard	JR530	Junction upstream of Sepulveda tributary confluence
Sepulveda Channel	JR490	Junction upstream of Ballona confluence
	R490W490	Basin draining to Ballona/Sepulveda confluence from west side of Ballona channel
	R530W530	Basin draining to Ballona/Sepulveda confluence from east side of Ballona channel
Centinela Channel	JR590	Junction upstream of Ballona confluence
	R590W590	Basin draining to Ballona/Centinela confluence from east side of Ballona channel
	R580W580	Basin draining to Ballona/Centinela confluence from west side of Ballona channel

A tide level of 2.6 feet NAVD, which corresponds to mean tide level (MTL) at Ballona Creek, was selected as the downstream stage boundary for the model run. This is a relatively low tidal boundary and represents a conservative assumption with respect to scour potential which is larger under lower tides and a steeper hydraulic gradient. For the temperature boundary condition, a uniform temperature of 60 °F was assumed for the entire length of each hydrograph.

5.1.1.5 Initial Conditions

Three sets of data are needed to define the initial conditions of a sediment transport model. The first of these are the “bed stations” which delineate the width of the channel that is susceptible to scour. The bed stations were set at the toe of the levees where the channel transitions from concrete bank to earthen bottom.

The second initial condition is the maximum scour depth at each cross section which defines the lowest elevation at which scour is expected. The underlying lithology of the site has not been examined at this time, and in lieu of additional information, 10 feet was used as a generic maximum depth of scour. Cross-sections were checked to compare simulated scour depths with the assumed maximum to identify locations where this assumption may need to be modified. For both existing and post-project conditions it was assumed that no scour could occur upstream of Centinela Avenue where the channel bottom is concrete.

The third initial condition of the model is sediment gradation. Sediment gradation for the site was characterized using the composite GSD from samples collected by the USACE (2003). This composite grain size was applied for the full length of the channel.

5.1.1.6 Sediment Transport Methods and Parameters

Due to the inherent uncertainty in sediment transport modeling, and the wide range of estimates furnished by the many transport functions, it is important to evaluate multiple transport functions to provide a range of plausible transport conditions. For this analysis, two sediment transport functions were utilized to evaluate the potential range of transport behavior. The two functions applied were the Yang (1973, 1984) total load function and the Toffaleti (1968) total load function. Both functions are appropriate for sand-bedded systems such as Ballona Creek. Initial review of the model results indicated that the Yang transport function produced more consistent results than the Toffaleti function with respect to likely scour and deposition behavior in Ballona Creek. All results presented with this report reflect HEC-RAS sediment transport modeling conducted using the Yang transport function. The Standard defaults were used for sorting and deposition: the Exner 5 three-layer bed mixing algorithm (Brunner, 2002), and the Rubey (1933) fall velocity equation, respectively.

5.2 RESULTS AND DISCUSSION

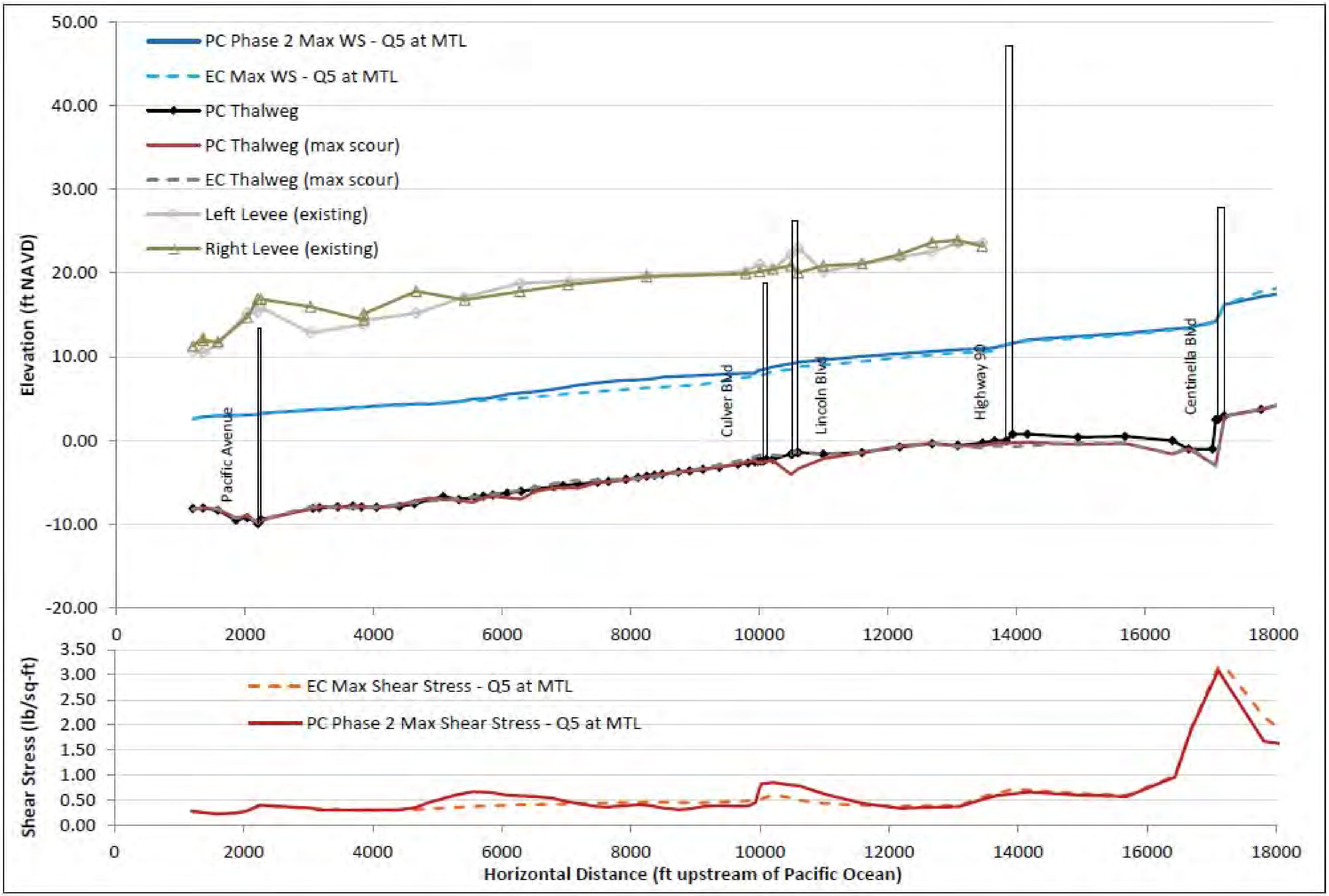
5.2.1 Existing Conditions

For the Q5 design event, the model results indicate that scour is likely to occur downstream of Centinela where the channel transitions from concrete to soft bottom. There is a significant grade break at this point in the channel which results in substantial energy dissipation focused at this location. This is evident in the thalweg of the channel through this transition which indicates that the channel has scoured up to 3.5 feet below the fixed concrete channel since the construction of the concrete channel. Model results indicate the channel is relatively stable downstream of this location, with slight aggradation occurring over the last mile of the reach where tidal levels dominate the hydraulic conditions. The initial and final thalweg profiles and maximum shear for existing and project conditions are shown in Figure 25.

The scour predicted by the model extends further downstream than indicated by the comparison between the design channel and the existing channel shown in Figure 22. This over-prediction of channel scour relative to the observed channel profile may be due to the over-representation of fine material contained in the composite GSD used for the transport analysis. A higher proportion of fines would result in higher sediment transport, particularly on the falling limb of the hydrograph. To improve the accuracy of the sediment transport analysis, additional sediment samples will be collected over the length of the channel to improve our understanding and representation of grain sizes present in the channel for future analyses.

5.2.2 Project Conditions

For project conditions, the results for the 5-year flood run are similar to existing conditions, with some scour occurring at the break in the thalweg profile downstream of Centinela. Additional scour is also indicated in the vicinity of the Lincoln Boulevard Bridge, where shear stress is increased under project conditions as the flow transitions into the project area. This result is consistent with hydraulic modeling results that reflect increased flow velocity upstream of the project under project conditions, and will be examined further to evaluate the potential need for design modifications in response to increased shear stress at this location. The profile and shear stress results of the project conditions are shown compared to existing conditions in Figure 25.



NOTE: Results derived using Yang transport function in HEC-RAS

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Figure 25

Existing and project conditions bed change and shear stress for Q5

6. GEOMORPHOLOGY

ESA PWA performed preliminary geomorphic analysis to inform the Preliminary Restoration Design and to assess how the site will develop and evolve over time in response to the restoration and physical processes. The geomorphic analyses rely on available existing and historic site data, reference site information, and empirical relationships, supported by the preceding hydraulic and sediment transport modeling analyses.

6.1 HISTORIC GEOMORPHOLOGY

A brief discussion of the geomorphology of the historic Ballona Wetlands system is included for context. A more complete assessment of the site evolution over geologic time is included in the Ballona Wetlands Existing Conditions Report (PWA and others 2006). Historic conditions and ecology at the time of the 1884 historic map are described in detail by Dark and others (2011). The existing site conditions and physical processes differ significantly from historic conditions (e.g., fill placement, construction of the flood control channel, urbanization of the watershed). The restoration is designed to function in response to the current hydrology and physical conditions and constraints rather than historic conditions.

Figure 26 shows a conceptual model of the pre-historic evolution of the Ballona estuary over an extended geologic time frame (Altschul, 2003). This geologic evolution shows:

- The estuary formed through inundation of the coastal plain during rates of rapid sea-level rise (7000-5000 years before present or BP).
- The Los Angeles River intermittently drained to the Ballona estuary, delivering sediment to the estuary. There was frequent switching of its course between Long Beach and Ballona Creek.
- Longshore sediment transport built a sand bar across the estuary as sea-level rise stabilized (4000 BP).
- Sediment from the Los Angeles River progressively filled in the estuary and formed wetlands (4000-200 BP).

Figure 27 (Grossinger and others 2011) and Figure 28 (Dark and others 2011) show the historic ecology of the Ballona Creek wetlands and watershed in 1850. During the 1825 flood, the course of the Los Angeles River avulsed to its current location with its mouth at Long Beach, where it was channelized between 1884 and 1939. Storm flows and sediment delivery from the smaller Ballona Creek watershed were likely reduced after the avulsion of the Los Angeles River. The mouth of the Ballona wetlands at this point in history was constricted and seasonally closed due to longshore sediment transport, reduced tidal flows, and possibly reduced fluvial storm flows following the avulsion of the Los Angeles River (Dark and others 2011, Jacobs and others 2010). The historic wetlands included a salinity range from brackish to salt marsh, with large areas of high intertidal flats or salt pans. The wetlands were likely inundated by creek discharge during larger storm events. During the dry season, the wetlands likely experienced limited tidal inundation and circulation due to the restricted inlet and evaporative non-tidal conditions when the inlet was seasonally closed.

The Existing Conditions Report (PWA and others 2006) includes a detailed discussion of existing site conditions. The existing flood control channel and urbanized watershed have significantly modified the hydrology and sediment processes of the Ballona Wetlands.

Appendix 2 shows a timeline of anthropogenic modifications to the Ballona Wetlands, which include:

- **1939:** Ballona Creek flood control channel and levees were constructed, disconnecting the remaining wetlands in Areas A, B and C from tidal and fluvial inundation and sedimentation. The leveed wetlands in Area B may have subsided due to oil extraction.
- **1957:** Marina del Rey harbor was constructed by dredging wetlands to the north of Ballona Creek. Between 10 and 15 ft of dredge spoils were placed over the wetlands in Areas A and C. Jetties were constructed for the Marina del Rey entrance channel. Offshore of the mouth, a shore-parallel breakwater was constructed which reduced wave penetration into the marina. These activities had significant impacts on the littoral sediment transport pathways.

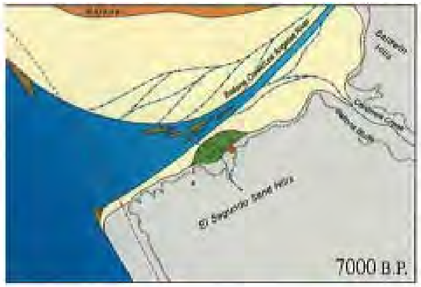
6.2 GEOMORPHIC ANALYSES

This section describes geomorphic analyses of Ballona Creek channel sizing (hydraulic geometry), deposition, wetland accretion, and coastal sediment transport. These analyses inform the projections of likely geomorphic evolution discussed in Section 6.3.

6.2.1 Hydraulic Geometry

Hydraulic geometry provides an estimate of the equilibrium channel size at various locations, in response to the tidal and fluvial hydraulic influences, as well as sediment availability. It allows prediction of the long term channel width, depth, and cross-sectional area. Empirical hydraulic geometry relationships between channel size (cross-section dimensions) and flows provide an estimate of the equilibrium channel dimensions that would form in sediment transport-limited conditions (i.e., with enough sediment in the system to deposit in the channel and reach equilibrium with tidal and fluvial flows). **Appendix 3** contains an analysis of the Ballona Creek channel hydraulic geometry, which is summarized below.

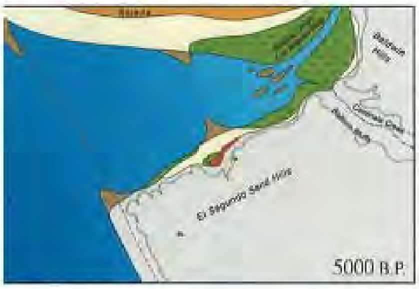
Figure 29 shows the existing Ballona Creek channel cross-section compared to predicted equilibrium dimensions for a natural unleveed creek channel from hydraulic geometry relationships. The existing Ballona Creek flood control channel is oversized compared to predicted equilibrium dimensions. This suggests that the existing channel is depositional during normal tidal conditions and more frequent channel-forming storm flows, but that deposition is limited by sediment supply.



7000 B.P.

Environment
- The coastline is 150 meters west of its current location
- Drainage system bifurcated into numerous tributaries flowing among freshwater marshes
- Mudflats and sandbars are created at the land-sea interface

Culture
- Earliest human settlement in the Ballona occurred ca. 6750 B.P.
- Small mobile groups camp on the bluff tops
- Early coastal sites are now submerged off shore



5000 B.P.

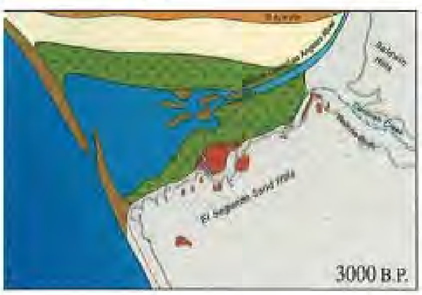
Environment
- Sea level rise slows
- "Ballona Bay" becomes established
- Land spits develop where sediment from Ballona Creek is deposited, and wave action deposits sand

Culture
- Residential base camp established at LAN-62
- Small mobile groups continue to camp on the bluff tops

4000 B.P.

Environment
- Sea level stabilizes
- Alluviation in inner bay leads to mudflats and sandbars
- Salt marsh expands to outer bay
- Beach spit barrier nearly closes outer bay
- Oyster and jackknife clams disappear, replaced by horn snails indicative of fresh water

Culture
- Settlement pattern remains stable
- LAN-62 community grows slowly



3000 B.P.

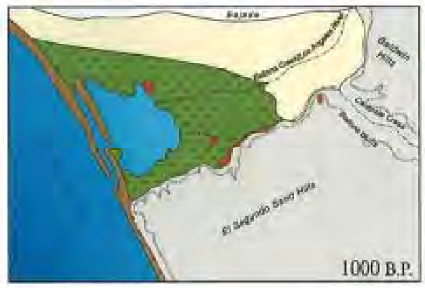
Environment
- Inner bay is replaced by intertidal deposits
- Coastal plain extends northward
- Salt marsh expands south
- Intertidal sandbars and mudflats migrate west

Culture
- Major settlement expansion on bluff tops and along Centinela Creek
- Desert traits replace coastal adaptation
- LAN-62 becomes year-round settlement

2000 B.P.

Environment
- Coastal plain continues to encroach on salt marsh to north
- Salt marsh expands to cover all sides of the bay and mouth of the creek
- Extensive intertidal, unvegetated mudflat develops

Culture
- Desert adaptation remains
- Year round settlement established along Ballona Creek (LAN-54)



1000 B.P.

Environment
- A double barrier develops
- Sedimentation from Ballona and Centinela creeks accelerate
- Salt marshes and mudflats expand

Culture
- Desert pattern gives way to coastal adaptation
- Year round sites established at the lagoon edge (LAN-47)
- Bluff tops largely abandoned
- Population concentrates at LAN-62

200 B.P.

Environment
- Sediments fill much of the lagoon
- Complex of sand islands and extensive salt and fresh water marshes develop

Culture
- Population congregates along lower Centinela Creek
- LAN-62 develops into a majc village
- *Rancheria* settlements are established along lower Centinela Creek (LAN-211/I-

Source: Statistical Research Institute (SRI)

Figure 26

Ballona Wetlands. D120367

Pre-historic Model of Ballona Estuary

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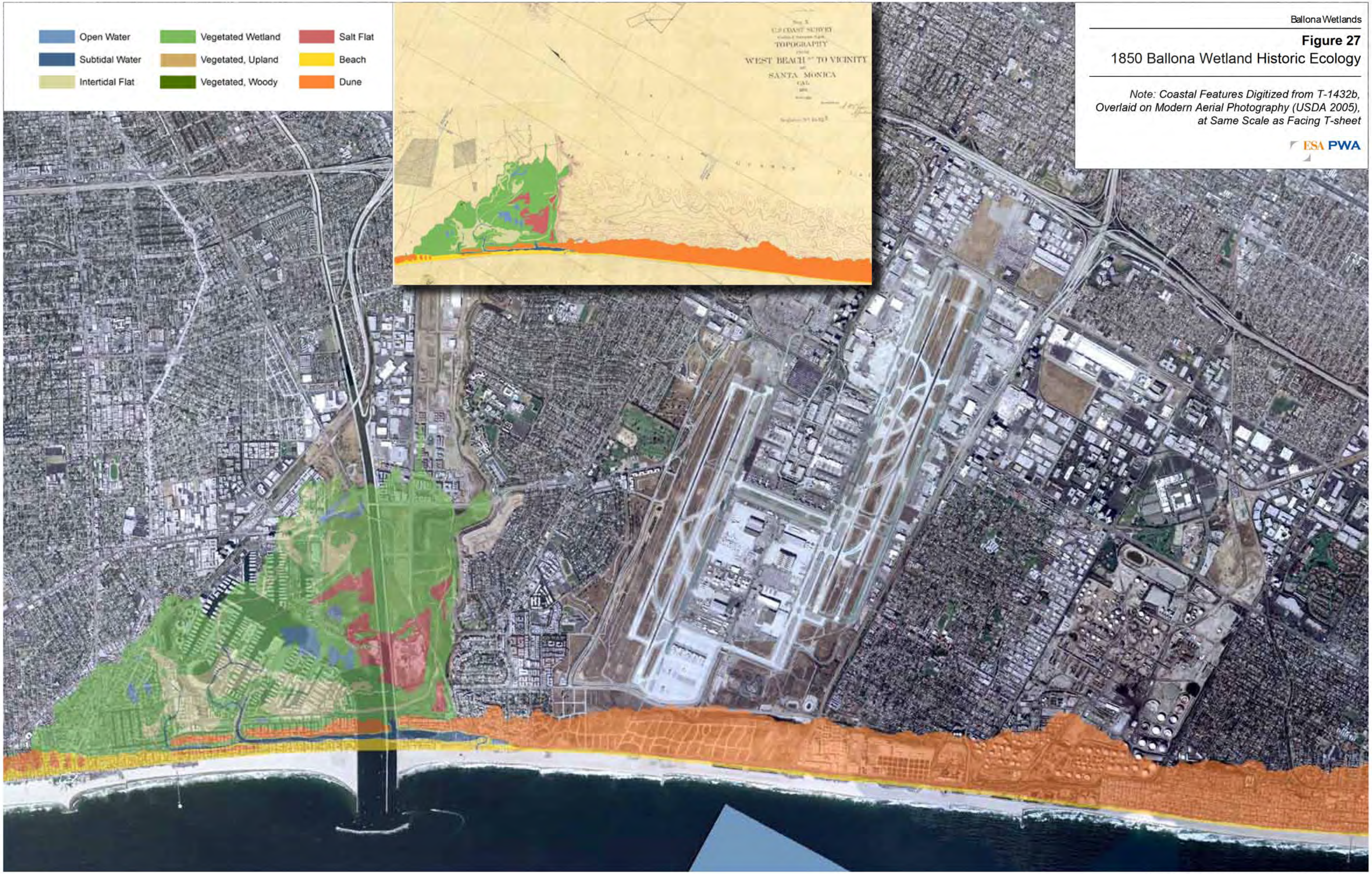
1:100,000



Ballona Wetlands

Figure 27

1850 Ballona Wetland Historic Ecology

Note: Coastal Features Digitized from T-1432b, Overlaid on Modern Aerial Photography (USDA 2005), at Same Scale as Facing T-sheet

Ballona Wetlands

Figure 28

1850 Ballona Creek Watershed Historic Ecology

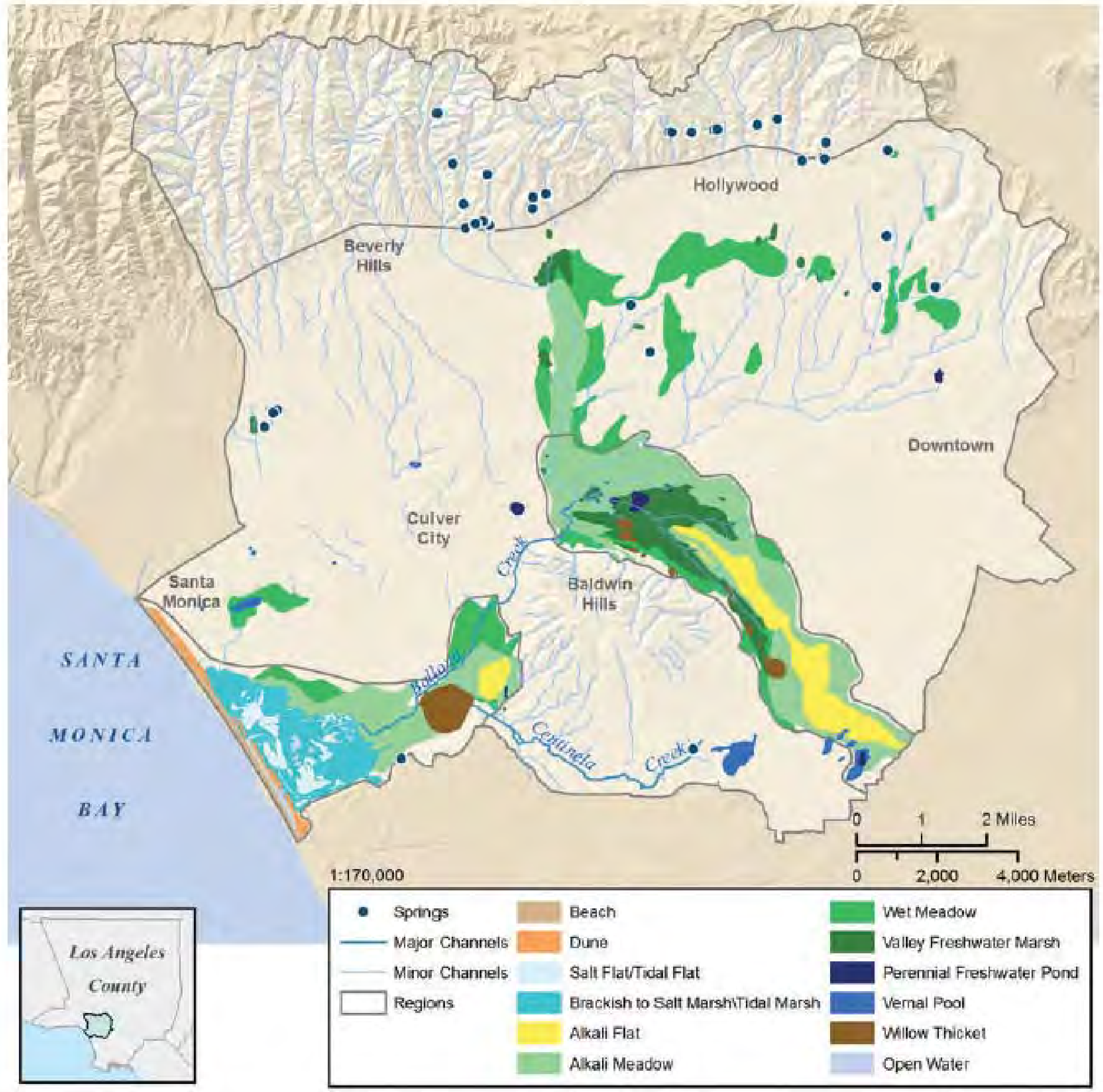
ESA PWA

A total of 174 unique wetland polygons were mapped comprising 14,149 acres (5,470 ha; TABLE 3). The dominant wetland types across the entire study area included alkali meadow (35%), valley freshwater marsh (10%), brackish to salt marsh/tidal marsh (9%), and alkali flats (8%). The watershed contained a wide diversity of wetlands ranging from vernal pools and alkali flats to wetland meadows and willow thickets (excluding willow-dominant riparian corridors). It is likely that our habitat map did not capture the total complexity of this landscape, due to a lack of documentation in the historical record, or inability to display using a habitat map. For example, textual citations describing features at a finer scale cannot be incorporated into a two-dimensional map, but lend depth to our understanding of habitat diversity. We hope to provide a cautioned insight into the complexity of this ecological system in the following pages.

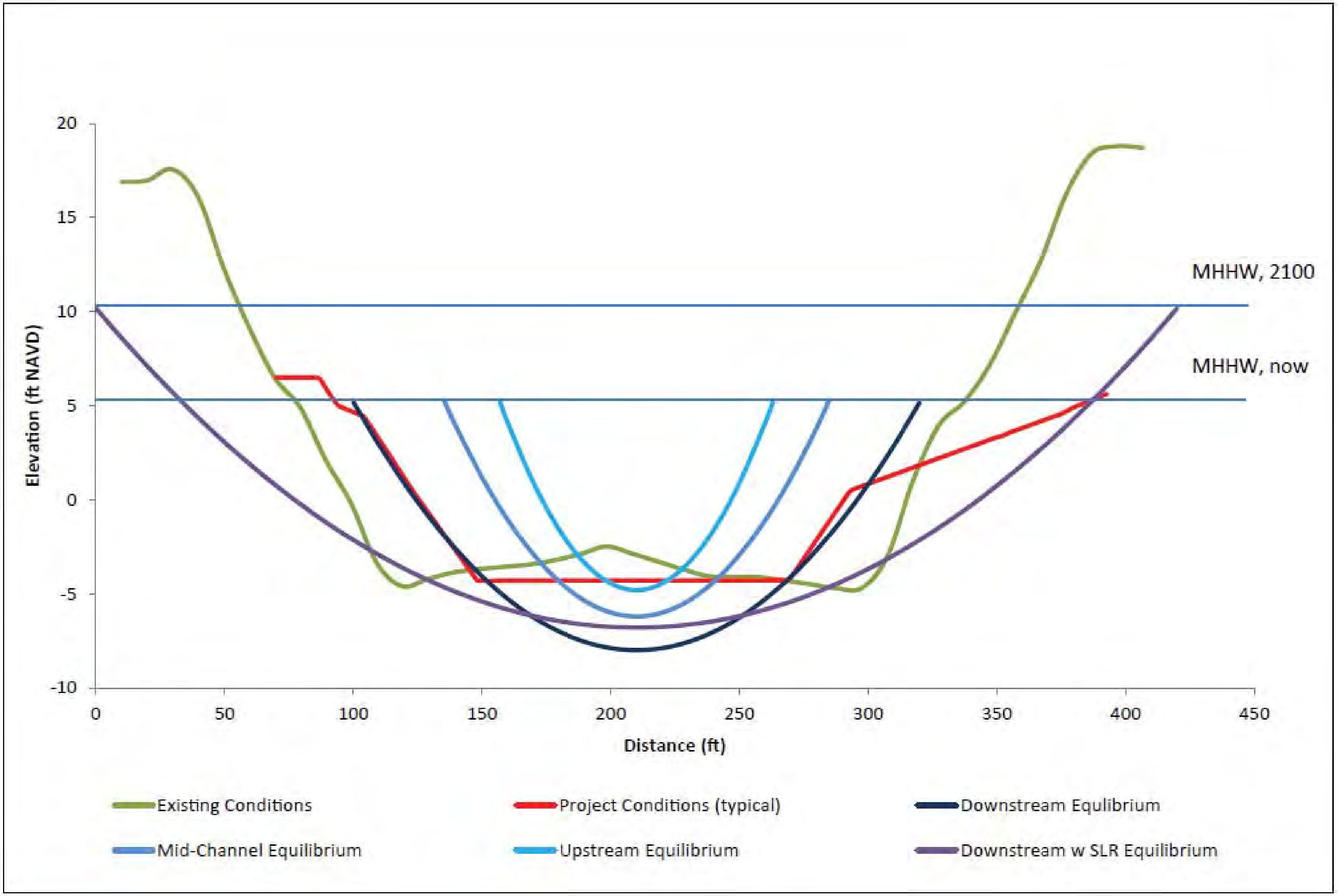
HABITAT CLASSIFICATION	UNIQUE WETLANDS	ACRES	HECTARES
ALKALI FLAT	5	1284	486
ALKALI MEADOW	21	5273	1915
BEACH	2	159	64
DUNE	8	187	76
OPEN WATER*	8	96	39
PERENNIAL FRESHWATER POND	8	110	45
SALT FLAT/TIDAL FLAT	15	423	171
SALT MARSH/TIDAL MARSH	20	1240	498
VALLEY FRESHWATER MARSH	35	1356	547
VERNAL POOL	15	260	105
WET MEADOW	24	3336	1351
WILLOW THICKET	13	425	173
TOTALS	174	14149	5470

*DOES NOT INCLUDE PACIFIC OCEAN

TABLE 3:
Summary of wetlands mapped on the Ballona Historical Ecology project.



F7-79



SOURCE: ESA PWA (2012)

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Ballona Wetlands. D120367

Figure 29
Ballona Creek
Hydraulic Geometry

With adequate sediment supply, the channel could fill in to the equilibrium dimensions. The predicted equilibrium dimensions therefore represent an estimate of a potential reduced cross-section. In subsequent analyses and design refinement, the project may consider a smaller "equilibrium" channel cross-section for the realigned channel (e.g., to encourage sediment deposition in the wetlands and reduce channel deposition, and to show that the estimated reduced cross-section maintains flood performance).

Figure 29 also shows predicted equilibrium dimensions with 59 inches of sea-level rise in 2100 (high end estimate per USACE 2011 and NRC 2012; see Section 2.3.2). In this scenario, the wetland area and volume of tidal flows (tidal prism) are larger and the equilibrium channel dimensions are closer to the existing channel dimensions.

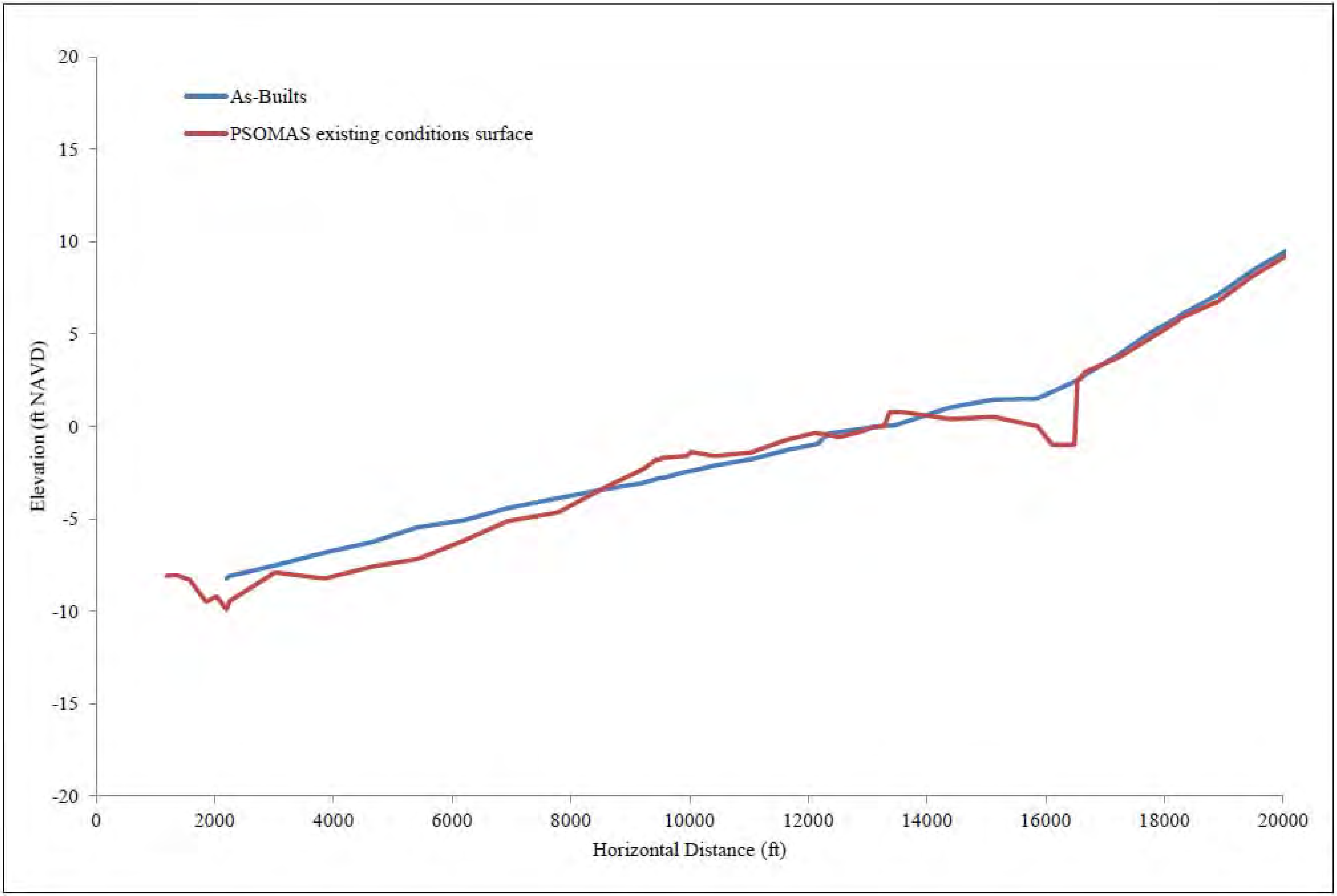
6.2.2 Channel Deposition

ESA PWA compared the 2012 channel bathymetry survey (Psomas 2012) to the 1959/1961 "as-built" channel survey to estimate net channel deposition (Figure 22). Table 14 shows the net amounts, volumes, and rates of deposition for the five reaches shown in Figure 22. The deposition rates are calculated from 1959 and also from the last major storm event, which was in 1994 (discharge greater than 10-year event), to capture the range of possible deposition sequences. The rate of deposition in the reach showing higher accretion (1,600 to 4,700 CY/yr) generally agrees with the estimated rate of watershed sediment supply (8,530 CY/yr, see Section 5.1.1). Figure 30 compares the thalweg profiles from the as-built survey and 2012 survey.

Table 14 Channel Deposition and Erosion Depths, Volumes, and Rates from 1959 to 2012

Reach	Depth (ft)	Volume (cubic yards)	Rate (ft/yr)	Rate (CY/yr)
Upstream fluvial scour reach (Centinella Blvd. to 2,300 ft downstream)	-4 to 0	-2,760	-0.2 to 0	-150 to -50
Downstream fluvial deposition reach (to 1,500 ft downstream of Culver Blvd)	0 to 3	85,330	0.1 to 0.2	1,600 to 4,700
Downstream tidal reach (to Pacific Ave.)	-2 to 2	17,570	-0.1 to 0.1	330 to 980
Creek mouth coastal reach (to end of south jetty)	3 to 9	43,700	0.2 to 0.5	820 to 2,400

Note Positive depths/volumes/rates indicate the depth/volume/rate of deposition; negative depths/volumes/rates indicate the depth/volume/rate of erosion. Rates are calculated between: 1) 1959 and 2012 and 2) 1994 (last major storm, discharge greater than 10-year event) to 2012 to give a range that accounts for the possible sequence of deposition. The accuracy of the volume and rate estimates is about +/-20% due to uncertain accuracy of the as-built survey.



SOURCE: USACE (2003); PSOMAS (2012)

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Ballona Wetlands. D2110367

Figure 30

Thalweg Profiles
1960 and 2012

The observed channel deposition patterns and other supporting analyses indicate the following sediment processes by reach for the soft-bottom channel (downstream of Centinella Blvd.):

1. Upstream concrete/soft-bottom channel transition scour reach: a scour hole has formed below the transition from concrete to soft-bottom channel.
2. Upstream depositional fluvial reach: sediment (primarily silty sand) from the watershed and upstream scour reach is deposited in the existing channel, presumably during more frequent storm flows (i.e., up to 10-year events).
3. Downstream "stable" tidal reach: net accretion is lower in this tidal-dominated reach due to lack of sediment supply. Watershed sediment supply is typically deposited upstream in the "fluvial reach." This pattern is supported by water level data and hydraulic modeling, which show that storm flows up to the 5-year event do not affect tidal water levels or velocities in this reach.
4. Creek mouth coastal depositional reach: deposition observed at the channel mouth is likely due to sand transport from the coast into the mouth (see Section 6.2.4 below).

Sediment samples will be collected from the reaches identified above and analyzed for grain size to provide additional data for this assessment. Additional assessment of the effects of the project on the observed patterns of sediment deposition will be completed in subsequent analyses.

6.2.3 Wetland Accretion

The restored wetlands are expected to accrete due to organic soil production (i.e., bioaccumulation in vegetated wetlands) and inorganic sediment deposition. Rates of organic accretion may range from 0.04 to 0.12 in/yr (1-3 mm/yr) (Stralberg 2011). A lower end rate of 0.04 in/yr (1 mm/yr) is expected for the tidal salt-marsh dominated habitat of the Ballona restoration. The rate of sediment deposition on the restored marshplain is limited by sediment supply and the frequency, period, and depth of inundation. ESA PWA modeled long-term sediment accretion assuming a constant low suspended sediment concentration of 50 mg/L, based on review of measured suspended sediment concentrations during storm events. Wetland accretion estimates and projected sea-level rise were applied to the preliminary grading plan (from the PDR) to model projected future wetland elevations and habitat zones (Figure 32).

Table 15 shows the volume and rates of modeled wetland sediment deposition. The modeled annual rate of wetland sediment deposition increases over time as the site becomes progressively lower in the tide frame.

The range of modeled wetland sediment deposition over time (160 cy/yr to 4,750 cy/yr per Table 15) is less than the watershed sediment supply rate (8,530 cy/yr or 6,520 m3/yr). Note that the watershed sediment supply rate includes both suspended sediment and bedload, whereas wetland deposition is expected to result primarily from suspended sediment deposition. Further assessment of deposition patterns in the wetland floodplain and channel will be performed in subsequent analyses considering suspended and bedload sediment transport. This preliminary comparison between the modeled wetland sedimentation rate and watershed sediment supply indicates that sediment supply may be adequate to support the modeled accretion shown in Figure 32 and higher rates of wetland deposition could possibly occur.

Table 15 Volume and Rate of Modeling Wetland Sediment Deposition

Sea-level rise scenario	Cumulative Volume (cy)	Incremental Volume (cy)	Sediment Volume (cy)	Organic Volume (cy)	Sediment Rate (cy/yr)	Organic Rate (cy/yr)
9 inches by 2030	12,500	12,500	2,980	9,520	160	530
19 inches by 2050	67,700	55,200	42,830	12,370	2,140	620
32 inches by 2070	141,700	74,000	59,860	14,150	2,990	710
59 inches by 2100	301,400	159,700	142,450	17,250	4,750	580

Note: All volumes are rounded

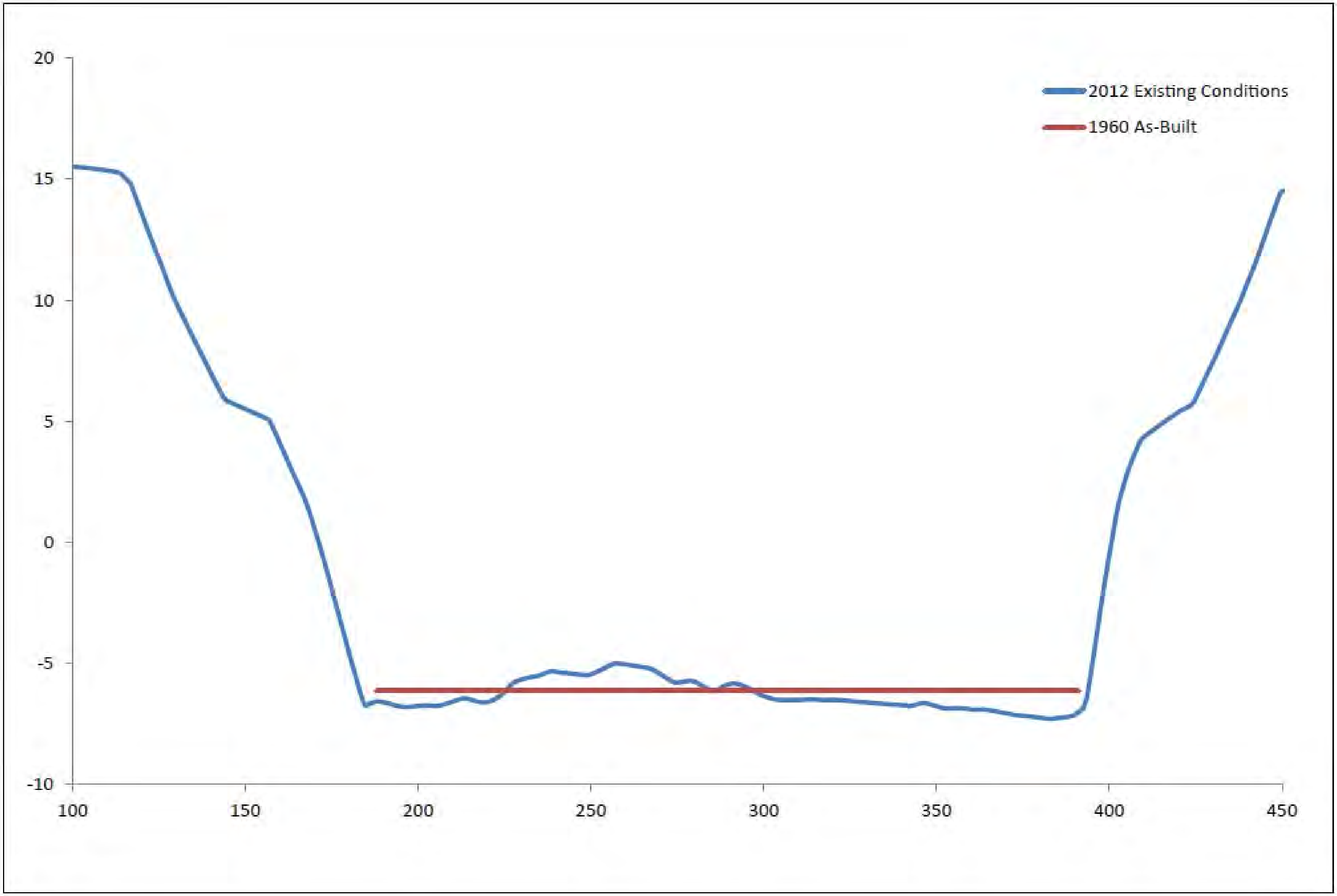
6.2.4 Coastal Sediment Transport

Available coastal sediment transport studies describe net longshore coastal sediment transport as being from north to south due to dominant north swells; however, south swells are also likely to cause transport from the south to north. Sediment transport is interrupted by the Marina del Rey harbor entrance channel and sand from the north is deposited in the harbor channel. A harbor channel maintenance dredging program for Marina Del Rey is in place, with the most recent channel dredging completed in 2012. The Ballona Creek channel mouth is not included in the harbor channel maintenance and has not been dredged since the 1959 county channel and levee improvements. A summary of available coastal sediment transport studies and analysis of recent dredging data are provided in **Appendix 2**.

Deposition in the dredged area downstream of the Ballona Creek channel mouth and south jetty is 7,650 CY/yr. This is substantially higher that the rate of deposition in the Ballona Creek channel mouth (820 to 2,400 CY/yr - see Section 6.2.2). The difference suggests that most of the sediment that accumulates at the mouth of the creek originates elsewhere and is deposited by longshore currents instead of being delivered by Ballona Creek. Mineralogical analysis could confirm this supposition.

ESA PWA observed waves from a small south swell propagating up the Ballona Creek channel on May 22, 2012. A shoal along the south jetty was also observed. The shoal extends approximately 600 ft downstream of the Pacific Ave. bridge (see Figure 22).This observation suggests that deposition in the Ballona Creek mouth could be associated with transport of sand from the coast into the mouth during south swells, forming a flood shoal at the creek mouth as is typical of coastal channels/lagoons. (Note that sediment samples will be collected and analyzed for grain size to confirm the shoal is sand.)

Figure 33 shows a cross-section at the Ballona Creek mouth/shoal with predicted equilibrium tidal channel dimensions (see Section 6.2.1). This indicates that the shoal has not reached equilibrium and sediment is likely to continue to deposit at the mouth under existing and project conditions. (Note that deposition would continue to decrease the cross-sectional area. However, the channel thalweg may be at equilibrium with the predicted tidal channel depth.)



SOURCE: USACE (2003); PSOMAS (2012)

ESA PWA

Ballona Wetlands. D120367

Figure 31
Tidal Reach Channel
Cross-sections

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SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habitat over time.

Ballona Wetlands. D120367

Figure 32a
Restored Habitat Zones

ESA PWA

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SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habitat over time.

ESA PWA

Ballona Wetlands. D120367

Figure 32b

Restored Habitat Zones

2030 Projection (9 in of sea-level rise)

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SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habitat over time.

ESA PWA

Ballona Wetlands. D120367

Figure 32c

Restored Habitat Zones

2050 Projection (19 in of sea-level rise)

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SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habitat over time.

ESA PWA

Ballona Wetlands. D120367

Figure 32d

Restored Habitat Zones

2070 Projection (32 in of sea-level rise)

J:\1793_Ballona\2100_v2.mxd

SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habitat over time.

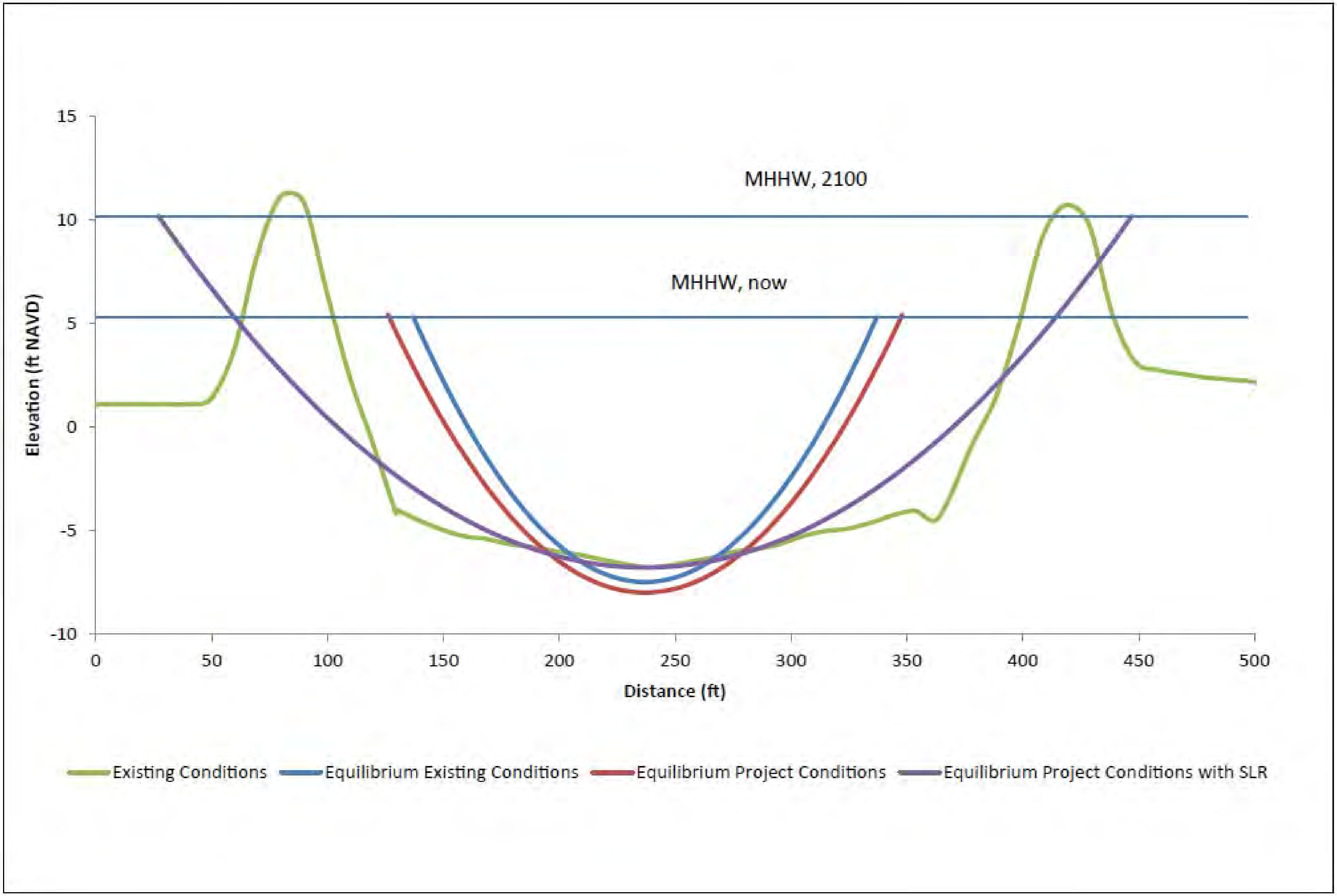
ESA PWA

Ballona Wetlands. D120367

Figure 32e

Restored Habitat Zones

2100 Projection (59 in of sea-level rise)



SOURCE: ESA PWA (2012)

ESA PWA

Ballona Wetlands. D120367

Figure 33

Ballona Creek Channel Cross Section at the Downstream Shoal

6.3 DISCUSSION OF SITE GEOMORPHIC EVOLUTION

The above analyses provide some indications on how the site will likely evolve in response to the restoration project, as well as future sea-level rise. The anticipated geomorphic evolution or physical response of the restored wetlands and channel to near- and long-term physical process is discussed below. Understanding the geomorphic evolution of the site is important for understanding the response of the restored wetlands, channel, and habitats to physical processes. This preliminary discussion will be refined in subsequent analyses based on additional data collection.

The current Ballona Creek channel represents the trapezoidal flood control channel constructed in the 1930s and improved in the 1960s. The channel has undergone minor changes in response to the flow and sediment regime over the past 50 years. There is evidence of some (1 to 4 ft) of channel incision (deepening) upstream, with deposition (0 to 3 ft) in the project reach and formation of a moderate sand shoal (about 5 ft high) at the Creek mouth. The channel banks are hardened, preventing changes in width or any channel migration. The removal of the hardened banks through the project reach will allow the channel to respond both vertically and horizontally over time. These changes are an important component in supporting the types of habitats important to the vegetation and wildlife species that the project will support. However, it is important that these changes occur within the footprint of the project, and not adversely increase flood or erosion hazards to adjacent infrastructure. This geomorphic assessment provides guidance on what types of changes might occur in the restored channel and wetlands and provides the basis for designing the project to allow for these changes to occur without impacting adjacent infrastructure. The preliminary understanding of site evolution discussed below indicates that the preliminary restoration design will support the desired habitat and flood management functions.

6.3.1 Net-depositional and sediment supply-limited system.

Under normal tidal conditions and more frequently occurring storm flows, the site acts as a depositional environment and sediment sink; however, watershed sediment supply is low and the rate of sediment deposition is slow. Under existing conditions, sediment carried by frequent storm flows is deposited in the soft bottom channel (starting at Centinella Blvd.) to approximately 2,000 ft downstream of Lincoln Blvd. Deposition and channel dimensions have not reached an equilibrium with the sediment transport capacity of the channel forming flows (approximately 1-year event; see Appendix 3). With the low rate of sediment supply (approximately 8,530 cy/yr or 6,520 m3/yr), the channel is unlikely to reach its equilibrium dimensions before a larger infrequent storm flow scours out the deposited sediment.

For restored project conditions, a slow rate of sediment deposition is expected to continue in the restored channel and upstream, with the potential for suspended sediment deposition in the restored wetland marshplain/floodplain.

While the project may decrease the size of the future channel (due to expanded flow area and reduced velocities), the rate of deposition is limited by sediment supply. Additional analysis of the channel with projected future deposition and SLR will be evaluated to investigate how deposition may affect flood performance. The predicted smaller equilibrium channel cross-section may be considered as the potential “minimum” cross-section to define a theoretical channel maintenance limit and/or as a design option for the realigned channel cross-section. Designing the realigned channel to have an equilibrium cross-section could possibly reduce channel deposition and encourage wetland deposition and accretion.

Note that previous estimates of watershed sediment supply range from 58,350 to 60,000 cy/yr (44,615 to 45,873 m3/yr) and appear to be based on the rate of sand deposition in the south entrance to the Marina del Rey harbor channel. Our analysis and estimates of watershed sediment supply and channel deposition indicate sand deposition at the creek mouth is due to coastal sand transport during south swells and that the watershed sediment supply is significantly lower (8,530 cy/yr or 6,520 m3/yr).

6.3.2 Channel dynamics during storm flow events.

During storm flow events, localized erosion of the restored vegetated channel bank is expected. Note that the channel bank will be armored in locations of high shear stress to reduce the potential for progressive erosion (e.g., at the first meander bend and flow convergence locations; see the PDR for more details). Some channel edge erosion will likely occur during flood events. However, erosion of the restored vegetated wetland marshplain/floodplain is expected to be limited because flow velocities across the marshplain are low (see Section 4.6).

Additional analyses of sediment erosion and deposition during larger storm flow events will be performed in subsequent analyses. Sediment samples are being collected from the site and Ballona Creek channel and the sediment erosion properties will be analyzed in a laboratory (Sedflume analysis of critical shear stress and rate of erosion). Additional hydrodynamic modeling of erosion and deposition during storm flow events will be performed using laboratory results. Model results will be incorporated into subsequent geomorphic assessments.

Based on this preliminary assessment, the amount of bank erosion during smaller more frequent storm flows (e.g., 10-year event and below) may not alter the site significantly. Localized bank erosion and channel/wetland deposition are expected to re-work sediment within the restored site as in natural river/wetland systems. A portion of eroded sediment may be deposited in the “over-sized” channel downstream.

Larger infrequent storm flows (e.g., greater than 20-year event) have the potential to cause a greater level of change to the restored channel and wetland system. (Note that armoring in key locations will be designed to reduce the potential for the channel to meander or avulse in locations near the perimeter levee systems; see the PDR for more details). Due to limited sediment supply, the restoration may only have limited potential for any areas of erosion during large storm events to “recover” through subsequent years of sediment deposition under tidal and small storm events. Subsequent modeling and analysis will be performed to assess the range of potential change during small and large storm events and the rate and degree of system “recovery.”

Note that the frequency of larger storm events (i.e., 20 years or more on average) is similar in time-scale to wetland response and change to projected future sea-level rise (see Section 6.3.4 below).

6.3.3 Channel mouth and coastal sediment processes

Preliminary assessments indicate that observed deposition/shoal in the channel mouth is due to coastal sand transport by tidal flows and/or south swells (see Section 6.2.4). The channel mouth is oversized compared to tidal flows and sand is expected to continue to deposit in the shoal until equilibrium is reached with the scour potential of tidal flows. The restoration will increase tidal flows; however, the effect of the restoration on the shoal may not be significant. Subsequent analyses will be performed to complete this assessment.

6.3.4 Sea-level rise

The rate of sea-level rise is expected to be greater than the rate of wetland accretion. Restored wetland habitats are expected to convert to lower elevation habitats over time (e.g., vegetated wetland to mudflat and mudflat to subtidal). Figure 32 shows this habitat conversion assuming low sediment supply. The sediment supply from the watershed to the wetlands may support a somewhat higher rate of wetland accretion and a slower rate of wetland conversion.

The restored wetlands are expected to transgress into restored transition and upland habitat zones as shown in Figure 32.

7. LIST OF ACRONYMS

DTM	Digital Terrain Model
GSD	Grain Size Distribution
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
MHHW	Mean Higher High Water
MTL	Mean Tide Level
MLLW	Mean Lower Low Water
NAVD	North American Vertical Datum of 1988
NGVD	National Geodetic Vertical Datum of 1929
PDR	Preliminary Design Report
RS	River Stationing
SCCWRP	Southern California Coastal Water Research Project
SLR	Sea Level Rise

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APPENDICES

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Appendix 1 Ballona Wetlands Tsunami Assessment

Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report
February 1, 2013 Administrative Draft
ESA PWA

APPENDIX 1
BALLONA WETLANDS TSUNAMI ASSESSMENT

1. INTRODUCTION

This technical memo provides an initial assessment of the potential impacts of tsunamis for the Ballona Wetlands Restoration Project. The purpose of this assessment is to review recent research on tsunamis, examine historic impacts from tsunamis for this stretch of California coast, and to identify risks to the project and additional risks caused by the project.

2. BACKGROUND

Tsunamis (often referred to as "tidal waves" for the way they approach similar to the rising tide) are a series of potentially large waves which are caused by catastrophic events including: earthquakes, underwater landslides, volcanic eruptions, and infrequently, asteroids. Tsunamis are categorized based on the source of the generating event. Nearfield tsunamis occur in relative close proximity to the site while farfield tsunamis are generated at longer distances typically on the opposite side of ocean basins.

The formation mechanisms for a tsunami are illustrated in Figure 1. First, a catastrophic event vertically displaces a volume of water as illustrated in the first stage of Figure 1. The second stage shows how waves are split and sent outward across the ocean. In the open ocean, these waves have small heights (amplitudes), but long periods (10-20 minutes) and fast speeds (350-500 mph) (Komar, 1997). (Note that Figure 1 is exaggerated for illustrative purposes). For comparison, a typical swell wave one would see at the coast is called a surface gravity wave with periods of 13-20 seconds and speeds of 30-75 mph. Viewed at sea, a tsunami is barely noticeable; however, as the waves reach the coast, they shoal on the continental shelf with water piling up as the sea floor becomes shallower, and the height of the wave increases dramatically as shown in stage 3. The first sign of an impending tsunami is often an unusual lowering of the water below a typical negative low tide level. This is the trough between wave crests and is followed by a stage 4 where water levels rise onshore and can cause flooding.

Southern California is threatened by both near and farfield tsunamis. Sources of nearfield tsunamis could be a submarine (underwater) landslide and/or a large earthquake on any of the nearby faults. These faults include the Palos Verdes fault zone which trends northwest off the Long Beach and Santa Ana coast, the San Pedro Basin fault zone, and Santa Cruz-Santa Catalina Ridge fault zones. The Palos Verdes Slide (PVS), which is off the Palos Verdes Peninsula, has the potential to cause significant damage in the Long Beach area. The large amounts of debris in the area indicate that significant avalanches have occurred before. Borrero, et al (2002) show that a slide on the PVS could cause up to a 20 meter tsunami that would hit the Palos Verdes Peninsula 7 minutes after it occurs, causing velocities over 3 m/s in the Port of LA. However, their model also show that, around the peninsula in the Redondo Beach area, a tsunami from the PVS would only be up to 0.5 meters and occur approximately 15 min after the slide.

Farfield tsunamis that would threaten the Ballona project site could originate anywhere along the Pacific Rim, Alaska, or South America. A tsunami originating from Japan would take 10-15 hours to reach Los

Angeles while an event in South America could take up to 20 hours to reach the area. While such an incident would provide substantial time for evacuations, the effects could be as damaging as a nearfield event. One example is the Japan earthquake (M9.0) which occurred on March 11, 2011 and generated a ~0.5m tsunami at Los Angeles that caused over $50 million dollars in damages along the California coast (LA Times, 2011). Figure 2 shows data from the Santa Monica water level gauge during this event and illustrates the exaggerated heights of the waves overlying the longer period tidal oscillations.

3. HISTORY OF TSUNAMIS IN LOS ANGELES

Two notable tsunamis have affected the Los Angeles area in the twentieth century. On May 22, 1960, a farfield tsunami originating in Chile, South America from an 8.7 magnitude earthquake reached Los Angeles 14 hours later with a height of 2.6 feet (NOAA). At least one death was associated with the tsunami in Los Angeles and $1,000,000 in damage was recorded (Whitmore 2003).

An 8.9 magnitude earthquake in Anchorage Alaska occurred on March 3, 1964 and resulted in run-up heights of 2 feet in Los Angeles (NOAA). The tsunami caused $200,000 in boat damage and one death in the Los Angeles area (Whitmore, 2003).

4. TSUNAMI MAPPING

Knowing the probability of tsunami run-up occurrences is essential in evaluating risk. The California Emergency Management Agency, the California Geologic Survey, and the University of Southern California have partnered to create statewide tsunami inundation maps to help predict areas that are at risk. These maps were created by first examining tsunamis originating from the Pacific Rim or Cascadia subduction zones, underwater earthquake or landslide events, and past tsunamis and then running them through the MOST (Method of Splitting Tsunami) model using a coarse grid to determine which events would have the greatest impact on the California coast. Once identified, these events were run through the model again using nested grids down to 30 meter for three sea ports and 90 meter for the rest of the coast. The results of each modeled event were then combined to create a worst-case scenario wave and run-up estimate. Using USGS 10 meter and interferometric radar 3 meter high resolution digital elevation models (DEMs), the inundation line was refined and verified in the field. This mapping effort, which is ongoing, provides the best information on the tsunami risk at Ballona (Figure 3).

The City of Los Angeles in their Safety Plan (1996) also created a map of potential tsunami hazard areas (Figure 4). However, the map does not seem to be derived from modeling, and the plan notes only that flooding would occur in low-lying areas.

5. BALLONA TSUNAMI RISK

The city tsunami map shows that all of the Ballona site, except for a western portion of Area A, could potentially be impacted by a tsunami. However, according to the state tsunami map, only Ballona Creek will feel the effects of a tsunami while the rest of the site is not expected to be inundated. While the state maps are not intended for planning purposes, they represent the best statewide tsunami mapping effort to date. Figure 5 shows a zoomed in image of the state inundation line near Ballona. The state mapping indicates that Del Rey Lagoon and the areas west of it could possibly flood. However, the existing Ballona Creek levees, which range in elevation from 13 to greater than 16 feet would prevent tsunami waters from entering the rest of the site.

The state maps do not include wave run-up velocities which would be important in predicting potential erosion impacts. Future sea level rise may increase flood risk as well. Tide level and sea level elevation at the time of arrival will affect the impact of tsunami run-up. These are independent factors that may reduce or exacerbate the impacts from such an event.

6. DESIGN CONSIDERATIONS

The proposed restoration design would maintain the same level of flood protection to surrounding areas as existing conditions. While more of the site itself would likely be inundated by a tsunami, the wetland vegetation and natural channel bottom would provide friction which would reduce the wave energy that would reach the levees. High water velocities could cause erosion along the levees and the tsunami could produce seiches within the site which would result in higher waves. However, Borrero et al (2002) modeled that a slide on the Palos Verdes fault would cause velocities of 3 m/s in the Port of LA, which is no faster than modeled velocities for a 50 year fluvial event.

LIST OF FIGURES

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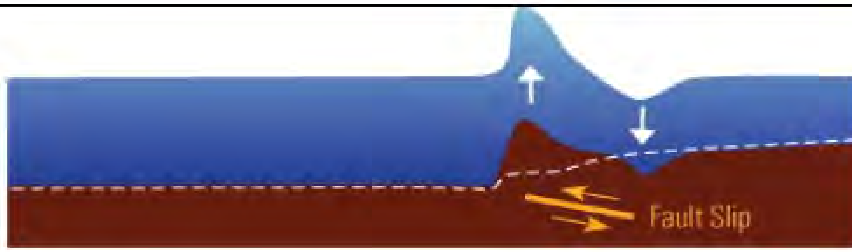
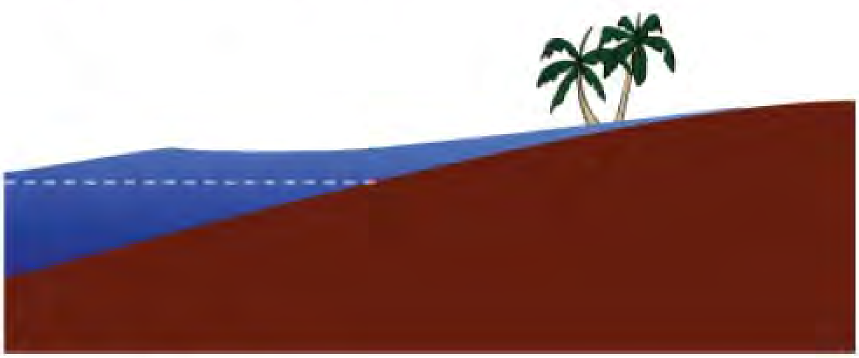


Stage 1- Initiation

Stage 2- Split

Stage 3- Amplification

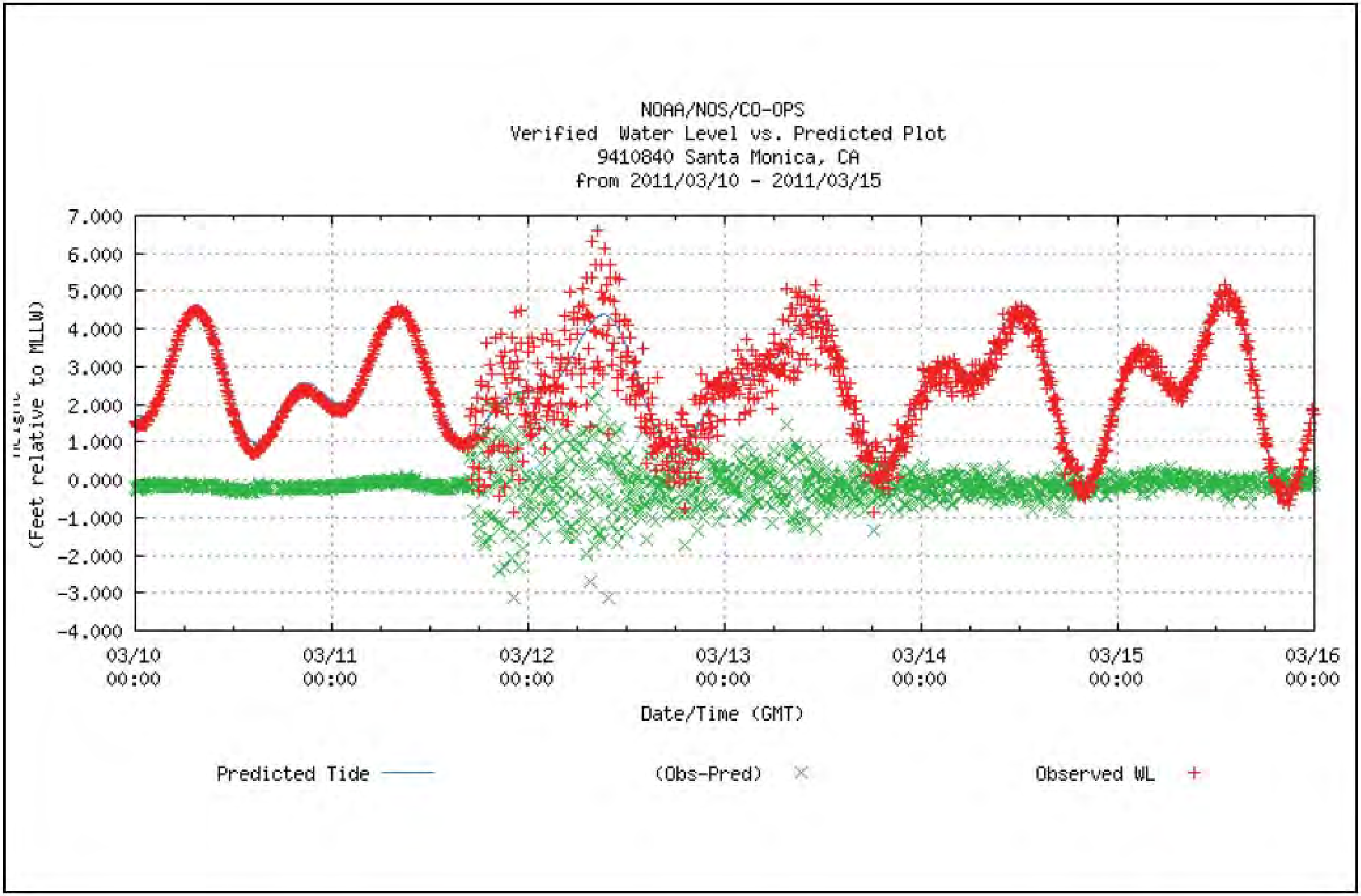


Stage 4- Run-up

The height of the waves above are exaggerated for illustrative purposes.

SOURCE: USGS. Life of a Tsunami
http://walrus.wr.usgs.gov/tsunami/basics.html. 7/12/2010.

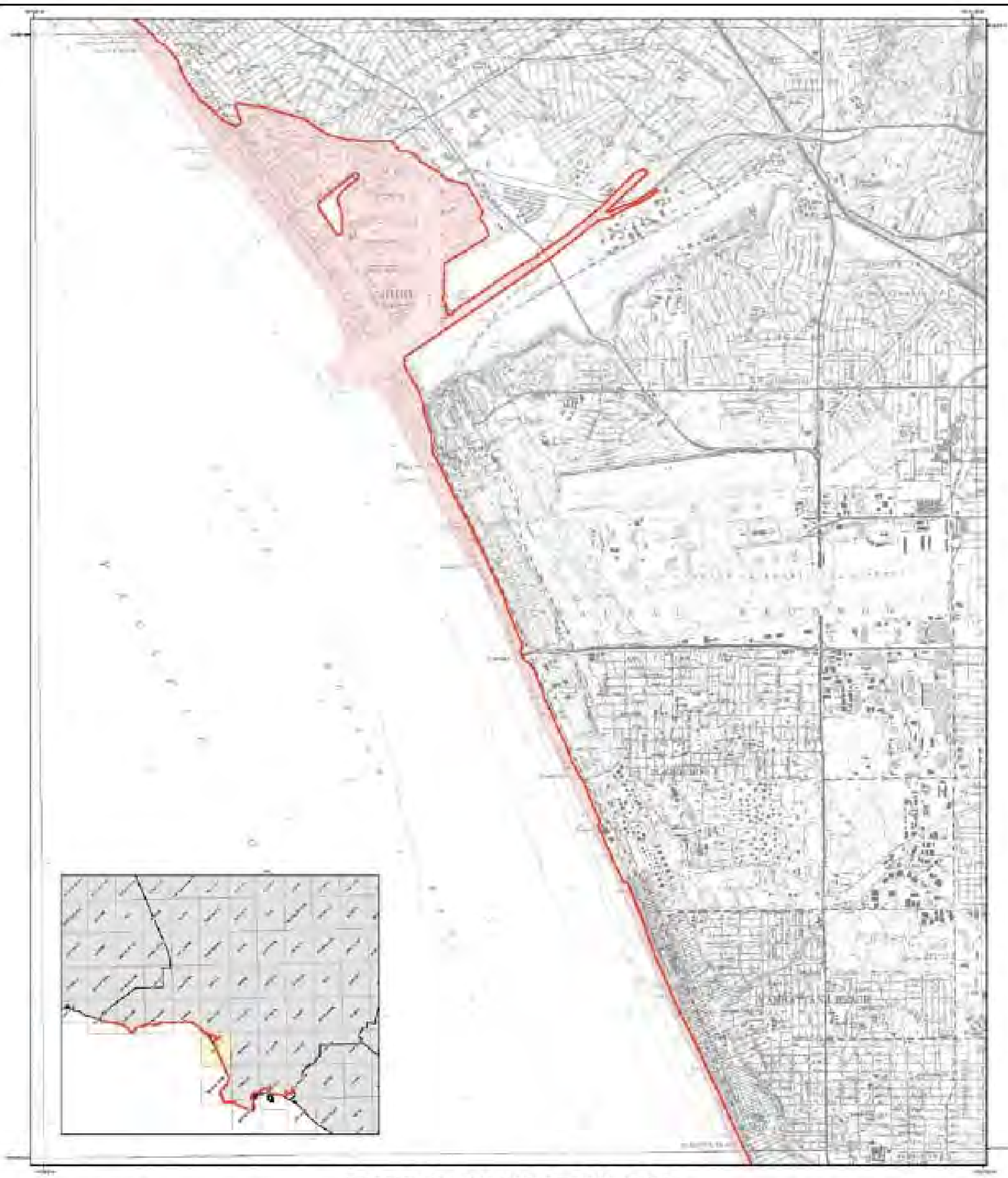
Figure 1
Typical Tsunami Formation



SOURCE: NOAA Tides and Currents.
http://tidesandcurrents.noaa.gov/data_menu.shtml?type=Historic+Tide+Data&mstn=9410840. 8/2/2012

Ballona Wetlands . D120367

Figure 2
Santa Monica Water Level Data
for the Tsunami on 3/12/11



METHOD OF PREPARATION

TSUNAMI INUNDATION MAP FOR EMERGENCY PLANNING

State of California ~ County of Los Angeles

VENICE QUADRANGLE

March 1, 2009

MAP EXPLANATION

Tsunami Inundation Line

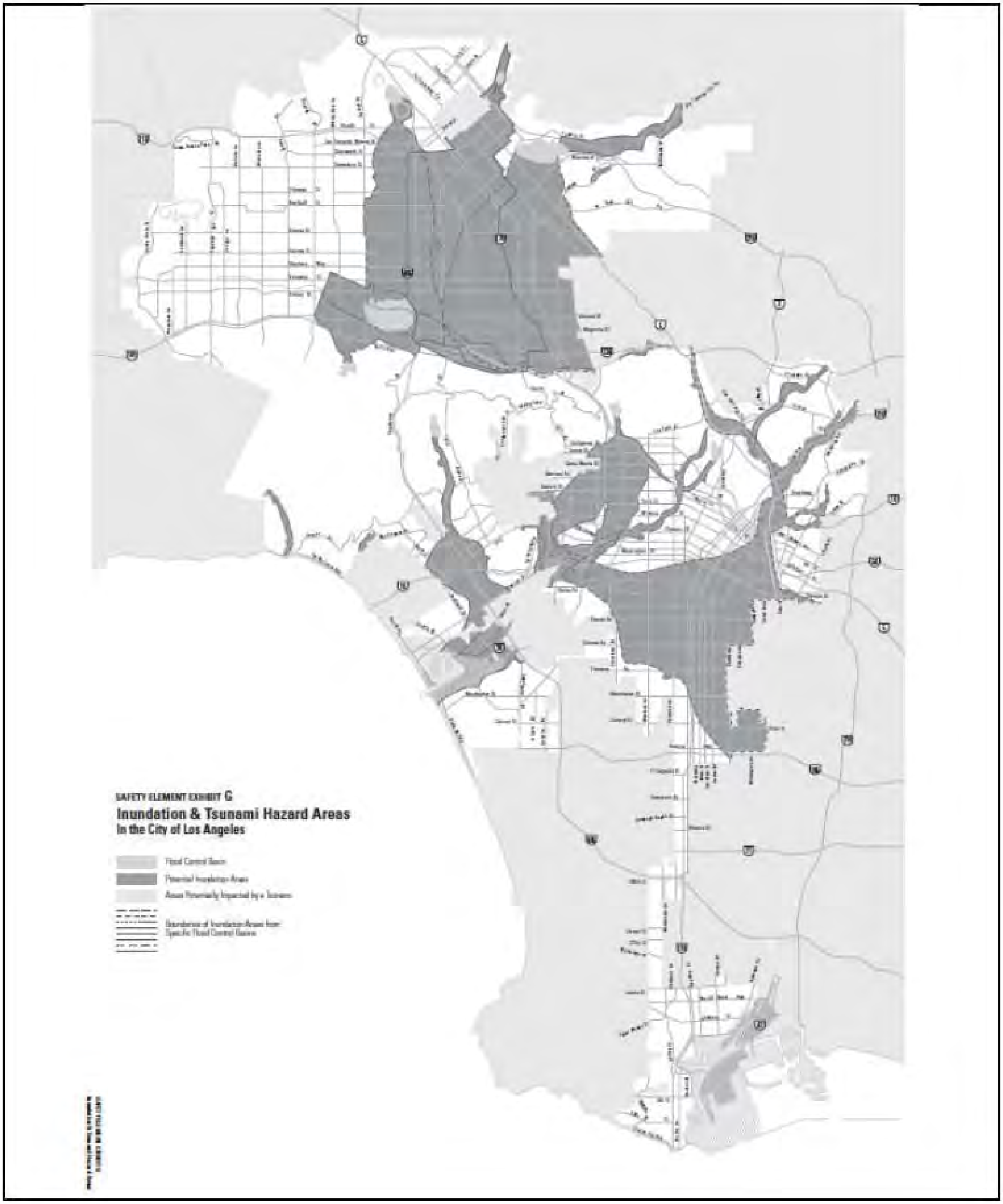
Tsunami Inundation Area

PURPOSE OF THIS MAP

SOURCE: State of California (2009).

Ballona Wetlands . D120367

Figure 3
State Map of Tsunami Inundation



SOURCE: City of Los Angeles (1996).

Ballona Wetlands . D120367

Figure 4
City Map of Tsunami Inundation

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SOURCE: State of California (2009).

Ballona Wetlands. D120367

Figure 5

State Tsunami Inundation Line at Ballona

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Appendix 2   Ballona Creek Sediment Budget

Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report
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APPENDIX 2
BALLONA CREEK SEDIMENT BUDGET

1. SEDIMENT TRANSPORT PROCESSES

Marina del Rey, which was opened in 1965 (Attachment 1), is part of the Santa Monica Littoral Cell (Figure 1). Sediment from Ballona Creek and other water ways in the area, enters the cell and is transported south to the Redondo Submarine Canyon where it is lost from the system. In the vicinity of Marina del Rey, the alignment of the coastline and the associated prevailing waves create a predominant net sediment transport to the southeast (downcoast). This may be reversed periodically, especially when southern swells approach the coastline during the summer, and when Santa Ana winds (offshore) prevail for extended periods of time (days). However, northern transport into Marina del Rey is considered negligible (USACE 2009).

The marina entrance, jetties, and breakwater act as a nearly complete littoral transport barrier. The jetties and breakwater extend into the littoral zone and interrupt both downcoast and upcoast longshore transport during normal conditions. Major storm events, mostly in the winter, are responsible for major movements of sediments, both transport and deposition, in and around littoral barriers. These events cause sediment from Ballona Creek and littoral transport to build shoals in the entrances to the marina which inhibits safe navigation and requires dredging. The shoals in the entrance areas tend to remain flat during the spring and summer because the tides rework the sediment and deposit it farther offshore.

Marina del Rey has a northern and southern entrance (Figure 2). The sediment that accumulates in the north entrance comes primarily from littoral transport, and is generally clean enough for beach or ocean disposal (USACE 2003b). Sediment that accumulates in the south entrance comes primarily from Ballona Creek, and is generally too contaminated to put on the beach or discharged to the ocean (USACE 2003b). Historically, sediments have been disposed of in three main locations: the beach, the LA-2 Ocean Dredged Material Disposal Site, and various opportunistic sites for the placement of contaminated sediments.

While the general direction of transport seems to be agreed upon between reports, the amount of sediment moving in the system is unclear. In the Ballona Creek Sediment Control Management Plan EIR/S, it is noted that approximately 65% of the sediments deposited in the harbor entrance come from Ballona Creek (USACE 2003b). However, the EIR/S also includes a figure (Figure 3) that presents a sediment yield of 44,615 m^3/yr from Ballona Creek and 48,000 m^3/yr from littoral transport. This suggests Ballona Creek contributes less than 50% of the sediment in the marina.

In 2009, the US Army Corp of Engineers (USACE) produced the Ballona Creek Ecosystem Restoration Feasibility Study with a Coastal Engineering Appendix. The appendix references the 1998 USACE Marina del Rey Shoaling and Disposal Feasibility Study which presents north to south sediment transport of 0 to 25,200 m^3/yr and 45,873 m^3/yr of sediment coming from Ballona. This estimate of the Ballona Creek sediment yield is similar to a 2003 estimate (44,615 m^3/yr), but the littoral transport from the north is about half that of the 2003 estimate (48,000 m^3/yr).

Inman and Jenkins (1999) used a sedimentation curve from a similar watershed along with flow rates from Ballona Creek to estimate a sediment yield of 10,800 m^3/yr. Using a suspended sediment rating curve derived from suspended sediment measurements collected by LACDPW (1999 – 2011) and SCCWRP (2001 – 2004), a much lower estimate of 6,520 m^3/yr is calculated. Table 1 summarizes the different estimates.

2. DREDGE HISTORY AND SHOALING RATES

A history of dredging events for Marina del Rey from 1969-2009 is provided in Table 2. Surveys are conducted to evaluate conditions in the harbor before dredging (pre-dredge), after dredging (post-dredge), and in between dredging events (conditions). There are some differences between the numbers reported by different sources for the1999 dredging event. See table notes for more details.

In 2003(a), Moffat and Nichol (M&N) and USACE revised their previously calculated shoaling rates by adding more recent data. They used two methods to calculate shoaling rates at the Marina del Rey entrance with data from 1991 to 2001. Using conditions, pre-, and post-dredge surveys, they developed bathymetric difference maps. The first method subtracts the first bathy survey (1991) from the last bathy survey (2001) and adds the total reported dredge quantities in between, then divides by the years in between the two surveys. This method estimated shoaling of 71,600 cubic meters (93,600 cubic yards) per year. M&N and USACE also divided the marina entrance into four areas labeled A, B, G, and H and shown in Figure 4. The second method calculates shoaling rates between each survey for each area, divides by the years in between, and then averages all of the rates. This method estimated shoaling of 109,100 cubic meters (142,700 cubic yards) per year. Table 3 presents the rates for both methods. Figure 3 shows the shoaling rates for each area in the overall sediment budget. The rates in Areas A and G are consistent with those calculated by M&N and USACE in Table 3, but the rates in Areas B and H are not (the calculated rates are shown in parenthesis below those from the figure). It is unclear how the shoaling rates in Areas B and H from the figure are calculated.

3. ACCRETION RATES

A similar analysis to that used by M&N and USACE was repeated including all the most recent data. Figure 5 shows the difference plots from the dredge surveys. The maximum, minimum, and average accretion in inches in each of the four areas was calculated and is summarized in Table 4. Figure 6 presents the averages and standard deviations by area. The figure shows that sedimentation in the north entrance of Marina del Rey is greater than in the south entrance which is likely due to the downcoast sediment transport. However, the standard deviation of each calculation is greater than the mean itself, so there is large variability in the system. Figure 7 shows the trends over time. Significant accretion in all areas occurred after El Nino events in 2002-2003 and 2009-2010 likely due to large storm events. Other than in early 2008 after a dredge event, Areas B and H (the northern entrance areas) have higher accretion rates than Areas A and G in the southern entrance. This also suggests that littoral transport to the south is more significant than transport to the north.

Historically, no bathymetric surveys of Ballona Creek were conducted upstream of dredging activities. The only available channel data is the as-built survey from 1959/1961 and the recent survey by PSOMAS. The existing conditions bathymetric survey by PSOMAS was compared to the as-built thalweg elevations to look at accretion within Ballona Creek (Figure 8). Sedimentation is observed at the far downstream end of the channel near the marina entrance and upstream of Lincoln Blvd. Within most of the site, accretion is minimal and located in the center of the channel.

Since 1988, there have only been one Q5 and one Q10 storm event in Ballona Creek. Hydraulic modeling shows that there is no fluvial influence of storms of Q5 or smaller within the site, so since the Q10 storm in 1994, sediment has likely not been flushed from the system. Assuming the current accretion in the channel has been building since 1994, it can be estimated that Ballona Creek provides 6,300 m^3/yr of sediment to the coastal system.

4. SEDIMENT SIZE

Based on past dredging event in the marina, sediments in the center of the main channel and near the bend of Marina del Rey were predominantly silt/clay. Sediments were coarser (sand-sized particles) along the sides of the entrance channel and at the mouth. The coarsest sediments were found at the mouth of Ballona Creek and at the entrance of Ballona Lagoon. The grain size of sediments at the harbor entrance is mostly between 0.1 and 0.25 mm. Sediments coming from Ballona Creek are 20% silt, 65% sand, and 15% gravel (USACE 2003b).

Leidersdorf, Hollar, and Woodell (1994) estimate that Ballona Creek inputs 46,000 cy/yr (35,000 m^3/yr) of fine sand to the littoral cell. USACE (2009) cites their 1998 Marina del Rey Shoaling and Disposal Feasibility Study to suggest that Ballona contributes 39,760 m^3/yr of sand, although the report later estimates that 45,873 m^3/yr of sediment moves through the system with 90% sand and 10% silt (or 41,300 m^3/yr of sand). Sediment sampling conducted in 2010 (Figure 9) showed that sediments in the north entrance of Marina del Rey tended to be sandier than those in the south entrance. This supports the idea that sand is moving south into the marina entrances with minimal sand moving north.

FIGURES

ATTACHMENT
Timeline for Ballona Creek and Marina del Rey Areas

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Table 1. Ballona Creek Sediment Yield Estimates

Source	Average Volumetric loading rate (m^3/yr)	Note
ESA PWA	6,300	Based on sediment accumulated in Ballona Creek
ESA PWA	6,520	Based on suspended sediment rating curve derived from suspended sediment measurements collected by LACDPW (1999 - 2011) and SCCWRP (2001 - 2004)
Inmann & Jenkins (1999)	10,800	Based on suspended sediment rating curve of a similar watershed and gage data at USGS 11103500 (data from 1944-1995)
USACE 2003	44,615	Based on sediment accumulated at mouth
USACE 2009	45,873	Based on sediment accumulated at mouth

Table 2. Dredge History of Marina del Rey

Date[1]	Location	Material	Method	Destination	Quantity (yd^3)	Source[2]
1969	Ballona Creek mouth		no record	Del Rey Beach	389,800	3
1973	South side of north jetty		no record	Upcoast of north jetty	16,100	3
1981	Entrance channel; Ballona creek mouth		no record	South of Dockweiler Beach	217,400	3
1987	Jetty tips; Ballona creek mouth		no record	Dockweiler Beach	35,300	3
1992	Ballona creek mouth	chemically challenged	dragging to fill voids	in situ	21,500	2
1994	Entrance channel	chemically challenged	clamshell	Port of LA shallow water habitat	57,000	2
1996	Entrance channel	beach quality	hydraulic dredge	Dockweiler State Beach	238,000	2
1998	Entrance channel	chemically challenged	clamshell	LA-2 Disposal Site	52,000	3
		beach quality	clamshell	Dockweiler State Beach	73,800	3
1999	Entrance channel	chemically challenged	clamshell	Port of Long Beach	390,000	4**
		beach quality	clamshell	Redondo Beach	282,000	4**
2007			clamshell	Dockweiler State Beach	327,000	4
2009			hydraulic dredge	Dockweiler State Beach	4,700	4

[1] Indicates year project was started

[2] Quantities from Source 2 are pay volumes; quantities from source 3 and 4 are unspecified, although volumes agree (with rounding) for 1969-1998

**** There is a large discrepancy between source 2, 3 and 4 (see hidden columns G, H, and I). Source 4 was the middle value and the most recent report, so those values are included. K:\projects_2012\D12XXXX.00 - Ballona\06 Project Library\Sediment_Studies\MDR Dredge History.xls**

Sources: 1. USACE 2003, Draft EIR/EIS for the Ballona Creek Sediment Control Management Plan,

2. USACE 2003, Marina Del Rey and Ballona Creek Feasibility Study, Ballona Creek Sediment Control Management Plan, Dredging Analysis Appendix

3. USACE 2004, LA Regional Dredged Material Management Plan Feasibility Study, Baseline Conditions (F3) Report Technical Appendix

4. Kinnetic Laboratories, Inc, Halcrow Inc, 2011. Marina Del Rey Maintenance Dredging Project Follow-Up Sediment Tier II and III Investigation, Final Report

Table 3. Shoaling Rates Marina del Rey

SURVEYS	YEARS*	A VOLUME (m^3)	A RATE (m^3/yr)	B VOLUME (m^3)	B RATE (m^3/yr)	G VOLUME (m^3)	G RATE (m^3/yr)	H VOLUME (m^3)	H RATE (m^3/yr)	TOTAL (m^3)
7/91-2/01 (Condition-Condition)	9.6	-49,900		-50,065		-38,445		25,202		-113,208
Total Dredging (USACE Reported Values)										799,550
Total Shoal Volume										686,342
Method 1 - Average Annual Shoaling Rate										71,618 m^3/yr
7/91-5/92 (Condition-Condition)	0.86	20,483	23,734	11,031	12,782	50,548	58,571			
5/92-10/92 (Condition-Pre)	0.36	-3,391	-9,448	-1,967	-5,481	-1,751	-4,879			
12/92-12/93 (Post-Condition)	1.00	26,297	26,297	18,785	18,785	-13,748	-13,748			
12/93-6/94 (Condition-Condition)	0.56	1,005	1,807	1,504	2,704	4,353	7,827			
6/94-10/94 (Condition-Pre)	0.50	-9,943	-20,051	-3,629	-7,318	-12,132	-24,465			
12/94-1/95 (Post-Condition)	0.10	23,569	238,963	11,987	121,535	1,260	12,775	25,153	255,023	
1/95-6/95 (Condition-Condition)	0.36	19,291	53,750	17,490	48,732	7,102	19,788			
6/95-12/95 (Condition-Condition)	0.50	-8,103	-16,206	-4,983	-9,966	-6,440	-12,880	3,820	3,445	
12/95-3/96 (Condition-Pre)	0.25	14,071	56,284	18,405	73,620	1,862	7,448			
4/96-9/96 (Post-Condition)	0.47	4,909	10,540	4,851	10,415	-1,208	-2,594	5,580	11,981	
9/96-8/97 (Condition-Condition)	0.90	8,065	8,975	9,626	10,712	2,515	2,799	38,853	43,236	
8/97-2/98 (Condition-Condition)	0.50	18,554	37,210	25,750	51,641	1,591	3,191	51,732	96,338	
2/98-3/98 (Condition-Pre)	0.04	6,219	162,138	1,952	50,891	2,469	64,370			
4/98-6/98 (Post-Condition)	0.14	-1,316	-9,418	-48,269	-77,957	-2,111	-15,108	-36,634	-59,166	
6/98-11/98 (Condition-Condition)	0.48	4,204	8,768			336	701			
11/98-5/99 (Condition-Condition)	0.48	310	647	14,280	29,784	-879	-1,833	32,293	67,354	
5/99-10/99 (Condition-Pre) **	0.44	-3,171	-7,145	-357	-804	-3,344	-7,534	-7,100	-15,997	
3/00-2/01 (Post-Condition)	0.96	8,373	8,732	9,637	10,050	10,439	10,886	56,390	58,807	
Avg. Annual Shoal Rate by Area:			31,977		20,007		5,851		51,225	
Method 2 - Average Annual Shoaling Rate (Sum of Rates for Sub-areas A, B, G & H)										109,059 m^3/yr

* Years 1991 through April, 1998 from M&N, 1999a

** Based on the survey data, Sub-area A shows -41,021 m^3 change in shoaling, Corps record indicated that 37,850 m^3 was actually dredged because dredging started 10 days prior to pre-dredged survey.

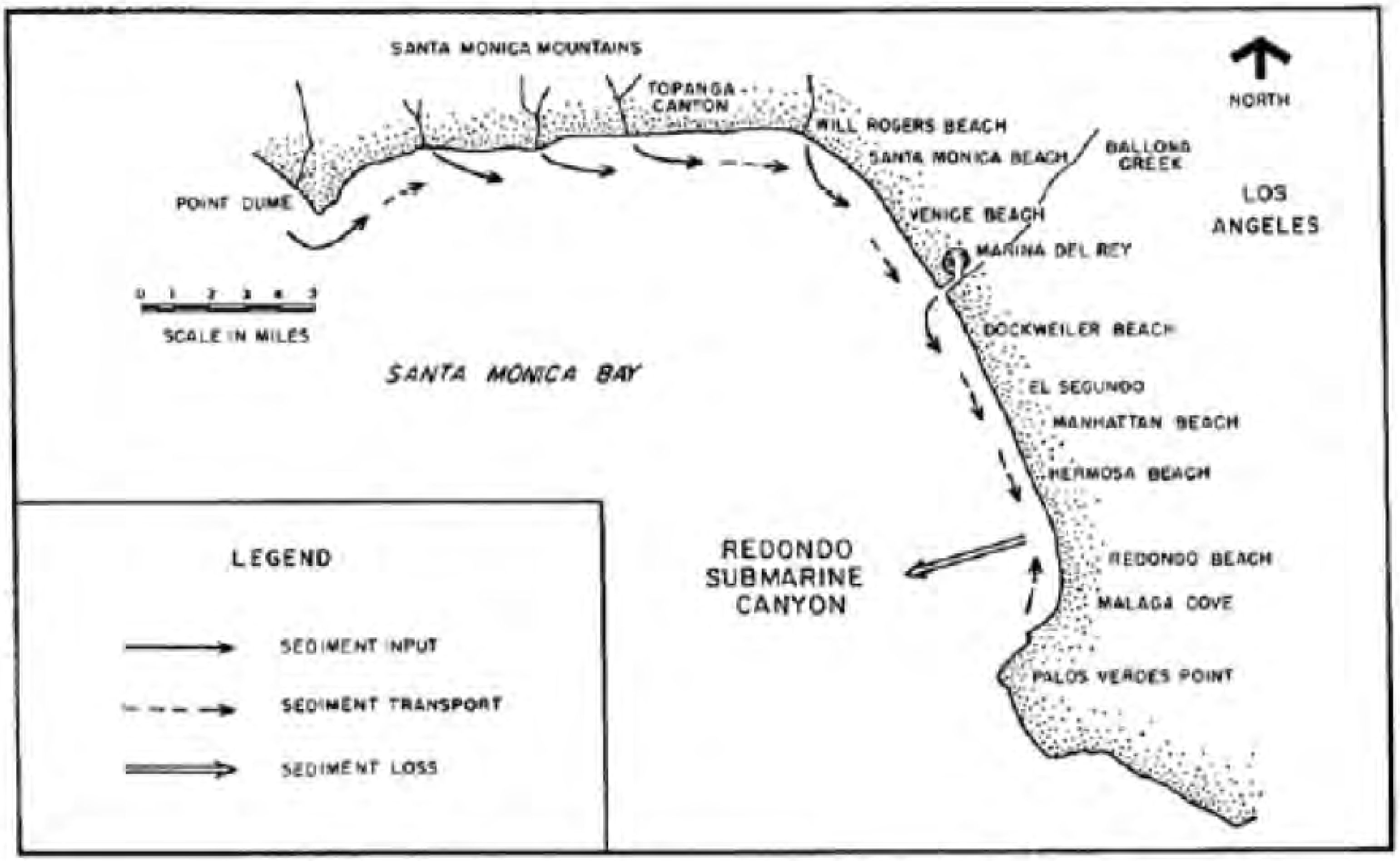
Source: Dredging Analysis Appendix of EIR/S

Table 4. Accretion Rates at Marina del Rey

Area A				
Years	**Minimum (in/yr)**	**Maximum (in/yr)**	**Mean (in/yr)**	**Std. Dev (in/yr)**
2000/2001	-29	67	9	8.9
2001/2002	-11	26	1	5.9
2002/2003	-90	189	20	10.7
2003/2005	-4	58	13	20.1
2005/2006	-28	24	3	8.1
2006/2007	-47	26	-3	7.9
2007/2008	-36	28	8	7.3
2008/2009	-31	10	0	7.1
2009/2011	-46	45	0	23.3
2011/2012	-41	77	3	8.1
Average[1]	**-36**	**58**	**5**	**6.9**

Area B				
Years	**Minimum (in/yr)**	**Maximum (in/yr)**	**Mean (in/yr)**	**Std. Dev (in/yr)**
2000/2001	-29	96	11	11.0
2001/2002	-25	73	6	15.5
2002/2003	-65	265	34	16.4
2003/2005	-9	75	12	23.9
2005/2006	-23	149	25	32.0
2006/2007	-35	29	0	7.3
2007/2008	-213	24	-54	73.7
2008/2009	-16	47	4	14.1
2009/2011	-45	98	16	39.7
2011/2012	-19	113	10	12.0
Average[1]	**-30**	**105**	**13**	**23.4**
Area G				
Years	**Minimum (in/yr)**	**Maximum (in/yr)**	**Mean (in/yr)**	**Std. Dev (in/yr)**
2000/2001	-100	121	10	22.7
2001/2002	-24	90	4	14.9
2002/2003	-71	159	17	12.9
2003/2005	-12	64	12	31.8
2005/2006	-30	38	-1	12.0
2006/2007	-36	11	-11	7.2
2007/2008	-7	22	5	6.0
2008/2009	-40	10	-5	12.2
2009/2011	-14	50	11	12.6
2011/2012	-37	25	-3	6.5
Average[1]	**-40**	**63**	**4**	**8.8**
Area H				
Years	**Minimum (in/yr)**	**Maximum (in/yr)**	**Mean (in/yr)**	**Std. Dev (in/yr)**
2000/2001	-13	284	79	79.0
2001/2002	-10	107	20	37.8
2002/2003	-39	453	88	42.4
2003/2005	-19	43	4	27.4
2005/2006	-26	129	36	29.2
2006/2007	-29	28	-4	7.4
2007/2008	-157	-2	-65	51.1
2008/2009	-12	58	7	18.5
2009/2011	8	101	38	28.9
2011/2012	-30	24	0	8.6
Average[1]	**-19**	**136**	**30**	**44.0**

[1] Averages do not include 2007/2008 since a dredge event occurred during this time



SOURCE: Figure 2, Leidersdorf, Hollar, and Woodell (1994).

Ballona Wetlands . D120367

Figure 1
Santa Monica Littoral Cell

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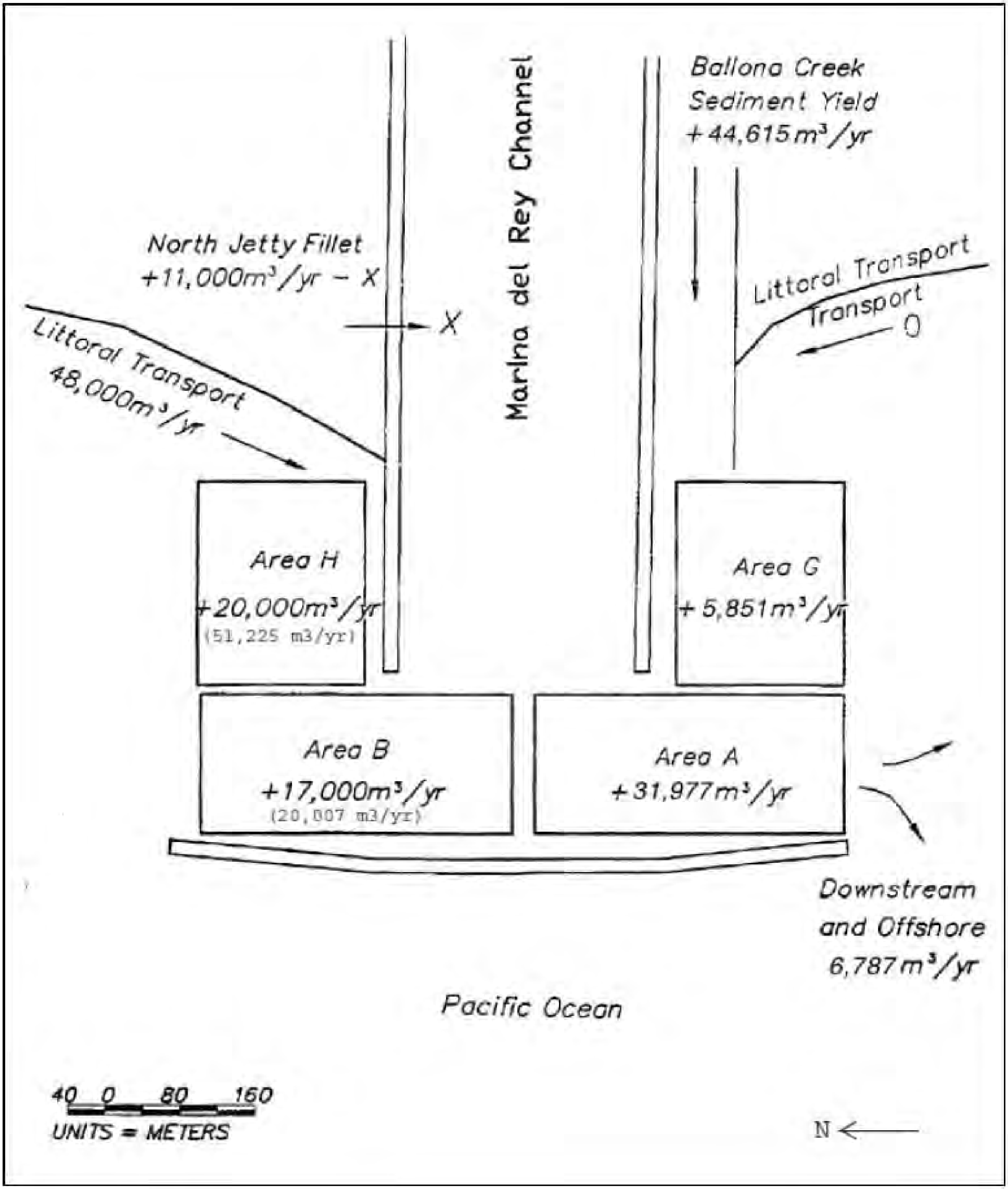
Ballona Wetlands. D120367

Figure 2
Ballona Creek Mouth and
Marina del Rey Entrances

ESA PWA



SOURCE: Reproduced from Figure 3.2-5 USACE (2003).

Ballona Wetlands . D120367

Figure 3
USACE, 2003, Marina del Rey
Sediment Budget

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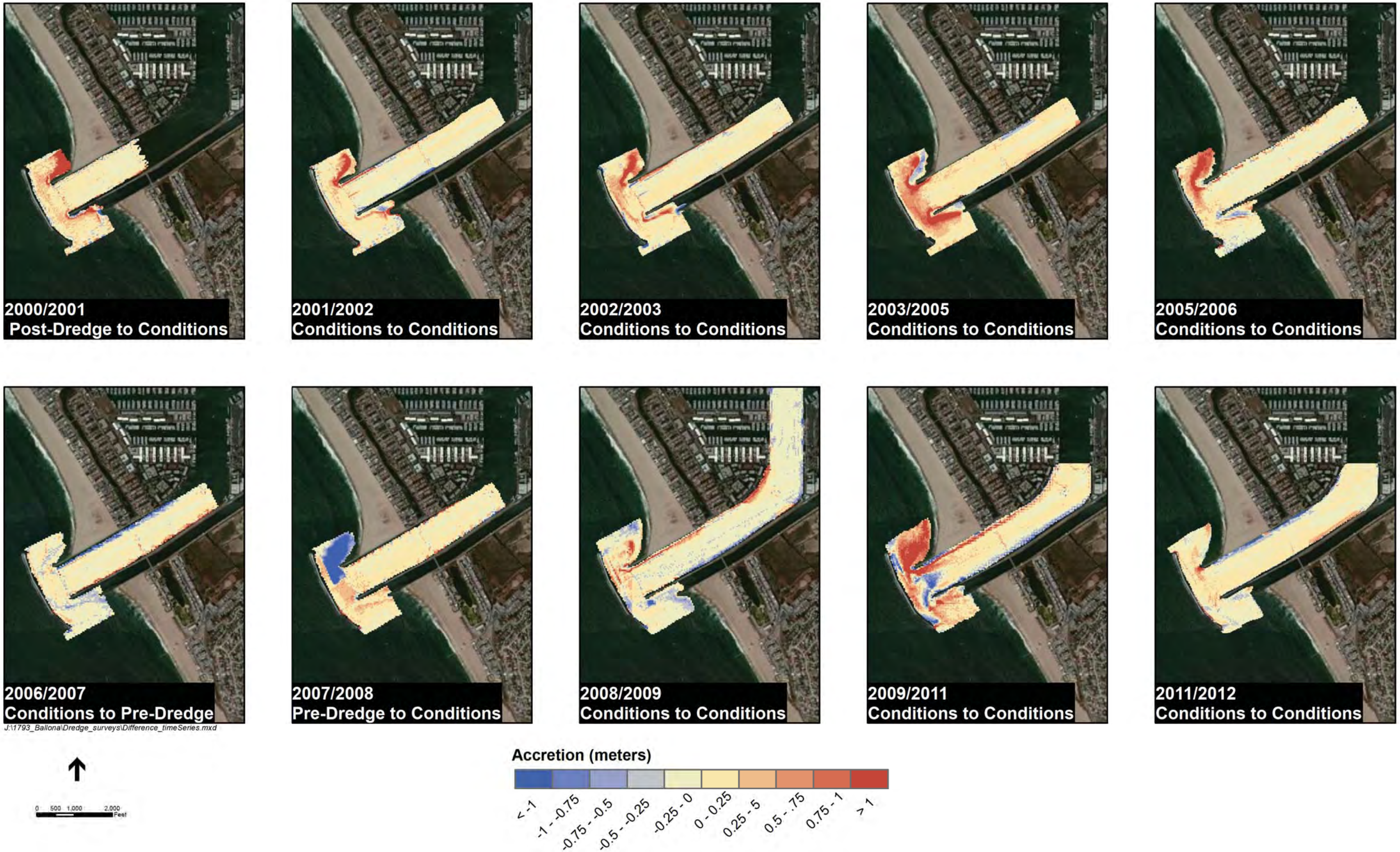
Ballona Wetlands. D120367

Figure 4
Marina del Rey
Entrance Areas

ESA PWA



Ballona Wetlands. D120367
Figure 5
Marina del Rey
Bathymetric Difference Maps

SOURCE: Managed wetlands inboard of Culver levee shown as being managed to maintain marsh habittat over time.

ESA PWA

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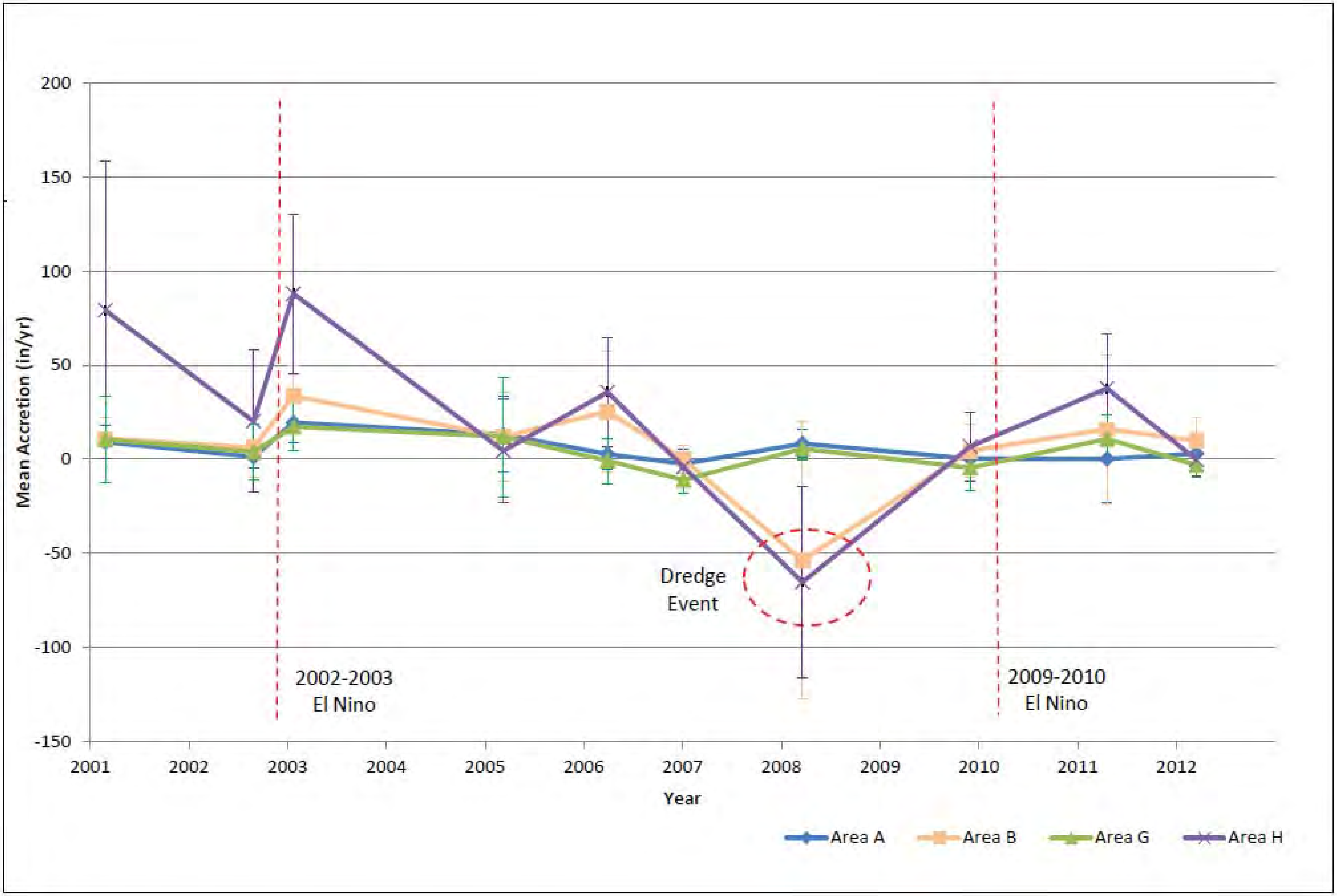
Ballona Wetlands. D120367

Figure 6
Marina del Rey Accretion Rates

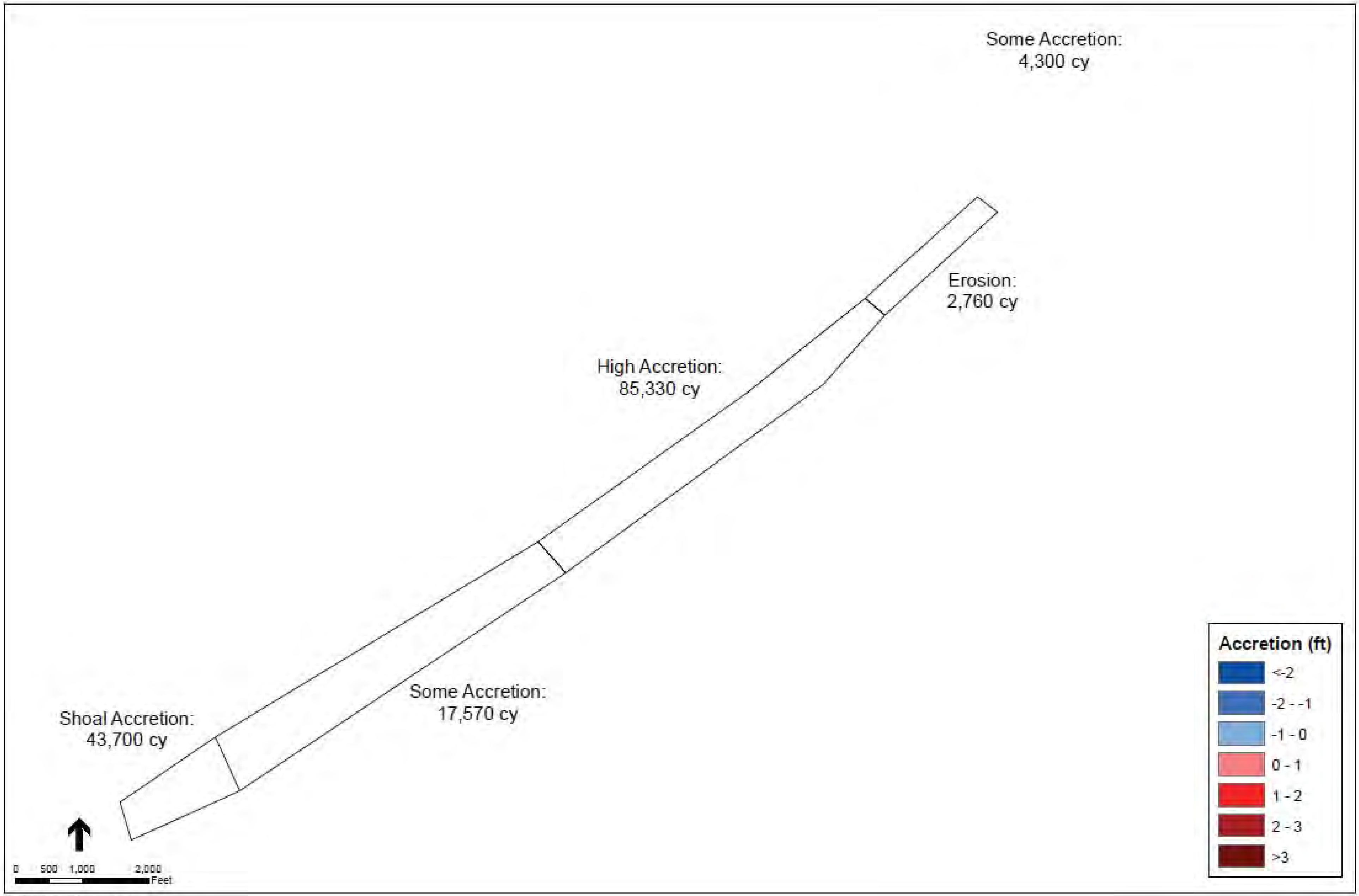
ESA PWA



Ballona. D12367

Figure 7

Marina del Rey Accretion by Area Over Time



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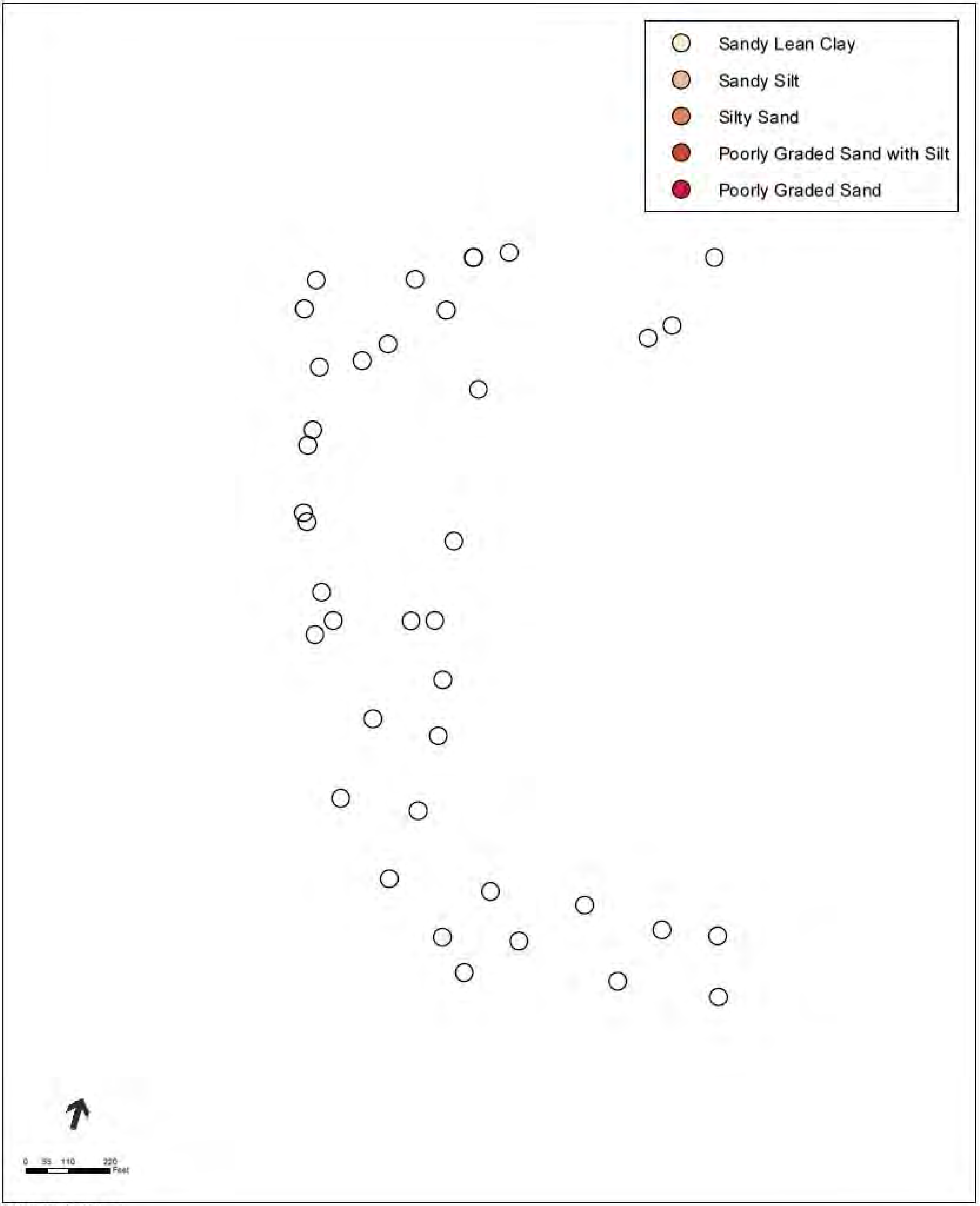
SOURCE: PSOMAS (2012)

ESA PWA

Ballona Wetlands. D120367

Figure 8

Ballona Creek Accretion between 1959 and 2012



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SOURCE: Kinnetic Laboratories (2010).

Ballona Wetlands. D120367

Figure 9
Marina del Rey
Sediment Sizes

ESA PWA

ATTACHMENT
TIMELINE FOR BALLONA CREEK AND MARINA DEL REY AREAS

Year	Item	Reference
1880 (earliest)	Rail lines constructed in wetlands	EPA, 2012
1900 (earliest)	Roadways constructed in wetlands	EPA, 2012
1904	Venice Pier & Breakwater (breakwater remains)	Shaw, 1980 and Tekmarine, 1985
1909	Old Ballona Creek Jetties (no longer exist)	Shaw, 1980 and Tekmarine, 1985
1909 & 1912	Santa Monica Pier	Shaw, 1980 and Tekmarine, 1985
1928 (earliest)	20 groins Sunset Blvd to Santa Monica Pier (4 remain)	Shaw, 1980 and Tekmarine, 1985
1930	Oil and gas exploration and production begins in wetlands	EPA, 2012
1934	Santa Monica Breakwater	Shaw, 1980 and Tekmarine, 1985
Pre-1935	Ocean Park Pier (no longer exists)	Shaw, 1980 and Tekmarine, 1985
1937 – 1988	21 bridge crossings constructed over creek throughout watershed	National Bridge Inventory, 2012
1938 (earliest)	3 groins Santa Monica Pier to Venice Breakwater (2 groins remain)	Shaw, 1980 and Tekmarine, 1985
1939	Ballona Creek flood control channels completed	USACE, 1995
1939	Redondo Beach Breakwater	Shaw, 1980 and Tekmarine, 1985
Pre-1946 (earliest)	4-8 groins Ballona Creek to Redondo Beach (4 remain	Shaw, 1980 and Tekmarine, 1985
1946	South Jetty, Marina del Rey	Shaw, 1980 and Tekmarine, 1985
Post-1946	Venice Beach groin	Shaw, 1980 and Tekmarine, 1985
1950-1960	Sawtelle-Westwood system channels completed	USACE, 1995
1957	Marina del Rey construction begins	LA County Department of Beaches and Harbors
1959	Middle and North Jetties, Marina del Rey	USACE, 1995
1962	Centinela Creek channel completed	USACE, 1995
1964	Benedict Canyon system channels completed	USACE, 1995
1965	Offshore breakwater, Marina del Rey completed; marina opened	USACE, 1995
1969	Dredging of Ballona Creek mouth	USACE, 2004
1973	Dredging of Marina del Rey entrance	USACE, 2004
1981	Dredging of Marina del Rey entrance and Ballona Creek mouth	USACE, 2004
1987	Dredging of Marina del Rey entrance and Ballona Creek mouth	USACE, 2004
1992	Dredging of Marina del Rey entrance	USACE, 2003
1994	Dredging of Marina del Rey entrance	USACE, 2003
1996	Dredging of Marina del Rey entrance	USACE, 2003
1998	Dredging of Marina del Rey entrance	USACE, 2004
1999	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
2004	State Coastal Conservancy funds Ballona Wetlands Restoration Project	State Coastal Conservancy
2007	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
2009	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011
2012	Dredging of Marina del Rey entrance	Kinnetic Laboratories, 2011

The Ballona Creek watershed drains urban Los Angeles and is almost 90 percent developed (Dojiri *et al.,* 2003). The Ballona Creek watershed (338 km^2) contains seven subbasins (LACDPW, 1999) and is relatively flat, with a maximum average slope of 6 percent. ***Ballona Creek has no dams or treatment plant discharges.***

- From Ackerman, Drew, Kenneth C. Schiff, and Stephen B. Weisberg, 2005. Evaluation HSPF in an Arid, Urbanized Watershed. Journal of the American Water Resources Association (JAWRA) 41(2):477-486.

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Appendix 3 Developing Design Dimensions for the Restored Ballona Creek Channel

Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report
February 1, 2013 Administrative Draft
ESA PWA

APPENDIX 3
DEVELOPING DESIGN DIMENSIONS FOR THE RESTORED BALLONA CREEK CHANNEL

1. BACKGROUND

Within and around the restoration area, Ballona Creek has an artificial channel that was designed to contain flood flows. However, for the restoration project it is desirable to construct a channel that is in geomorphic equilibrium with its watershed, which typically means a channel that has a much smaller cross section than a flood control channel. In addition to being more stable (in balance between erosion and deposition), an appropriately-sized channel will provide better ecological function by overflowing onto its floodplain at frequencies that mimic the desired natural environments. This memo describes the analyses used to develop a preliminary channel size for the restoration area. The channel dimensions will be refined as additional data become available.

There are numerous ways of estimating natural channel dimensions, ranging from mimicking historic or nearby reference channels, using regional empirical relationships or employing sediment transport analyses. Complicating the issue, within the restoration area Ballona Creek is at the intersection of the fluvial and tidal regimes, and is likely shaped by both. Three approaches have been used to determine channel size: estimation of dominant discharge based on fluvial sediment transport analysis, the use of regional regressions to estimate bankfull channel width and depth for fluvial regimes, and the use of regression equations based on tidal flow.

- Dominant discharge is the flow range which cumulatively transports the most sediment over a period of several decades. Cumulative sediment transport capacity for any given flow range is the sum of flow frequency and sediment transport capacity per event within that range. It has been observed that for most environments dominant discharge corresponds to bankfull discharge (Q_{bf}), suggesting that this is the mechanism that shapes natural channels.

- The bankfull flow is defined as the maximum discharge that can be contained by the main channel before it overflows onto the floodplain under natural channel conditions. Bankfull geometry is the channel cross section shape that holds the bankfull flow. In fluvial systems bankfull dimensions within a region typically correlate with watershed area.

- Tidal channel dimensions can be related to tidal flow (the volume of water making up the tidal prism at MHHW) through the empirical relationships of Williams et al (2002). These relationships are based on data from tidal channels in mature natural marshes located throughout the San Francisco Bay.

Estimating the dominant discharge and associated fluvial and tidal channel geometry will help inform the channel design for the proposed realignment. We have also assumed that where one regime (e.g. tidal) produces much larger estimates of channel cross section than the other regime (e.g. fluvial), the former is likely dominant in that location. We would expect Ballona Creek to gradually transition from tidally-dominated in its lower reaches to fluvially-dominated in its upper reaches.

2. DOMINANT DISCHARGE ESTIMATE

Dominant discharge is calculated by estimating or measuring sediment transport at a range of flows, dividing the flows into bins, and identifying the range of flows that cumulatively transport the most sediment over a period of several decades. It is assumed that the channel will adjust through erosion and deposition to carry the dominant discharge. ESA PWA estimated the dominant discharge for the downstream reach of Ballona Creek using four steps: 1) Selection and summary of flow data, 2) preliminary estimate of bankfull channel dimensions, 3) development of a bed material sediment rating curve, and 4) integration of the flow data and the sediment rating curve to produce a sediment load histogram (sediment load as a function of discharge over the period of record). The histogram peak represents the bankfull discharge increment - i.e. the range of flows that transport the most sediment over time.

2.1.1 Flow Data

An hourly flow record from the Sawtelle Boulevard streamflow gage (F38-C) from October 1988 to December 2010 was used to evaluate the range of expected flows in the Ballona Creek channel. An hourly flow duration curve for this gage is shown in Figure 2. The data demonstrates that 99% of the hourly flow is less than 2,000 cfs. The maximum recorded flow over the 1988-2010 period occurred on 3/10/1995 and had a magnitude of 23,340 cfs.

2.1.2 Initial Assumed Bankfull Dimensions for Dominant Discharge Analysis

In order to estimate sediment transport capacity it is necessary to assume an initial channel cross section. The cross section was initially estimated based on the observed channel geometry at the Sawtelle Blvd gage. This was used to drive the sediment load histogram and bankfull discharge estimation method described in this section, the results of which were used to revise estimates for bankfull flow width. The sediment transport analysis was then repeated iteratively varying channel dimensions until the flow width derived from the regression equations converged with the bankfull flow estimated using the sediment load histogram approach.

2.1.3 Bed Material Sediment Rating Curve

Using the Bedload Assessment in Gravel-bedded Streams (BAGS) program developed for the U.S. Forest Service (USFS) (Pitlick et al., 2008, 2009), and the substrate-based Parker Klingerman Mclean (PKM) transport function (1982), a bed material sediment rating curve (SRC) was developed for the downstream reach of Ballona Creek. (Note that although the program is named for gravel streams, the sediment transport function selected was based on sand.) Inputs for the SRC development included bankfull flow width, an estimate of main channel roughness, a representative bed grain size distribution, a representative slope estimate, and a range of flows.

- Representative bankfull top width: As described above, the initial estimate of 300 feet was used based on the observed cross-section of the flood control channel. Through a series of iterations an average top width of 103 feet was derived. Little difference was observed between results for the top width estimates based on the two sediment transport functions used.
- Main channel roughness: A roughness of 0.03 was assumed for the main channel.

- Bed grain size distribution: The composite grain size distribution curve for Ballona Creek (USACE 2003) was used to represent sediment size present in the main channel. The 20 sediment samples collected by the USACE were taken at several locations over the length of Ballona Creek and its tributaries. Though the composite distribution was utilized for this analysis, results may be improved by using the data for samples collected within the analyzed reach. This data was not available at the time of this assessment.
- Representative slope: An average friction slope for the downstream reach was estimated using the Q100 profiles from the HEC-RAS model for Ballona Creek. The slope was estimated at 0.0009 ft/ft.
- Based upon the range of flows reported for the Sawtelle Boulevard gage, the sediment rating curve was calculated for up to 24,000 cfs.

One limitation of the BAGS program in this application is that it was originally designed for gravel-bedded streams. The transport functions available in BAGS are less appropriate for channels where the majority of the sediment falls in the sand and silt range which is the case for Ballona Creek. Evaluating the transport of the cohesive fraction of the bed sediment is even more problematic. Cohesion between sediment particles introduces large levels of uncertainty in sediment transport analysis. In-situ shear strength analysis is required to produce transport predictions within a reasonable degree of uncertainty. It is likely that that finer sediment would have a lower dominant discharge than coarser sediment, resulting in a smaller channel estimate.

2.1.4 Sediment Load Histogram

Using the flow data and the bed material SRC, an hourly sediment load was calculated for each average hourly discharge value (discharge values less than 5 cfs were excluded, as little-to-no bed material would be mobilized at such flows). The flow data, and associated total sediment loads, were summarized into a histogram of arithmetic class intervals (or bins), subsequently creating a sediment load histogram as well. The effective discharge was taken as the mid-point of the bin with the largest total sediment load (i.e., the peak of the sediment load histogram).

In previous studies, the number of arithmetic class intervals has ranged from 8 to 54, with 20 to 25 being the most common (Soar and Thorne, 2001). The selected class interval should be small enough to accurately represent the frequency distribution of flows, but large enough to produce a continuous distribution, with no classes having a flow frequency of zero (Shields et al., 2008, *Chapter 9*; Soar and Thorne, 2001). Using a range of several bin sizes, the average most effective sediment transporting flow was 2,100 cfs. This was assumed to be the dominant discharge at the Sawtelle Boulevard gage. The sediment load histogram for a class interval of 50 (corresponding to a bin size of 470 cfs) is shown in Figure 3.

2.2 Prorated Dominant Discharge and Channel Dimensions for the Restoration Site

The dominant flow estimate was conducted using streamflow recorded at the Sawtelle Boulevard gage which is approximately 3.8 miles upstream of the Ballona Creek outlet. This gage drains approximately 70% of the total Ballona Creek watershed, with an additional 36 square miles draining to the outlet. The ratio of flows between the two locations from the USACE flood frequency analysis (2008) was used to scale the dominant discharge estimate from the gage to the channel outlet. As shown in Table 1, the ratio between predicted flows is generally consistent over several return periods.

Table 1. Flood frequency estimates and ratio for n-year floods on Ballona Creek at Sepulveda Avenue and the channel outlet

	Drainage Area	n-year discharge (cfs)					
Ballona Creek	(sq-mi)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}
At Sepulveda ave	87.12	12,610	18,070	21,600	25,040	29,420	32,900
At outlet	122.8	17,170	24,840	29,690	34,020	40,150	44,690
Ratio	1.41	1.36	1.37	1.37	1.36	1.36	1.36

The scaled dominant discharge estimate at the restoration site is approximately 2,900 cfs. We would thus expect the channel cross section that contains this flow to be the stable channel dimensions. Based on the analysis the channel would have a width of approximately 103 feet.

3. FLUVIAL METHODS OF ESTIMATING BANKFULL CHANNEL GEOMETRY

The inputs and methodologies employed to estimate bankfull discharge and channel geometry based on watershed area and other attributes are described in the following sections.

3.1 Dunne and Leopold Analysis

Dunne and Leopold (1972) collected data relating bankfull width, depth and cross-sectional area to drainage area for four regions within the United States. This included the San Francisco Bay region at locations with 30-inches of mean annual precipitation and encompassed watershed areas greater than 100 square miles. The mean annual precipitation for the Ballona Creek watershed is approximately 27 inches based on the 1971-2000 rainfall dataset compiled by the PRISM climate group at Oregon State University, and the watershed area is 122.8 square miles. It should be noted that regression relationships vary between regions based on rainfall, vegetation and geology, but the San Francisco curve is believed to be the closest regional curve with a large dataset. The San Francisco Bay regional relationships were used to estimate the bankfull channel dimensions for Ballona Creek.

The Dunne and Leopold regression predicts a bankfull channel cross section of 518.4 square feet, with a width of 105.3 feet and a depth of 5.1 feet (Table 2). Dunne and Leopold’s equations can also be used to estimate bankfull discharge based on watershed size; for the watershed area and rainfall described above the estimated bankfull discharge would be 4,650 cfs.

3.2 Wilkerson and Parker Analysis

Wilkerson and Parker developed bankfull channel and discharge relationships using data collected on sand-bed rivers across the world. The relationships derived relate bankfull width, depth, and slope to bankfull discharge and median particle diameter. The dataset analyzed in this study contained sediment with a median bed particle size (D_{50}) between 0.062 mm and 0.50 mm. Sediment data collected for the Ballona Creek Channel presented by the USACE (2003) showed a reach-averaged D_{50} of 0.4 mm. The grain size distribution for 20 samples collected on Ballona Creek and its tributaries along with a composite average is shown in Figure 1.

The bankfull geometry relationships presented in Wilkerson and Parker (2011) rely on an estimate of bankfull discharge which, circularly, requires information on bankfull channel dimensions. Thus this analysis was solved iteratively until the predicted channel dimensions agreed with the predicted bankfull discharge. Our analysis bracketed the range of potential bankfull discharges, with a dominant discharge analysis (described in Section 2.) providing the lower value of 2,900 cfs and the Leopold and Dunne equation the higher potential value of 4,650 cfs.

Assuming a bankfull discharge of 2,900 cfs, the channel width estimated using the Wilkerson and Parker equation is 123.5 feet, with a depth of 5.6 feet. If a bankfull discharge of 4,650 cfs was used, the width would be expected to be 170.6 feet and the depth 6.4 feet (Table 2).

3.3 Soar and Thorne Analysis

The Soar and Thorne report provided updated relationships between bankfull width and discharge for sand-bed streams in 58 U.S. locations. This study demonstrated improved correlation in variables when accounting for vegetation coverage in the channel. For this preliminary estimate, the average relationships, regardless of channel vegetation, were assumed.

Soar and Thorne's equation predicts a channel width of 121.4 feet assuming a lower bankfull discharge of 2,900 cfs, and 156 feet for a higher discharge of 4,650 cfs (Table 2).

Table 2. Bankfull channel dimensions for the Ballona Creek channel

Source	Q_{bf} = 2,900 cfs			Q_{bf} = 4,650 cfs		
	Area (ft^2)	Width (ft)	Depth (ft)	Area (ft^2)	Width (ft)	Depth (ft)
Wilkerson and Parker	-	123.5	5.6	-	170.6	6.4
Soar and Thorne	-	121.4	-	-	156	-
Dunne & Leopold	518.4	105.3	5.1	518.4	105.3	5.1

4. TIDAL HYDRAULIC GEOMETRY ESTIMATES

The hydraulic geometry relationships from Williams et al (2002) provide expected channel dimensions once a site has developed into a mature marsh, based on the volume of water flowing in and out of the site. Because the sediment load in Ballona Creek is low and sedimentation would be slow or non-existent, tidal prism may not decrease significantly with time (due to marsh accretion), so the relationship between tidal prism at existing grade and channel dimensions is used. This approach is consistent with the Design Guidelines for Tidal Wetland Restoration in San Francisco Bay (PWA 2004).

Because tidal channels vary in size along their length, the channel dimensions of Ballona Creek were evaluated upstream of the site, at the transition into the site, mid-meander, at the transition out of the site, downstream of the site and at the end of the jetties (Figure 4). Tidal prism at each of these points was calculated as the volume above the conceptual grade between -0.2 ft NAVD (MLLW) and 5.2 ft NAVD (MHHW). This calculation was done for both existing and project conditions. To calculate channel dimensions with sea level rise, the tidal prism was calculated between 4.7 ft NAVD and 10.1 ft NAVD (59 in of sea level rise). Table 3 shows the channel dimensions for each scenario while Figure 5 and Figure 6 illustrate two channel cross-sections.

Table 3. Ballona Creek Tidal Hydraulic Geometry Channel Dimensions

Dimension	Scenario	All	Downstream	Downstream Transition	Mid-meander	Upstream Transition	Upstream
Depth (ft below MHHW)	Existing Conditions	12.7	12.3	11.8	11.2	10.5	10.0
	Project Conditions	13.2	12.8	12.0	11.4	10.5	10.0
	SLR Project Conditions	16.9	16.7	15.6	15.0	12.8	11.7
Top Width (ft at MHHW)	Existing Conditions	199	182	164	143	121	106
	Project Conditions	220	205	170	149	122	106
	SLR Project Conditions	419	408	340	307	202	160
Area (ft^2 below MHHW)	Existing Conditions	1472	1295	1124	925	734	607
	Project Conditions	1695	1532	1180	977	738	607
	SLR Project Conditions	4192	4035	3131	2710	1505	1082

5. DISCUSSION AND RECOMMENDATIONS

The set of fluvial-based methods produces a range of estimated channel cross sections from approximately 103 feet wide, based on dominant discharge, to 105 – 170 feet wide based on empirical regression equations. Channel depths range from 5-6 feet. Bankfull discharge vary from 2,100 cfs to 4,650 cfs, with an associated recurrence interval ranging from approximately 0.5 to 1.0 years (Table 3). By comparison, a regional regression based on tidal processes produces a range of channel widths from 162 at the upstream limit of the new channel to 221 feet at the downstream transition, with depths varying from 11.7 to 13.2 feet below MHHW (Table 5). It should be noted that all the methods used have considerable natural variability and uncertainty associated with them, and that the apparent differences between tidal and fluvial dimensions are not necessarily significant without additional supporting evidence. In general, the results of the channel geometry suggest that tidal processes are more significant in shaping the channel than fluvial processes. The downstream transition out of the site can be considered tidally dominated since it is so close to the ocean and because the tidal equations produce a larger cross section. At the upstream transition into the site, the results are not as clear, since the tidal prism is smaller and large fluvial events (greater than the one-year flow) are expected to exert a strong local influence on hydraulics and sediment transport processes. The analyses suggest that the restored channel should have a bankfull width at the marsh plain elevation of approximately 220 feet at the downstream transition and 160-170 feet at the upstream transition. The existing flood control channel is approximately 200 feet wide at the equivalent elevation, so it will be feasible to transition between artificial and restored channels without a sharp change in geometry. The details of this transition and the resulting channel morphology should be based on hydraulic modeling to develop a relatively smooth transition between flood channel and restoration site.

Table 4. Estimates for bankfull channel dimensions and discharge on Ballona Creek

	Cross-sectional Area (ft^2)	Width (ft)	Depth (ft)	Q_{bf} (cfs)
Existing Conditions	4500 - 5000	350 - 400	10 - 15	2,900- 4,650
Proposed Conditions	518.4	105 - 171	5.1- 6.4	

Table 5. Estimates for tidal channel dimensions on Ballona Creek

	Cross-sectional Area (ft^2 below MHHW)	Width (ft at MHHW)	Depth (ft below MHHW)
Existing Conditions	600 – 1500	110 – 200	10 – 12.7
Proposed Conditions	600 – 1700	110 – 220	10 – 13.2
Sea Level Rise Conditions	1100 – 4200	160 – 420	11.7 – 16.9

LIST OF FIGURES

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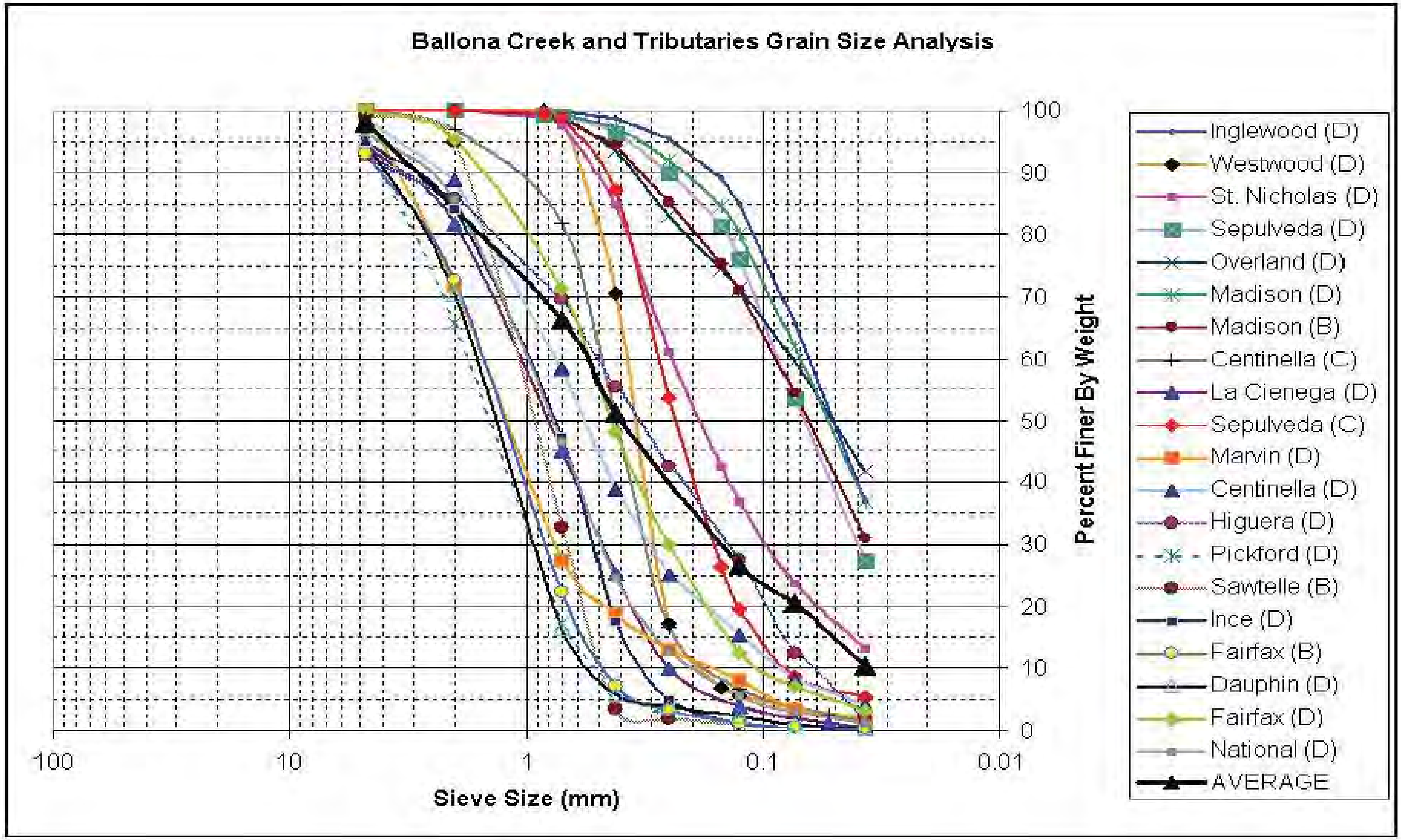

SOURCE: Reproduced from Figure 5 of USACE 2003

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Figure 1
Grain Size Distribution in
Ballona Creek and Its Tributaries

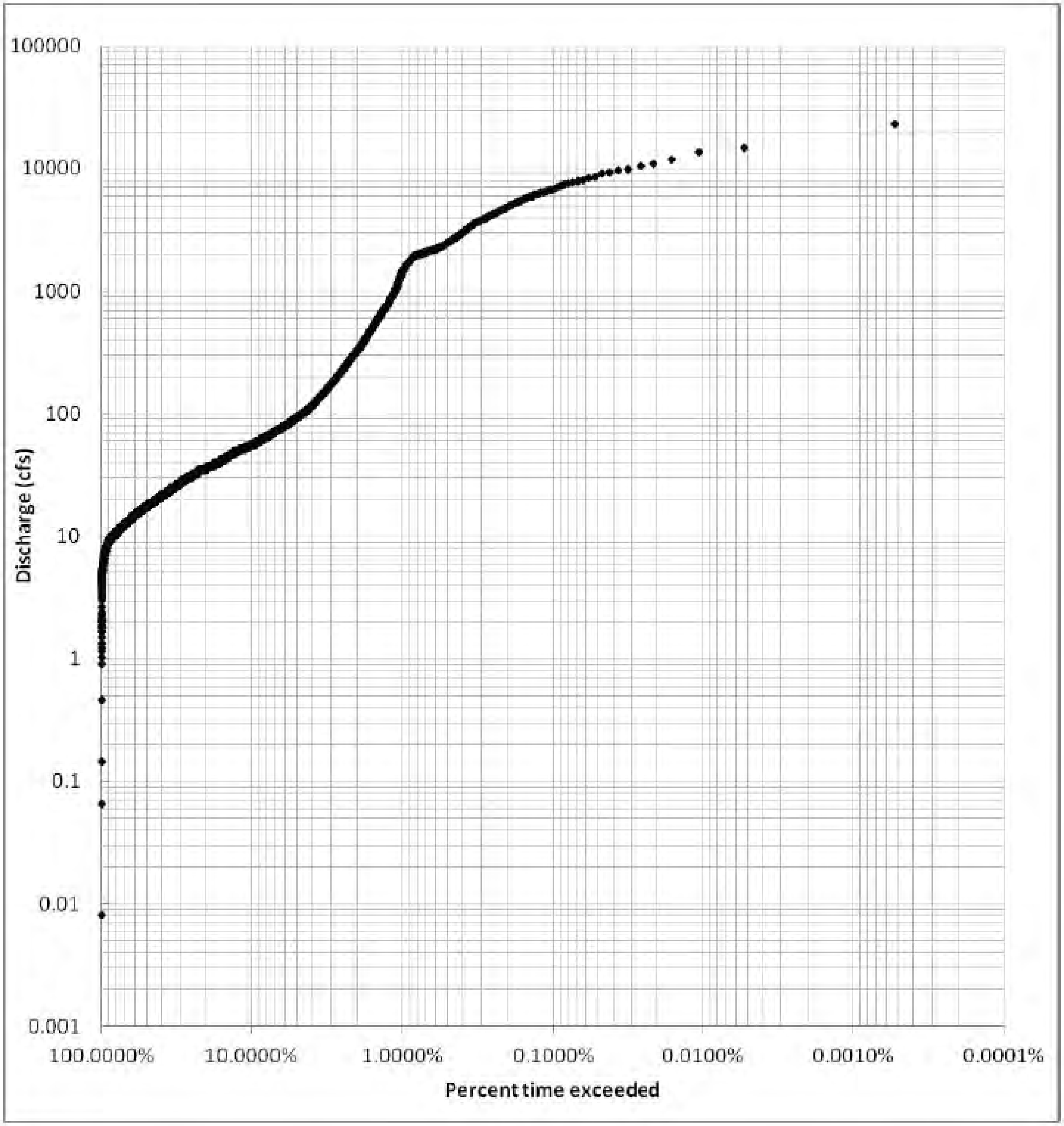

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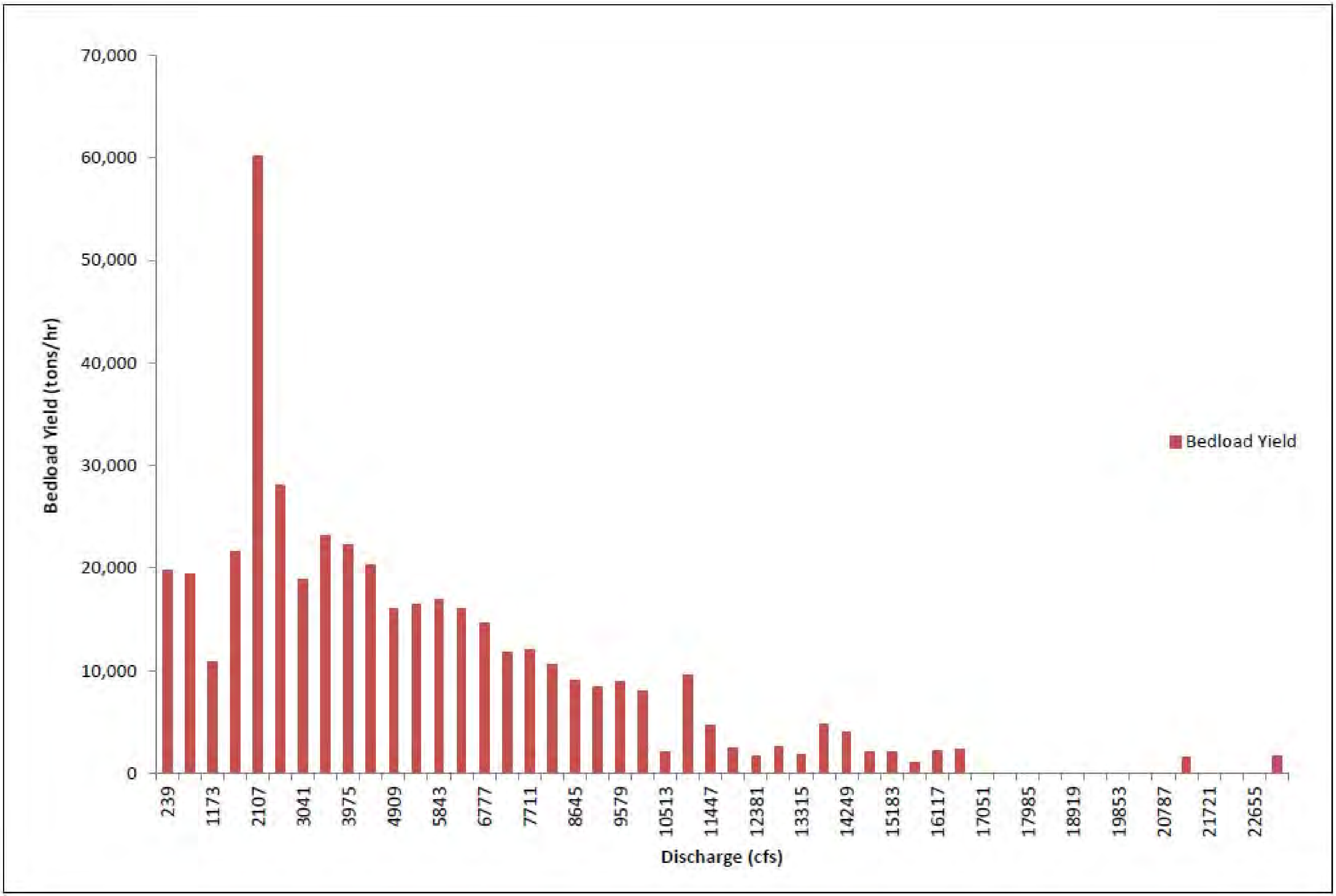
Figure 2
Flow Duration Curve for Sawtelle Blvd Gage F38-C on Ballona Creek



Note: Peak sediment transport at the Sawtelle Blvd gauge occurs at 2,100 cfs

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Figure 3

Sediment Load Histogram for 50 Class Intervals

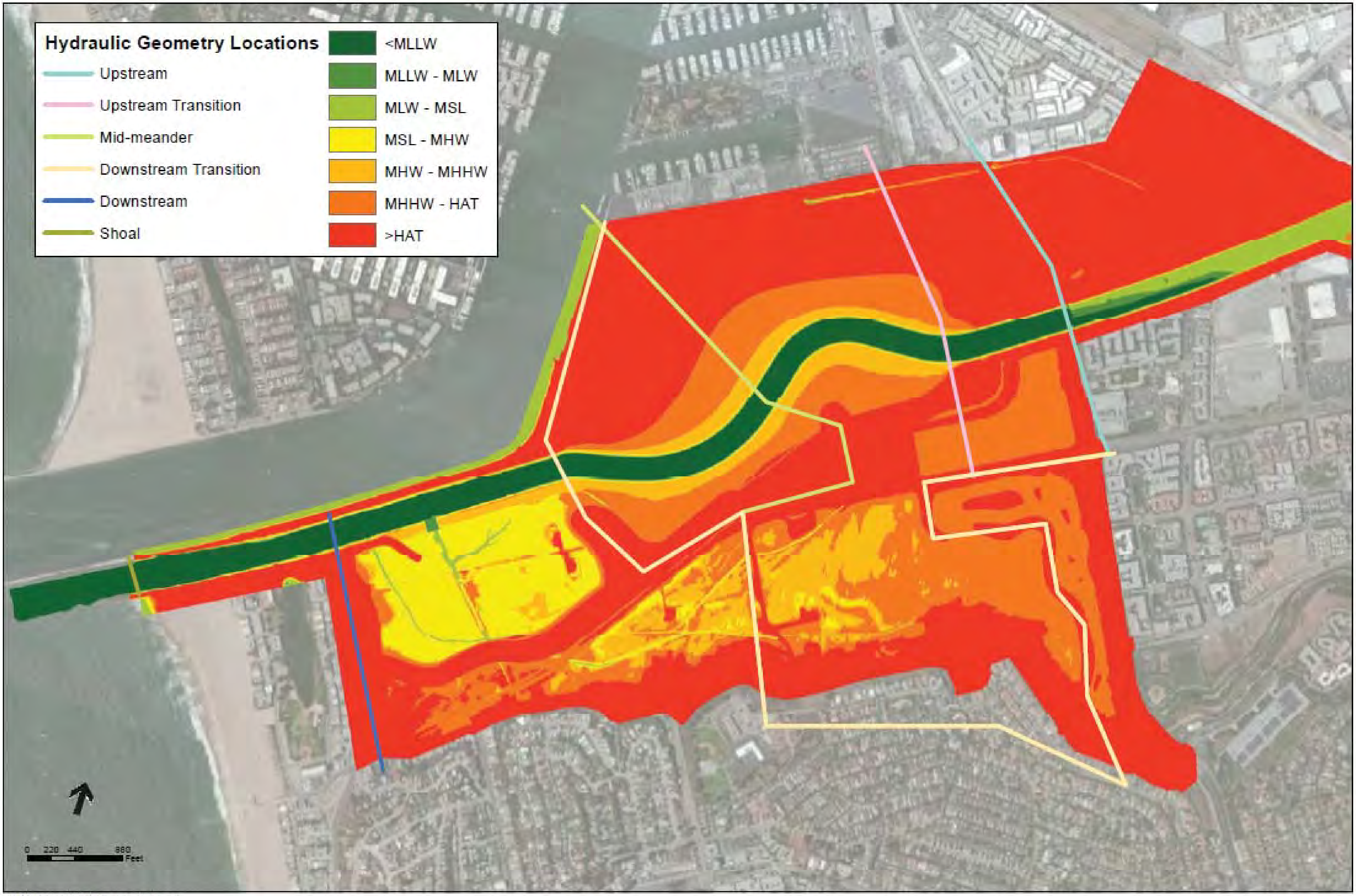

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Figure 4

Tidak Hydraulic Geometry Calculation Locations

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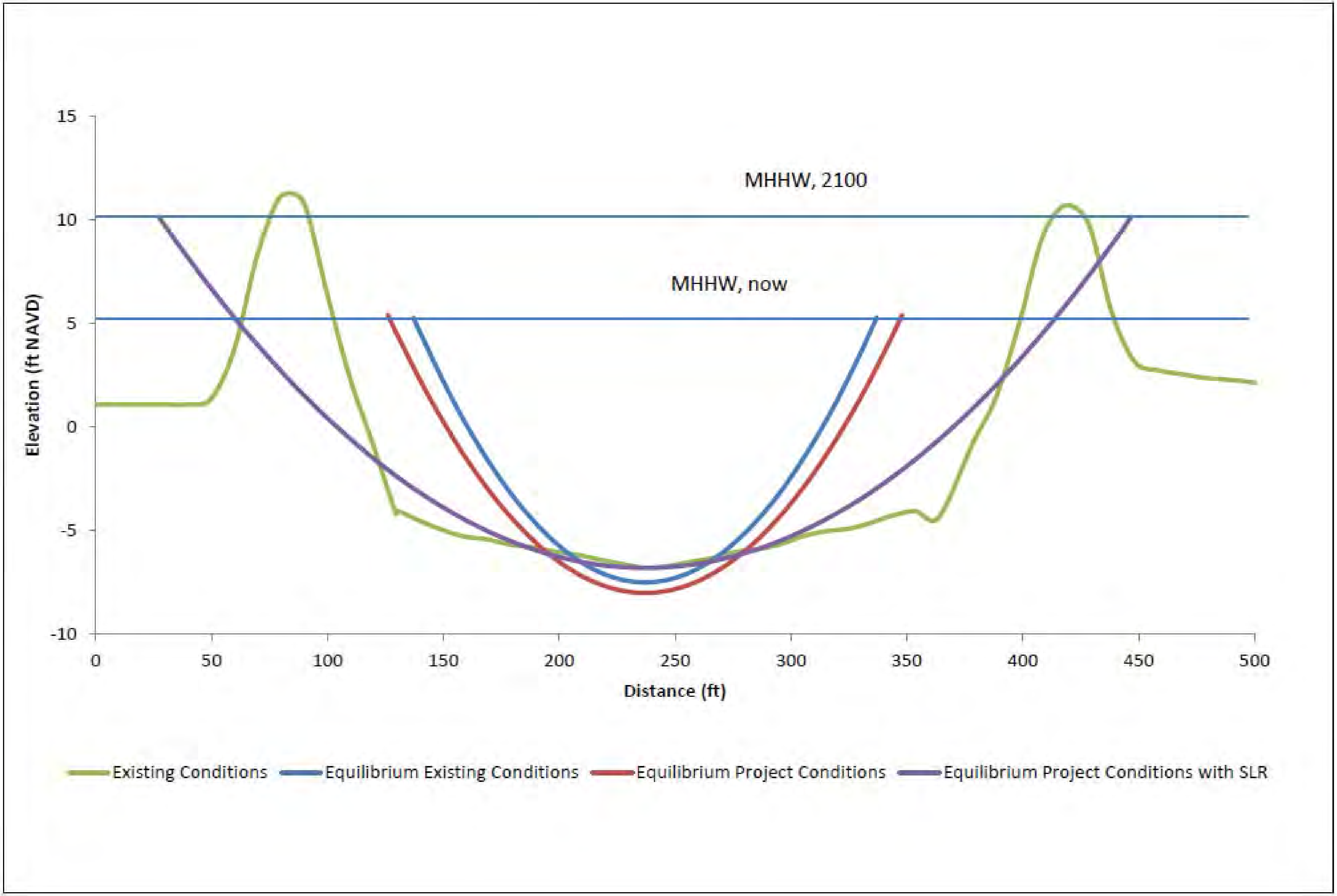

SOURCE: ESA PWA (2012)

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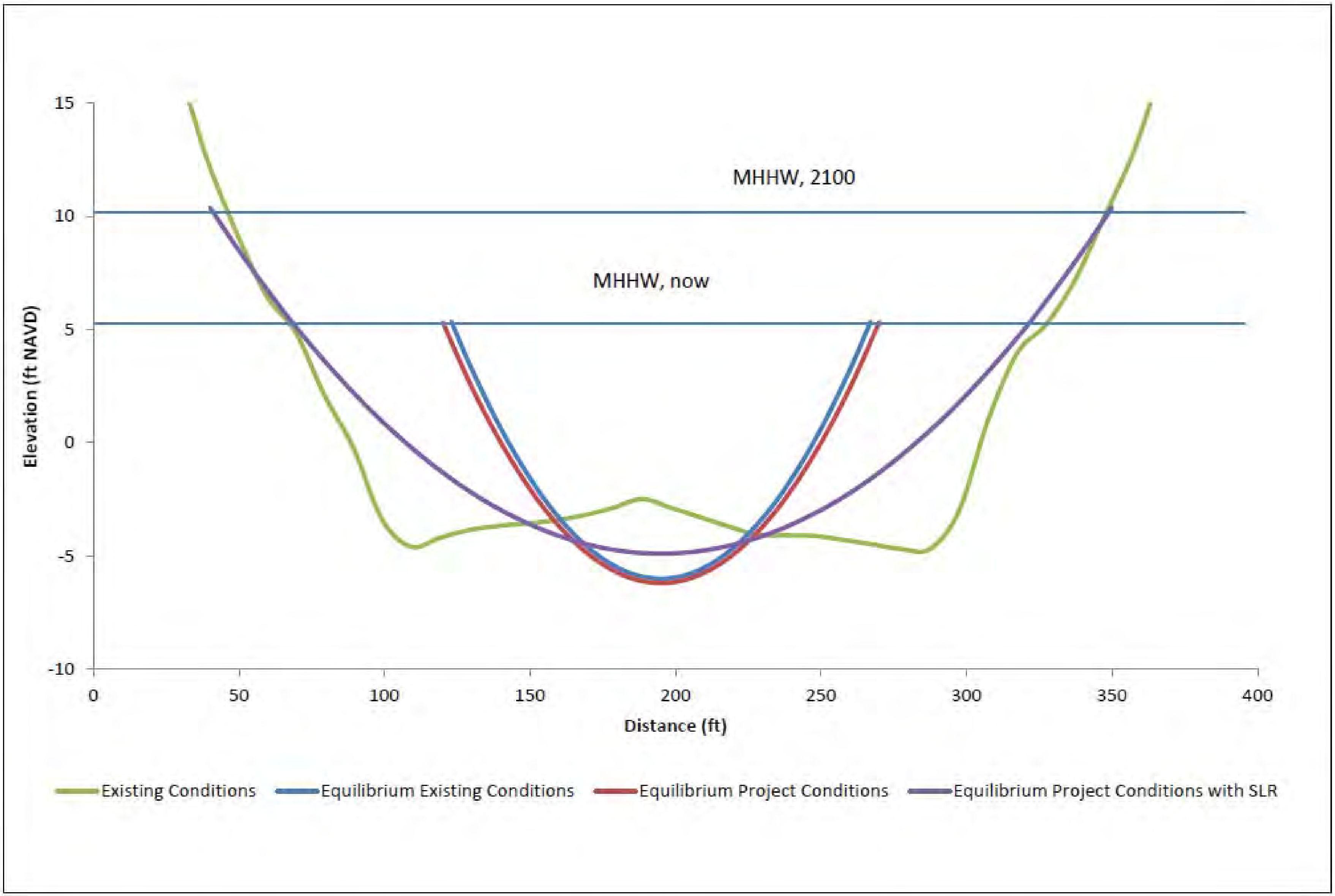
Figure 5

Ballona Creek Channel Cross Section at the Downstream Shoal



SOURCE: ESA PWA (2012)

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Figure 6

Ballona Creek Channel Cross Section
Mid-Meander

Appendix 4 Preliminary HEC-RAS Model Results

Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report
February 1, 2013 Administrative Draft
ESA PWA

Appendix 4 - Preliminary HEC-RAS Model Results – Ballona Creek Submittal A (1/30/2013)

Existing conditions results:

Station		Thalweg (ft NAVD)	Q100 WSE (ft NAVD)			46,000 cfs design flow WSE (ft NAVD)	
Existing alignment	Project alignment		MHHW	MHHW + SLR	MHHW + SLR w/Aggraded bed	7.63 ft NAVD	7.63 ft + SLR w/Aggraded bed
1187	1187	-8.09	5.20	10.10	10.10	7.63	12.53
1345	1345	-8.03	6.45	10.41	10.56	8.26	12.45
1575	1575	-8.30	6.80	10.52	10.84	8.48	12.71
1856	1856	-9.50	6.96	10.58	10.92	8.58	12.71
2030	2030	-9.19	7.01	10.60	11.05	8.62	12.70
2193	2193	-9.89	7.13	10.65	11.17	8.71	12.78
2201	2201	-9.89	7.08	10.62	11.13	8.67	12.75
2245	2245	-9.45	6.90	10.55	11.05	8.54	12.69
2246	2246	-9.45	7.84	10.88	11.71	9.16	13.15
3016	3016	-7.90	8.77	11.25	12.40	9.82	13.67
3846	3846	-8.23	9.34	11.57	13.00	10.31	14.64
4657	4657	-7.58	10.01	11.94	13.63	10.88	14.83
5416	5415	-7.18	10.61	12.30	14.18	11.39	15.04
6204	6272	-6.17	11.05	12.59	14.62	11.79	15.43
6928	7024	-5.13	11.68	12.99	15.03	12.34	15.79
7777	8247	-4.66	12.40	13.48	15.48	12.98	16.19
8536	9072	-3.36	12.73	13.72	15.77	13.30	16.46
9224	9789	-2.31	13.68	14.42	16.18	14.18	16.85
9434	10002	-1.80	13.89	14.59	16.30	14.38	16.96
9495	10063	-1.80	13.86	14.56	16.28	14.35	16.93
9543	10111	-1.68	13.71	14.43	16.18	14.19	16.84
9639	10207	-1.68	14.80	15.31	16.75	15.25	17.38
9926	10495	-1.60	14.97	15.46	16.86	15.42	17.49

9947	10516	-1.60	14.95	15.44	16.84	15.39	17.47
10022	10591	-1.40	15.01	15.49	16.88	15.45	17.50
10037	10606	-1.40	15.51	15.94	17.20	15.95	17.82
10425	10993	-1.61	15.64	16.05	17.28	16.08	17.89
11028	11597	-1.42	16.04	16.40	17.54	16.47	18.13
11613	12182	-0.75	16.40	16.73	17.78	16.81	18.36
12121	12689	-0.35	16.70	17.00	17.99	17.11	18.56
12520	13088	-0.58	17.02	17.30	18.23	17.43	18.79
12520	13088	-0.58	17.02	17.30	18.23	17.43	18.79
12902	13470	-0.28	17.02	17.30	18.22	17.12	18.54
13093	13661	-0.02	17.11	17.38	18.28	17.23	18.62
13270	13838	-0.02	17.23	17.49	18.37	17.38	18.72
13372	13940	0.76	17.01	17.28	18.19	17.09	18.50
13602	14170	0.76	18.50	18.66	19.27	19.19	19.90
14390	14959	0.39	18.86	19.01	19.57	19.59	20.23
15122	15691	0.52	18.89	19.03	19.56	19.58	20.20
15859	16428	0.00	19.42	19.54	20.00	20.18	20.70
16110	16680	-1.00	19.54	19.65	20.10	20.31	20.80
16484	17053	-1.00	18.64	18.80	19.38	19.31	19.90
16534	17103	2.54	19.31	19.31	19.31	20.35	20.35
16572	17141	2.54	19.76	19.76	19.76	20.81	20.81
16662	17231	2.95	21.08	21.08	21.08	21.08	21.08
16672	17241	2.95	24.21	24.21	24.21	25.96	25.96
17237	17806	3.74	24.39	24.39	24.39	26.10	26.10
17781	18350	4.80	24.61	24.61	24.61	26.26	26.26
18195	18764	5.64	24.90	24.90	24.90	26.51	26.51
18201	18771	5.64	24.38	24.38	24.38	25.26	25.26
18276	18846	5.87	24.70	24.70	24.70	32.02	32.02
18281	18851	5.87	28.45	28.45	28.45	38.03	38.03

18902	19471	6.76	28.60	28.60	28.60	38.08	38.08
19467	20036	8.09	28.59	28.59	28.59	38.12	38.12
19467	20036	8.09	28.59	28.59	28.59	38.12	38.12
19762	20332	8.66	30.49	30.49	30.49	37.98	37.98
20304	20874	9.74	30.52	30.52	30.52	38.03	38.03
20951	21521	11.00	31.17	31.17	31.17	38.25	38.25
20951	21521	11.00	31.07	31.07	31.07	37.58	37.58
21116	21686	11.23	30.83	30.83	30.83	37.69	37.69
21117	21687	11.23	33.37	33.37	33.37	41.16	41.16
21688	22259	12.54	33.80	33.80	33.80	41.27	41.27
21974	22544	13.00	33.79	33.79	33.79	41.15	41.15
21975	22545	13.00	33.71	33.71	33.71	39.90	39.90
22041	22611	13.00	33.46	33.46	33.46	39.78	39.78
22051	22621	13.00	34.99	34.99	34.99	44.86	44.86
22501	23071	14.06	35.34	35.34	35.34	45.19	45.19

Existing Conditions						Freeboard (ft)									
						Q100						46,000 cfs			
Coverage (relative to full project)		Station		Levee El. (ft NAVD)		MHHW		MHHW + SLR		MHHW + SLR wAggraded Bed		7.63 ft		7.63+ SLR wAggraded bed	
Left	Right	EC	PC	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
DS of West Area B	Marina	1187	1187	10.7	11.3	5.5	6.1	0.6	1.2	0.6	1.2	3.1	3.6	-1.8	-1.3
		1345	1345	10.5	12.3	4.1	5.8	0.1	1.9	0.0	1.7	2.2	4.0	-1.9	-0.2
		1575	1575	10.6	11.9	3.7	5.1	0.0	1.4	-0.3	1.1	2.1	3.5	-2.2	-0.8
		1856	1856	11.5	11.8	4.5	4.8	0.9	1.2	0.6	0.9	2.9	3.2	-1.2	-0.9
		2030	2030	15.3	14.7	8.2	7.7	4.6	4.1	4.2	3.7	6.6	6.1	2.5	2.0
		2193	2193	15.3	16.9	8.2	9.8	4.7	6.3	4.2	5.8	6.6	8.2	2.6	4.2
		2201	2201	15.4	16.9	8.3	9.8	4.8	6.3	4.3	5.8	6.8	8.3	2.7	4.2
		2245	2245	15.9	16.9	9.0	10.0	5.3	6.3	4.8	5.8	7.3	8.3	3.2	4.2
		2246	2246	15.9	16.9	8.0	9.0	5.0	6.0	4.2	5.2	6.7	7.7	2.7	3.7
		3016	3016	12.9	16.0	4.1	7.2	1.7	4.8	0.5	3.6	3.1	6.2	-0.8	2.3
West Area B		3846	3846	13.9	14.4	4.5	5.1	2.3	2.9	0.9	1.4	3.6	4.1	-0.8	-0.2
		4657	4657	14.4	15.2	4.4	5.2	2.4	3.2	0.7	1.5	3.5	4.3	-0.5	0.3
		5416	5415	15.2	17.8	4.6	7.2	2.9	5.5	1.1	3.6	3.8	6.4	0.2	2.8
North Area B	Area A	6204	6272	17.1	16.8	6.1	5.8	4.6	4.2	2.5	2.2	5.4	5.0	1.7	1.4
		6928	7024	18.8	17.8	7.1	6.1	5.8	4.8	3.8	2.8	6.5	5.5	3.0	2.0
		7777	8247	19.1	18.6	6.7	6.2	5.6	5.1	3.6	3.1	6.1	5.6	2.9	2.4
		8536	9072	19.7	19.6	6.9	6.8	5.9	5.8	3.9	3.8	6.4	6.3	3.2	3.1
		9224	9789	20.2	19.9	6.5	6.3	5.8	5.5	4.0	3.7	6.0	5.8	3.4	3.1
		9434	10002	21.1	20.2	7.2	6.3	6.5	5.6	4.8	3.9	6.7	5.8	4.1	3.2
		9495	10063	20.9	20.3	7.0	6.4	6.3	5.7	4.6	4.0	6.5	5.9	3.9	3.3
Upstream of Project		9543	10111	20.7	20.3	7.0	6.6	6.3	5.9	4.6	4.1	6.5	6.1	3.9	3.5
		9639	10207	20.5	20.5	5.7	5.7	5.1	5.1	3.7	3.7	5.2	5.2	3.1	3.1
		9926	10495	22.2	20.9	7.3	5.9	6.8	5.4	5.4	4.0	6.8	5.5	4.7	3.4

	9947	10516	22.4	20.7	7.4	5.8	6.9	5.3	5.5	3.9	7.0	5.3	4.9	3.3
	10022	10591	22.9	20.1	7.9	5.1	7.4	4.6	6.0	3.3	7.5	4.7	5.4	2.6
	10037	10606	23.0	20.0	7.5	4.5	7.1	4.1	5.8	2.8	7.1	4.1	5.2	2.2
	10425	10993	20.2	20.9	4.5	5.2	4.1	4.8	2.9	3.6	4.1	4.8	2.3	3.0
	11028	11597	21.1	21.1	5.0	5.1	4.7	4.7	3.6	3.6	4.6	4.7	3.0	3.0
	11613	12182	21.9	22.2	5.5	5.8	5.2	5.5	4.1	4.4	5.1	5.4	3.5	3.8
	12121	12689	22.5	23.7	5.9	7.0	5.5	6.7	4.6	5.7	5.4	6.6	4.0	5.1
	12520	13088	23.6	23.9	6.6	6.9	6.3	6.6	5.4	5.7	6.2	6.5	4.8	5.1
	12520	13088	23.6	23.9	6.6	6.9	6.3	6.6	5.4	5.7	6.2	6.5	4.8	5.1
	12902	13470	23.6	23.2	6.6	6.2	6.3	5.9	5.4	5.0	6.5	6.1	5.1	4.7
	13093	13661	26.0	25.4	8.9	8.3	8.6	8.0	7.7	7.1	8.7	8.1	7.3	6.7
	13270	13838	25.4	25.0	8.2	7.8	7.9	7.5	7.0	6.7	8.0	7.7	6.7	6.3
	13372	13940	25.1	24.8	8.1	7.8	7.8	7.6	6.9	6.7	8.0	7.8	6.6	6.3
Upstream of Project	13602	14170	24.4	24.4	5.9	5.9	5.7	5.8	5.1	5.1	5.2	5.2	4.5	4.5
	14390	14959	24.4	24.6	5.6	5.7	5.4	5.6	4.9	5.0	4.9	5.0	4.2	4.4
	15122	15691	25.5	25.5	6.7	6.6	6.5	6.5	6.0	5.9	6.0	5.9	5.3	5.3
	15859	16428	26.3	26.0	6.9	6.5	6.7	6.4	6.3	6.0	6.1	5.8	5.6	5.3
	16110	16680	26.5	25.6	6.9	6.1	6.8	6.0	6.4	5.5	6.2	5.3	5.7	4.8
	16484	17053	26.2	27.7	7.5	9.1	7.4	8.9	6.8	8.3	6.9	8.4	6.3	7.8
	16534	17103	27.5	28.0	8.2	8.7	8.2	8.7	8.2	8.7	7.1	7.6	7.1	7.6

Interim project conditions results:

Station	Thalweg (ft NAVD)	Q100 WSE (ft NAVD)		46,000 cfs design flow WSE (ft NAVD)
Project alignment		MHHW	MHHW + SLR	7.63 ft NAVD
1187	-8.09	5.20	10.10	7.63
1345	-8.03	6.45	10.41	8.26
1575	-8.30	6.80	10.52	8.48
1856	-9.50	6.96	10.58	8.58
2030	-9.19	7.01	10.60	8.62
2193	-9.89	7.13	10.65	8.71
2201	-9.89	7.08	10.62	8.67
2245	-9.45	6.90	10.55	8.54
2246	-9.45	7.84	10.88	9.16
3055	-8.06	8.72	11.24	9.80
3152	-7.99	8.80	11.29	9.87
3438	-7.89	8.93	11.36	9.97
3676	-7.79	9.29	11.54	10.27
3812	-7.90	9.33	11.56	10.30
4044	-7.94	9.68	11.75	10.59
4403	-7.83	9.92	11.89	10.79
4634	-7.51	10.02	11.95	10.88
5081	-6.66	10.14	12.12	11.05
5329	-7.03	10.32	12.18	11.16
5576	-6.75	10.43	12.27	11.28
5707	-6.62	10.29	12.18	11.15
5853	-6.47	11.93	13.11	12.53
6077	-6.26	12.03	13.18	12.62
6293	-6.04	12.74	13.74	13.31

6506	-5.79	12.68	13.67	13.24
6805	-5.49	12.85	13.80	13.40
6946	-5.36	13.31	14.18	13.85
7180	-5.17	13.82	14.60	14.34
7482	-4.96	13.85	14.63	14.37
7650	-4.85	13.90	14.67	14.42
7924	-4.61	13.95	14.70	14.46
8111	-4.40	13.89	14.65	14.40
8249	-4.24	13.89	14.65	14.39
8369	-4.11	13.95	14.69	14.45
8488	-3.99	13.99	14.72	14.48
8740	-3.75	13.97	14.70	14.46
8915	-3.61	13.97	14.70	14.46
9123	-3.42	13.98	14.70	14.46
9378	-3.15	13.97	14.68	14.45
9669	-2.81	13.77	14.49	14.23
9822	-2.64	13.70	14.43	14.16
9931	-2.52	13.86	14.56	14.32
9976	-2.48	14.03	14.70	14.49
10019	-2.43	13.91	14.60	14.37
10063	-2.43	13.88	14.57	14.33
10111	-2.21	13.74	14.44	14.19
10207	-2.21	14.52	15.09	14.96
10495	-1.60	14.53	15.10	14.97
10516	-1.60	14.50	15.07	14.94
10591	-1.40	14.57	15.13	15.01
10606	-1.40	15.14	15.62	15.58
10993	-1.61	15.28	15.74	15.71
11597	-1.42	15.73	16.13	16.15
12182	-0.75	16.12	16.48	16.53

12690	-0.35	16.44	16.77	16.84
13088	-0.58	16.79	17.09	17.19
13088	-0.58	16.79	17.09	17.19
13470	-0.28	16.79	17.09	16.86
13661	-0.02	16.89	17.18	16.99
13838	-0.02	17.01	17.29	17.15
13940	0.76	16.79	17.08	16.85
14170	0.76	18.38	18.54	19.11
14959	0.39	18.75	18.90	19.52
15691	0.52	18.78	18.92	19.52
16428	0.00	19.34	19.45	20.13
16679	-1.00	19.46	19.57	20.26
17052	-1.00	18.52	18.68	19.31
17102	2.54	19.31	19.31	20.35
17141	2.54	19.76	19.76	20.81
17231	2.95	21.08	21.08	21.08
17241	2.95	24.21	24.21	25.96
17806	3.74	24.39	24.39	26.10
18349	4.80	24.61	24.61	26.26
18764	5.64	24.90	24.90	26.51
18770	5.64	24.38	24.38	25.26
18845	5.87	24.70	24.70	32.02
18850	5.87	28.45	28.45	38.03
19471	6.76	28.60	28.60	38.08
20036	8.09	28.59	28.59	38.12
	0.00	0.00	0.00	0.00
20036	8.09	28.59	28.59	38.12
20331	8.66	30.49	30.49	37.98
20873	9.74	30.52	30.52	38.03

21519	11.00	31.17	31.17	38.25
21520	11.00	31.07	31.07	37.58
21685	11.23	30.83	30.83	37.69
21686	11.23	33.37	33.37	41.16
22257	12.54	33.80	33.80	41.27
22543	13.00	33.79	33.79	41.15
22543	13.00	33.71	33.71	39.90
22609	13.00	33.46	33.46	39.78
22619	13.00	34.99	34.99	44.86
23070	14.06	35.34	35.34	45.19

Interim Project conditions					Freeboard (ft)					
					Q100 WSE (ft NAVD)				46,000 cfs WSE (ft NAVD)	
Coverage (relative to full project)		Station	Levee El. (ft NAVD)		MHHW		MHHW + SLR		7.63 ft	
Left	Right	PC	Left	Right	Left	Right	Left	Right	Left	Right
DS of West Area B	Marina	1187	10.7	11.3	5.5	6.1	0.6	1.2	3.1	3.6
		1345	10.5	12.3	4.1	5.8	0.1	1.9	2.2	4.0
		1575	10.6	11.9	3.7	5.1	0.0	1.4	2.1	3.5
		1856	11.5	11.8	4.5	4.8	0.9	1.2	2.9	3.2
		2030	15.3	14.7	8.2	7.7	4.6	4.1	6.6	6.1
		2193	15.3	16.9	8.2	9.8	4.7	6.3	6.6	8.2
		2201	15.8	17.1	8.7	10.0	5.2	6.5	7.1	8.5
		2245	15.9	16.9	9.0	10.0	5.3	6.3	7.4	8.4
		2246	15.9	16.9	8.0	9.0	5.0	6.0	6.7	7.7
		3055	14.0	15.9	5.3	7.2	2.7	4.7	4.2	6.1
		3152	13.3	15.2	4.5	6.4	2.0	3.9	3.4	5.4
West Area B		3438	13.8	15.6	4.9	6.7	2.4	4.2	3.8	5.6
		3676	14.8	15.5	5.5	6.2	3.3	3.9	4.5	5.2
		3812	14.0	15.4	4.6	6.0	2.4	3.8	3.7	5.1
		4044	13.9	15.5	4.2	5.8	2.1	3.7	3.3	4.9
		4403	14.6	14.7	4.7	4.8	2.7	2.8	3.8	3.9
		4634	18.5	15.5	8.4	5.5	6.5	3.6	7.6	4.6
		5081	20.5	17.6	10.4	7.5	8.4	5.5	9.5	6.6
		5329	20.5	17.6	10.2	7.3	8.3	5.5	9.3	6.5
		5576	20.5	17.5	10.1	7.1	8.2	5.2	9.2	6.2
		5707	20.5	20.0	10.2	9.7	8.3	7.8	9.3	8.8
		5853	20.5	20.4	8.6	8.4	7.4	7.3	8.0	7.8
North Area B	Area A	6077	20.5	20.0	8.5	8.0	7.3	6.8	7.9	7.4
		6293	20.0	20.0	7.3	7.3	6.3	6.3	6.7	6.7

		6506	20.0	20.0	7.3	7.3	6.3	6.3	6.8	6.8
		6805	20.0	20.0	7.1	7.1	6.2	6.2	6.6	6.6
		6946	20.5	20.6	7.2	7.3	6.3	6.4	6.7	6.8
		7180	20.5	20.6	6.7	6.8	5.9	6.0	6.2	6.3
		7482	20.5	20.6	6.6	6.7	5.9	6.0	6.1	6.2
		7650	20.5	20.6	6.6	6.7	5.8	5.9	6.1	6.2
		7924	20.5	20.6	6.6	6.7	5.8	5.9	6.0	6.1
		8111	20.5	23.0	6.6	9.1	5.8	8.3	6.1	8.6
		8249	20.5	20.0	6.6	6.1	5.9	5.4	6.1	5.6
		8369	20.5	20.0	6.6	6.1	5.8	5.3	6.0	5.5
		8488	20.5	20.3	6.5	6.3	5.8	5.5	6.0	5.8
		8740	20.5	20.6	6.5	6.6	5.8	5.9	6.0	6.1
		8915	20.5	20.6	6.5	6.6	5.8	5.9	6.0	6.1
		9123	20.5	20.6	6.5	6.6	5.8	5.9	6.0	6.1
		9378	20.5	20.6	6.5	6.6	5.8	5.9	6.1	6.2
		9669	20.7	20.6	7.0	6.8	6.2	6.1	6.5	6.4
		9822	20.5	20.6	6.8	6.9	6.1	6.2	6.3	6.4
		9931	20.5	20.0	6.6	6.1	5.9	5.4	6.2	5.7
		9976	20.5	20.6	6.4	6.6	5.8	5.9	6.0	6.1
		10019	21.1	21.1	7.2	7.2	6.5	6.5	6.7	6.7
Upstream of Project Site		10063	21.1	21.0	7.2	7.1	6.5	6.4	6.7	6.6
		10111	21.0	21.0	7.3	7.3	6.6	6.6	6.8	6.8
		10207	21.0	30.1	6.5	15.6	5.9	15.1	6.0	15.2
		10495	22.2	20.9	7.7	6.4	7.1	5.8	7.3	5.9
		10516	20.6	20.7	6.1	6.2	5.5	5.6	5.7	5.8
		10591	20.6	20.1	6.0	5.5	5.5	5.0	5.6	5.1
		10606	23.0	20.0	7.9	4.8	7.4	4.3	7.5	4.4
		10993	20.2	20.9	4.9	5.6	4.4	5.1	4.5	5.1
		11597	21.1	21.1	5.4	5.4	5.0	5.0	4.9	5.0
		12182	21.9	22.2	5.8	6.1	5.4	5.7	5.4	5.7

	12690	22.5	23.7	6.1	7.2	5.8	6.9	5.7	6.8
	13088	23.6	23.9	6.8	7.2	6.5	6.9	6.4	6.8
Upstream of Project Site	13088	23.6	23.9	6.8	7.2	6.5	6.9	6.4	6.8
	13470	23.6	23.2	6.8	6.4	6.5	6.1	6.8	6.3
	13661	26.0	25.6	9.1	8.7	8.8	8.4	9.0	8.6
	13838	25.4	25.2	8.4	8.2	8.1	7.9	8.3	8.0
	13940	25.1	24.9	8.3	8.2	8.1	7.9	8.3	8.1
	14170	24.5	24.4	6.1	6.0	5.9	5.9	5.3	5.3
	14959	24.4	24.6	5.7	5.8	5.5	5.7	4.9	5.1
	15691	25.5	25.5	6.8	6.7	6.6	6.6	6.0	6.0
	16428	26.3	26.0	7.0	6.6	6.8	6.5	6.2	5.8
	16679	26.5	25.6	7.0	6.2	6.9	6.0	6.2	5.4
	17052	26.2	27.7	7.6	9.2	7.5	9.0	6.9	8.4
	17102	27.5	28.0	8.2	8.7	8.2	8.7	7.1	7.6

Full project conditions results:

Station	Thalweg (ft NAVD)	Q100 WSE (ft NAVD)			46,000 cfs design flow WSE (ft NAVD)	
Project alignment		MHHW	MHHW + SLR	MHHW + SLR w/Aggraded bed	7.63 ft NAVD	7.63 ft + SLR w/Aggraded bed
1187	-8.09	5.20	10.10	10.10	7.63	12.53
1345	-8.03	6.45	10.56	10.41	8.26	12.45
1575	-8.30	6.80	10.85	10.52	8.48	12.71
1856	-9.50	6.96	10.92	10.58	8.58	12.71
2030	-9.19	7.01	11.06	10.60	8.62	12.70
2193	-9.89	7.13	11.17	10.65	8.71	12.78
2201	-9.89	7.08	11.13	10.62	8.67	12.75
2245	-9.45	6.90	11.05	10.55	8.54	12.69
2246	-9.45	7.84	11.71	10.88	9.16	13.15
3055	-8.06	8.72	12.38	11.24	9.80	13.63
3152	-7.99	8.80	12.47	11.29	9.87	13.71
3438	-7.89	8.82	12.53	11.27	9.87	13.74
3632	-8.09	9.75	13.63	11.93	10.75	14.72
3701	-7.73	10.21	14.10	12.28	11.19	15.14
3812	-7.90	10.38	14.22	12.39	11.34	15.26
4044	-7.94	10.59	14.37	12.53	11.52	15.38
4403	-7.83	10.84	14.52	12.68	11.74	15.51
4658	-7.67	10.90	14.56	12.72	11.79	15.55
4863	-7.00	10.57	14.41	12.51	11.47	15.43
5305	-7.05	10.63	14.35	12.43	11.36	15.38
5546	-6.78	10.76	14.46	12.58	11.65	15.45
5707	-6.62	10.78	14.46	12.57	11.65	15.45
5853	-6.47	10.94	14.58	12.70	11.85	15.55
6079	-6.26	11.04	14.65	12.80	12.03	15.60
6293	-6.04	11.95	15.03	13.31	12.75	15.91

6506	-5.79	11.90	14.95	13.24	12.68	15.83
6805	-5.49	12.13	15.08	13.39	12.87	15.94
6946	-5.36	12.65	15.46	13.80	13.37	16.30
7180	-5.17	13.25	15.82	14.26	13.91	16.62
7482	-4.96	13.30	15.84	14.29	13.95	16.64
7650	-4.85	13.36	15.87	14.33	14.00	16.67
7924	-4.61	13.41	15.89	14.37	14.05	16.69
8111	-4.40	13.34	15.86	14.32	13.99	16.66
8249	-4.24	13.34	15.85	14.31	13.98	16.64
8369	-4.11	13.43	15.88	14.36	14.05	16.67
8488	-3.99	13.48	15.90	14.40	14.09	16.68
8740	-3.75	13.46	15.87	14.37	14.07	16.66
8915	-3.61	13.47	15.87	14.37	14.07	16.65
9123	-3.42	13.48	15.87	14.38	14.08	16.65
9378	-3.15	13.48	15.85	14.37	14.07	16.63
9669	-2.81	13.27	15.67	14.17	13.85	16.44
9822	-2.64	13.21	15.60	14.10	13.78	16.36
9931	-2.52	13.38	15.65	14.24	13.95	16.42
9976	-2.48	13.57	15.85	14.40	14.13	16.61
10019	-2.43	13.37	15.68	14.22	13.93	16.45
10063	-2.43	13.33	15.66	14.19	13.89	16.42
10111	-2.21	13.19	15.54	14.06	13.74	16.30
10207	-2.21	14.09	16.09	14.77	14.61	16.82
10495	-1.60	14.10	16.14	14.78	14.62	16.86
10516	-1.60	14.07	16.11	14.75	14.58	16.84
10591	-1.40	14.15	16.16	14.82	14.66	16.88
10606	-1.40	14.79	16.54	15.35	15.28	17.24
10993	-1.61	14.95	16.64	15.48	15.43	17.33
11597	-1.42	15.45	16.94	15.91	15.91	17.60
12182	-0.75	15.88	17.22	16.27	16.32	17.86

12690	-0.35	16.23	17.46	16.58	16.65	18.09
13088	-0.58	16.59	17.73	16.92	17.02	18.34
13088	-0.58	16.59	17.73	16.92	17.02	18.34
13470	-0.28	16.60	17.72	16.92	16.68	18.07
13661	-0.02	16.70	17.79	17.01	16.82	18.16
13838	-0.02	16.83	17.89	17.13	16.98	18.28
13940	0.76	16.60	17.70	16.91	16.67	18.04
14170	0.76	18.28	18.93	18.44	19.07	19.63
14959	0.39	18.67	19.25	18.81	19.48	19.98
15691	0.52	18.70	19.26	18.84	19.48	19.96
16428	0.00	19.27	19.74	19.39	20.10	20.50
16679	-1.00	19.40	19.84	19.51	20.23	20.60
17052	-1.00	18.43	19.05	18.59	19.31	19.63
17102	2.54	19.31	19.31	19.31	20.35	20.35
17141	2.54	19.76	19.76	19.76	20.81	20.81
17231	2.95	21.08	21.08	21.08	21.08	21.08
17241	2.95	24.21	24.21	24.21	25.96	25.96
17806	3.74	24.39	24.39	24.39	26.10	26.10
18349	4.80	24.61	24.61	24.61	26.26	26.26
18764	5.64	24.90	24.90	24.90	26.51	26.51
18770	5.64	24.38	24.38	24.38	25.26	25.26
18845	5.87	24.70	24.70	24.70	32.02	32.02
18850	5.87	28.45	28.45	28.45	38.03	38.03
19471	6.76	28.60	28.60	28.60	38.08	38.08
20036	8.09	28.59	28.59	28.59	38.12	38.12
20036	8.09	28.59	28.59	28.59	38.12	38.12
20331	8.66	30.49	30.49	30.49	37.98	37.98
20873	9.74	30.52	30.52	30.52	38.03	38.03

21519	11.00	31.17	31.17	31.17	38.25	38.25
21520	11.00	31.07	31.07	31.07	37.58	37.58
21685	11.23	30.83	30.83	30.83	37.69	37.69
21686	11.23	33.37	33.37	33.37	41.16	41.16
22257	12.54	33.80	33.80	33.80	41.27	41.27
22543	13.00	33.79	33.79	33.79	41.15	41.15
22543	13.00	33.71	33.71	33.71	39.90	39.90
22609	13.00	33.46	33.46	33.46	39.78	39.78
22619	13.00	34.99	34.99	34.99	44.86	44.86
23070	14.06	35.34	35.34	35.34	45.19	45.19

Full project conditions					Freeboard (ft)									
					Q100						46,000 cfs			
Coverage		Station	Levee El. (ft NAVD)		MHHW		MHHW + SLR		MHHW + SLR w/Aggraded Bed		7.63 ft		7.63+ SLR w/Aggraded bed	
Left	Right	PC	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
DS of West Area B	Marina	1187	10.7	11.3	5.5	6.1	0.6	1.2	0.6	1.2	3.1	3.6	-1.8	-1.3
		1345	10.5	12.3	4.1	5.8	0.1	1.9	0.0	1.6	2.2	4.0	-1.9	-0.2
		1575	10.6	11.9	3.7	5.1	0.0	1.4	-0.3	1.0	2.1	3.5	-2.2	-0.8
		1856	11.5	11.8	4.5	4.8	0.9	1.2	0.6	0.7	2.9	3.2	-1.2	-0.9
		2030	15.3	14.7	8.2	7.7	4.6	4.1	4.2	3.5	6.6	6.1	2.5	2.0
		2193	15.3	16.9	8.2	9.8	4.7	6.3	4.2	5.6	6.6	8.2	2.6	4.2
		2201	15.8	17.1	8.7	10.0	5.2	6.5	4.6	5.8	7.1	8.5	3.0	4.4
		2245	15.9	16.9	9.0	10.0	5.3	6.3	4.8	5.7	7.3	8.3	3.2	4.2
		2246	15.9	16.9	8.0	9.0	5.0	6.0	4.2	4.9	6.7	7.7	2.7	3.7
		3055	14.0	15.9	5.3	7.2	2.7	4.7	1.6	3.2	4.2	6.1	0.3	2.3
		3152	13.3	15.2	4.5	6.4	2.0	3.9	0.8	2.4	3.4	5.4	-0.4	1.5
West Area B		3438	20.5	15.6	11.7	6.8	9.2	4.3	7.9	2.7	10.6	5.7	6.7	1.8
		3632	20.5	15.9	10.8	6.2	8.6	4.0	6.9	1.8	9.8	5.2	5.8	1.2
		3701	20.5	15.1	10.3	4.9	8.2	2.8	6.4	0.5	9.3	3.9	5.4	0.0
		3812	20.5	15.3	10.1	4.9	8.1	2.9	6.3	0.6	9.2	3.9	5.2	0.0
		4044	20.5	15.5	9.9	4.9	8.0	2.9	6.1	0.6	9.0	3.9	5.1	0.1
		4403	20.5	14.8	9.7	3.9	7.8	2.1	6.0	-0.2	8.8	3.0	5.0	-0.8
		4658	20.5	15.5	9.6	4.6	7.8	2.8	5.9	0.4	8.7	3.7	4.9	-0.1
		4863	20.5	16.2	9.9	5.7	8.0	3.7	6.1	1.3	9.0	4.8	5.1	0.8
		5305	20.5	17.7	9.9	7.1	8.1	5.3	6.1	2.9	9.1	6.4	5.1	2.4
		5546	20.5	18.5	9.7	7.7	7.9	5.9	6.0	3.5	8.9	6.8	5.1	3.0
		5707	20.5	17.0	9.7	6.2	7.9	4.4	6.0	2.0	8.8	5.3	5.1	1.5
		5853	20.5	20.5	9.6	9.6	7.8	7.8	5.9	5.5	8.7	8.7	5.0	5.0
North	Area A	6079	20.5	20.0	9.5	9.0	7.7	7.2	5.9	4.9	8.5	8.0	4.9	4.4

Area B		6293	20.0	20.0	8.0	8.0	6.7	6.7	5.0	4.5	7.3	7.3	4.1	4.1
		6506	20.0	20.0	8.1	8.1	6.8	6.8	5.0	4.6	7.3	7.3	4.2	4.2
		6805	20.0	20.0	7.9	7.9	6.6	6.6	4.9	4.5	7.1	7.1	4.1	4.1
		6946	20.5	20.6	7.9	8.0	6.7	6.8	5.0	4.7	7.1	7.2	4.2	4.3
		7180	20.5	20.6	7.2	7.3	6.2	6.3	4.7	4.3	6.6	6.7	3.9	4.0
		7482	20.5	20.6	7.2	7.3	6.2	6.3	4.7	4.3	6.5	6.6	3.9	4.0
		7650	20.5	20.6	7.1	7.2	6.2	6.3	4.6	4.2	6.5	6.6	3.8	3.9
		7924	20.5	20.6	7.1	7.2	6.1	6.2	4.6	4.2	6.5	6.6	3.8	3.9
		8111	20.5	20.6	7.2	7.3	6.2	6.3	4.6	4.2	6.5	6.6	3.8	3.9
		8249	20.5	20.0	7.2	6.7	6.2	5.7	4.7	3.7	6.5	6.0	3.9	3.4
		8369	20.5	20.0	7.1	6.6	6.1	5.6	4.6	3.6	6.4	5.9	3.8	3.3
		8488	20.5	20.3	7.0	6.8	6.1	5.9	4.6	3.9	6.4	6.2	3.8	3.6
		8740	20.5	20.6	7.0	7.1	6.1	6.2	4.6	4.2	6.4	6.5	3.8	3.9
		8915	20.5	20.6	7.0	7.1	6.1	6.2	4.6	4.2	6.4	6.5	3.8	3.9
		9123	20.5	20.6	7.0	7.1	6.1	6.2	4.6	4.3	6.4	6.5	3.9	4.0
		9378	20.5	20.6	7.0	7.1	6.1	6.2	4.6	4.3	6.4	6.5	3.9	4.0
		9669	20.7	20.6	7.5	7.3	6.6	6.4	5.1	4.5	6.9	6.8	4.3	4.2
		9822	20.5	20.6	7.3	7.4	6.4	6.5	4.9	4.6	6.7	6.8	4.1	4.2
		9931	20.5	20.0	7.1	6.6	6.3	5.8	4.8	3.9	6.6	6.1	4.1	3.6
		9976	20.5	20.6	6.9	7.0	6.1	6.2	4.6	4.3	6.3	6.5	3.8	4.0
		10019	21.1	21.1	7.7	7.7	6.9	6.9	5.4	5.0	7.2	7.2	4.6	4.6
Upstream of Project Site		10063	21.1	21.0	7.7	7.6	6.9	6.8	5.4	4.9	7.2	7.1	4.6	4.6
		10111	21.0	21.0	7.8	7.8	7.0	7.0	5.5	5.0	7.3	7.3	4.7	4.7
		10207	21.0	20.6	6.9	6.5	6.2	5.8	4.9	4.0	6.4	6.0	4.2	3.8
		10495	20.6	20.9	6.5	6.8	5.8	6.1	4.5	4.3	6.0	6.3	3.7	4.0
		10516	20.6	20.7	6.5	6.7	5.8	6.0	4.5	4.1	6.0	6.1	3.8	3.9
		10591	20.6	20.1	6.4	5.9	5.8	5.3	4.4	3.5	5.9	5.4	3.7	3.2
		10606	20.6	20.0	5.8	5.2	5.2	4.6	4.1	2.9	5.3	4.7	3.4	2.7
		10993	20.2	20.9	5.2	5.9	4.7	5.4	3.5	3.7	4.7	5.4	2.9	3.5
		11597	21.1	21.1	5.6	5.7	5.2	5.2	4.2	3.7	5.2	5.2	3.5	3.5

	12182	21.9	22.2	6.0	6.3	5.6	5.9	4.7	4.5	5.6	5.9	4.0	4.3
	12690	22.5	23.7	6.3	7.5	6.0	7.1	5.1	5.7	5.9	7.0	4.5	5.6
	13088	23.6	23.9	7.0	7.3	6.7	7.0	5.9	5.7	6.6	6.9	5.2	5.6
	13088	23.6	23.9	7.0	7.3	6.7	7.0	5.9	5.7	6.6	6.9	5.2	5.6
	13470	23.6	23.2	7.0	6.6	6.7	6.3	5.9	5.0	6.9	6.5	5.6	5.1
	13661	26.0	25.6	9.3	8.9	8.9	8.6	8.2	7.3	9.1	8.8	7.8	7.4
	13838	25.4	25.2	8.6	8.3	8.3	8.0	7.5	6.8	8.5	8.2	7.2	6.9
	13940	25.1	24.9	8.5	8.3	8.2	8.0	7.4	6.7	8.5	8.3	7.1	6.9
Upstream of Project Site	14170	24.5	24.4	6.2	6.1	6.0	6.0	5.5	4.9	5.4	5.3	4.8	4.8
	14959	24.4	24.6	5.8	5.9	5.6	5.8	5.2	4.8	5.0	5.1	4.5	4.6
	15691	25.5	25.5	6.8	6.8	6.7	6.6	6.3	5.7	6.1	6.0	5.6	5.5
	16428	26.3	26.0	7.0	6.7	6.9	6.6	6.6	5.7	6.2	5.9	5.8	5.5
	16679	26.5	25.6	7.1	6.2	7.0	6.1	6.6	5.2	6.2	5.4	5.9	5.0
	17052	26.2	27.7	7.7	9.3	7.6	9.1	7.1	8.2	6.9	8.4	6.5	8.1

APPENDIX F8
Hydraulic Modeling Addendum

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memorandum

date September 28, 2015 – *updated November 5, 2015*

to Ballona Wetlands Restoration Project Management Team

from James Gregory, PE, Christie Beeman, PE, and Nick Garrity, PE

subject Ballona Wetlands Restoration Project - Preliminary Hydrology and Hydraulics Report ADDENDUM

This memorandum was prepared as an addendum to the Draft Preliminary Hydrology and Hydraulics Report dated May 8, 2013. It describes additional hydraulic analyses performed to evaluate the Ballona Wetlands Restoration Project Alternatives and sediment deposition scenarios for the Ballona Creek channel to inform potential channel maintenance limits.

The hydraulic analyses described in this Addendum were performed to evaluate and compare potential flood impacts from the following project alternatives, relative to existing conditions:.

Alternative 1, Phase 1 – would restore connectivity of Ballona Creek with the floodplain by removing the existing levees, lowering the grade in Area A and North Area B, and creating a sinuous channel. New earthen levees would be built around the northern perimeter of Area A and along the north side of Culver Boulevard in North Area B to the junction of Culver Boulevard and Jefferson Boulevard, and then connect to the existing West Area B levee.

Alternative 1, Phase 2 – would remove the levee along the north side of West Area B and build a new levee to the south of West Area B and east of the dune habitat in the west.

Alternative 2 – would restore connectivity of Ballona Creek with the floodplain by removing the existing levees, lowering the grade in Area A and North Area B, and creating a sinuous channel. New earthen levees would be built around the northern perimeter of Area A and along the north side of Culver Boulevard in North Area B to the junction of Culver Boulevard and Jefferson Boulevard, and then connect to the existing West Area B levee. Alternative 2 is similar to Alternative 1, Phase 1; however, the levee geometry in North Area B is different.

Alternative 3 – would restore connectivity of Ballona Creek with the floodplain by lowering the grade in Area A and installing open culverts through the north Ballona Creek levee. A new earthen levee would be built around the northern perimeter of Area A.

Alternative 4 is the No Action Alternative and is therefore the same as existing conditions for this hydraulic analysis. These alternatives are described in detail in Chapter 2, Project Description, of the EIR/S.

Three sedimentation scenarios were applied to each Alternative to evaluate the potential effect of sedimentation on flood levels and channel maintenance needs. For the purposes of this evaluation, three sedimentation scenarios were modeled to evaluate the sedimentation threshold that would raise water levels enough to require channel maintenance. These sedimentation scenarios are:

> **Equilibrium Tidal Channel Hydraulic Geometry** – represents the channel dimensions at which the tidal hydraulic influences are in balance with sedimentation. The method used to estimate these dimensions is presented in the Draft Preliminary Hydrology and Hydraulics Report (ESA 2013).
>
> **2 feet of deposition in the channel bottom** – represents the channel dimensions with 2 feet of deposition over the channel bed.
>
> **4 feet of deposition in the channel bottom** – represents the channel dimensions with 4 feet of deposition over the channel bed.

The first scenario assumes tidal sediment transport processes will dominate long term sedimentation in the channel and that sufficient sediment is available for the channel to aggrade to equilibrium hydraulic geometry dimensions. This is considered a conservative assumption because the channel is sediment supply limited (as described in ESA PWA 2013) and therefore not expected to aggrade to equilibrium hydraulic geometry dimensions.

The 2- and 4-foot deposition scenarios assume a uniform depth of sediment deposition throughout the entire channel. These deposition scenarios are considered conservative because fluvial sediment transport modeling results indicate the restored channel will experience both erosion and deposition during storm events, with a maximum of 0.7 ft of deposition at any given cross section for the modeled scenarios. While erosion and deposition patterns will vary with the magnitude of the modeled event and specific location along the channel, modeling results indicate that larger flood events are likely to produce net erosion under project conditions. (Sediment transport modeling results and discussion are presented in the Ballona Creek and Wetlands Sediment Dynamics and Sediment Budget Analysis, Appendix F1).

HEC-RAS Model

For the current analysis, ESA used the same hydraulic modeling inputs and parameters as described in the Draft Preliminary Hydrology and Hydraulics Report (ESA 2013). Channel geometry was modified to reflect the project alternatives and sedimentation scenarios as described above.

ESA modified cross section geometry in the existing HEC RAS model (described in ESA 2013) to reflect the Alternative 1 Phase 1, Alternative 1 Phase 2, Alternative 2, and Maintenance Limit scenarios. Channel geometry for Alternative 3 is identical to Existing Conditions except that it includes an open connection between Ballona Creek and Area A via culverts through the Ballona Creek levee. As a result of the culvert connection, the water level in Area A will be in equilibrium with the Ballona Creek water level under steady-state conditions. Therefore, steady-state hydraulic modeling results for Existing Conditions reflect the same conditions that will exist under Alternative 3.

Model geometry for the Equilibrium Tidal Channel Hydraulic Geometry scenario was developed based on tidal hydraulic geometry relationships (Section 6.2.1 of ESA 2013). For the 2-, and 4-foot deposition scenarios, these depths were added to the channel bottom uniformly between the left and right toe of the channel.

The model was run for each of the scenarios under a variety of boundary conditions. Table 1 provides a hydraulic modeling run catalog that summarizes the model scenarios applied to each of the alternatives.

Table 1. Hydraulic model run catalog

Scenario	Flow Rate (Q)	Downstream Boundary	Bed Aggradation
Design Flood	46,000 cfs	7.63 ft NAVD	-
Sea Level Rise (SLR)	46,000 cfs	7.63 ft NAVD + SLR	-
SLR + Aggradation	46,000 cfs	7.63 ft NAVD + SLR	SLR
Flood Frequency	Q2, 5, 10, 25, 50, 100, 200, 500	MHHW	-
Sedimentation Scenario	46,000 cfs	7.63 ft NAVD	Tidal Geometry, 2 feet, 4 feet deposition

Results

HEC RAS modeling results for the scenarios summarized in Table 1 are presented in Figures 1-4 listed below. In each of the figures, model results for Existing Conditions are also shown for comparison.

Figure 1 - Design flood EC, Alt 1 Ph1, Alt 1, Alt2
Figure 2a - Design Flood Profiles with Sea Level Rise and Bed Aggradation for EC and Alt1 Phase 1
Figure 2b - Design Flood Profiles with Sea Level Rise and Bed Aggradation for EC and Alt1
Figure 2c - Design Flood Profiles with Sea Level Rise and Bed Aggradation for EC and Alt2
Figure 3a – Flood Frequency Q2 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3b – Flood Frequency Q5 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3c – Flood Frequency Q10 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3d – Flood Frequency Q25 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3e – Flood Frequency Q50 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3f – Flood Frequency Q100 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3g – Flood Frequency Q200 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 3h – Flood Frequency Q500 for EC, Alt1 Phase 1, Alt 1, and Alt2
Figure 4 – Design Flood Profiles for Project Alternatives with Tidal Geometry
Figure 5 – Design Flood Profiles for Project Alternatives with 2 feet of Deposition
Figure 6 – Design Flood Profiles for Project Alternatives with 4 feet of Deposition
Figure 7 – Cross-sections in Area A for existing and project conditions with sedimentation scenarios

Table 2 summarizes hydraulic modeling results for the Design Flood scenario for existing conditions and the Alternatives in terms of freeboard. Table 3 summarizes the freeboard results for the sedimentation scenarios. Freeboard is the difference between the water surface elevation (from hydraulic model results) and the elevation of the levee top. For existing conditions, freeboard is calculated relative to existing levee elevations. For all other scenarios it is calculated relative to the proposed levee elevations. Where model results show the water surface elevation higher than the levee top elevation, freeboard equal to zero is reported in the table. Because the model was not set up to recognize flow reductions that may result from levee overtopping, model results may somewhat overstate water surface elevations for scenarios where the water surface elevation exceeds the levee elevation.

Table 2 HEC RAS Results for Design Flood Scenario – Ballona Creek Freeboard (feet)

	Adjacent to Area A/North Area B (RS 6079 to 10019)			Adjacent to West Area B (RS 3055 to 5853)		
	Reach Average	Maximum	Minimum	Reach Average	Maximum	Minimum
Existing Conditions[1]	5.6	6.3	5.0	3.7	4.2	3.1
Alt 1, Phase 1[2]	5.7	6.9	5.4	5.1[1]	8.1[1]	3.2[1]
Alt 1, Phase 2[2]	4.7	5.8	4.4	5.0	7.4	3.1
Alternative 2[2]	3.8	4.6	3.6	4.9[1]	7.1[1]	3.2[1]
Alternative 3[1]	5.6	6.3	5.0	3.7	4.2	3.1

[1] Freeboard based on existing levee elevation
[2] Freeboard based on project levee elevation of 20.5 ft NAVD

Table 3 HEC RAS Results for Sedimentation Scenarios – Ballona Creek Freeboard (feet)

	Adjacent to Area A/North Area B (RS 6079 to 10019)			Adjacent to West Area B (RS 3055 to 5853)		
	Reach Average	Maximum	Minimum	Reach Average	Maximum	Minimum
Alt 1, Phase 1[2]	5.7	6.9	5.4	5.1[1]	8.1[1]	3.2[1]
Alt 1, Phase 1 tidal hydraulic geometry[2]	1.7	2.5	1.2	0	3.0	0
Alt 1, Phase 1 2 feet of deposition	4.7	5.7	4.4	4.0	6.8	2.3
Alt 1, Phase 1 4 feet of deposition	3.5	4.4	3.2	2.7	5.4	1.0
Alt 1, Phase 2[3]	4.7	5.8	4.4	5.0	7.4	3.1
Alt 1, Phase 2 tidal hydraulic geometry [3]	0.8	1.2	0.4	0.0	1.6	0.0
Alt 1, Phase 2 2 feet of deposition[3]	4.0	4.9	3.8	3.9	6.1	2.0
Alt 1, Phase 2 4 feet of deposition[3]	3.1	3.7	2.9	2.5	4.5	0.6
Alternative 2[2]	3.8	4.6	3.6	4.9	7.1	3.2
Alternative 2 tidal hydraulic geometry [2]	0	0.2	0	0	1.2	0
Alt 2, 2 feet of deposition	2.8	3.4	2.6	3.8	5.0	2.3
Alt 2, 4 feet of deposition	1.3	1.7	1.1	2.5	4.2	1.0

[1] Freeboard based on existing levee elevation
[2] Freeboard based on project levee elevation of 20.5 ft NAVD
[3] Freeboard based on project levee elevation varying from 18.5 feet to 16.5 feet

Discussion

The results show that freeboard is greater than three feet for all alternative conditions and phases. Additional hydraulic analysis to ensure that the design levee meets 90-percent non-exceedance criteria (e.g., risk and uncertainty analysis) will be performed for the U.S. Army Corps of Engineers (USACE) Section 408 Permit Submittal B.

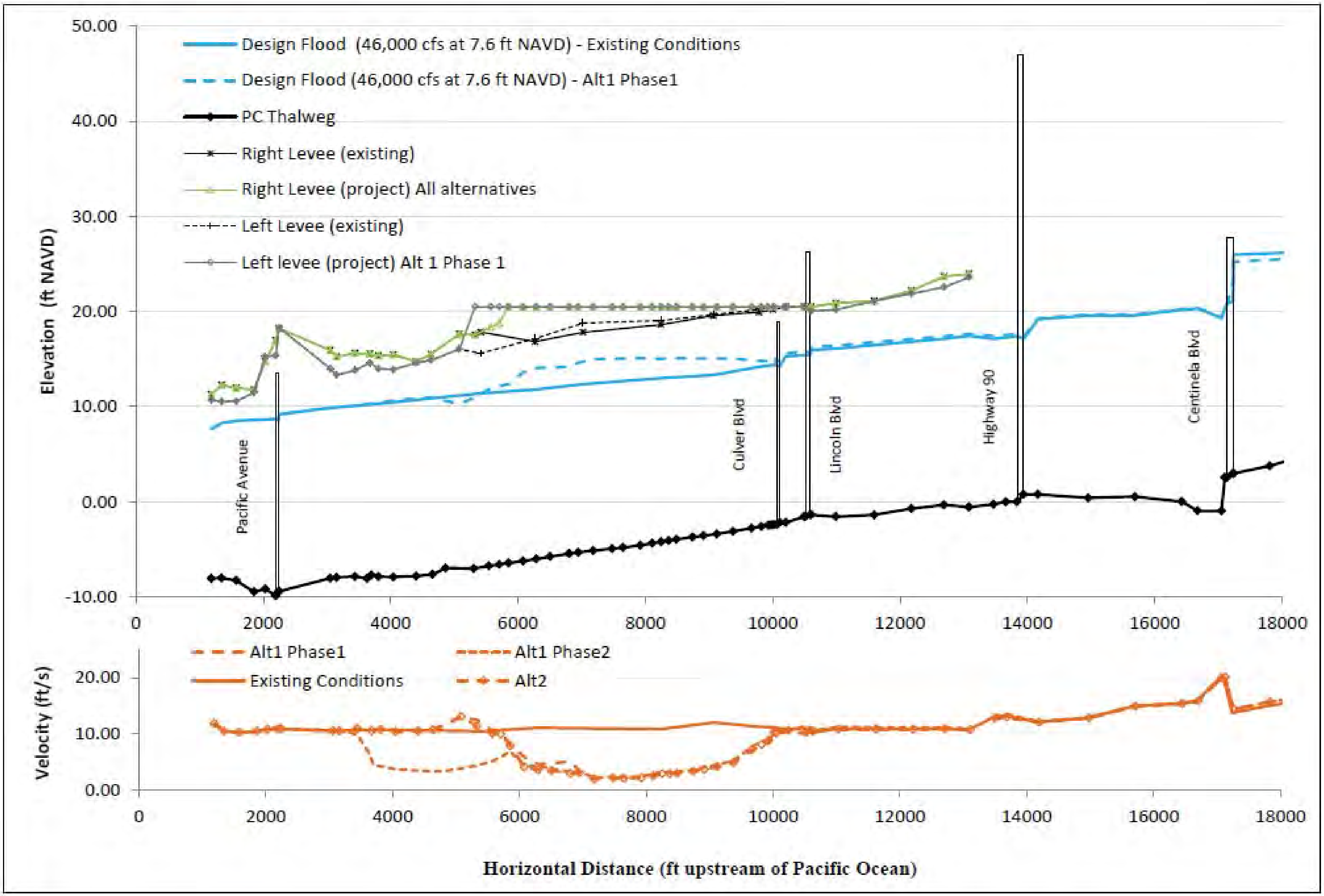
For the sedimentation scenarios, model results summarized in Table 3 show that all of the alternative scenarios maintain some level of positive freeboard in Area A and West Area B with 2 feet and 4 feet of sedimentation. Under the equilibrium tidal channel hydraulic geometry scenario, modeled water levels exceed the elevation of the existing West Area B levee and the jetty between Ballona Creek and Marina del Rey harbor during the design flood event. (Note that in Alternative 1 Phase 1 and Alternative 2, the levee along West Area B would be maintained at existing elevations.) Additionally, Alt 2 shows overtopping in Area A with the tidal hydraulic geometry condition. The results indicate that channel maintenance to remove sedimentation from the channel could potentially be required if deposition reaches the level represented by equilibrium tidal geometry; however, as described above, the tidal geometry scenario assumes conservatively high levels of channel deposition.

Further analysis will be performed in subsequent steps of the project, including risk and uncertainty analyses required for the USACE Section 408 approval process, to assess the potential for channel deposition to increase flood hazards under project conditions. These analyses could include modeling the equilibrium tidal geometry in only reaches that are expected to be depositional and evaluating erosion of deposited material during more frequent storm events.

These results were used to inform the sedimentation and erosion components of the Hydrology and Water Quality Monitoring and Adaptive Management Plan (MAMP) (Appendix F11), including the potential need for channel maintenance to maintain flood performance. Per the Hydrology and Water Quality MAMP, channel deposition will be monitored and, if significant deposition is observed, further analysis will be required. For Alternative 1, Phase 1 and Phase 2, and Alternative 2, any deposition greater than 4 ft would trigger an analysis of flood performance.

References

ESA PWA. 2013. Draft Ballona Wetlands Restoration Project, Preliminary Hydrology and Hydraulics Report. Prepared for the California State Coastal Conservancy. May 8, 2013

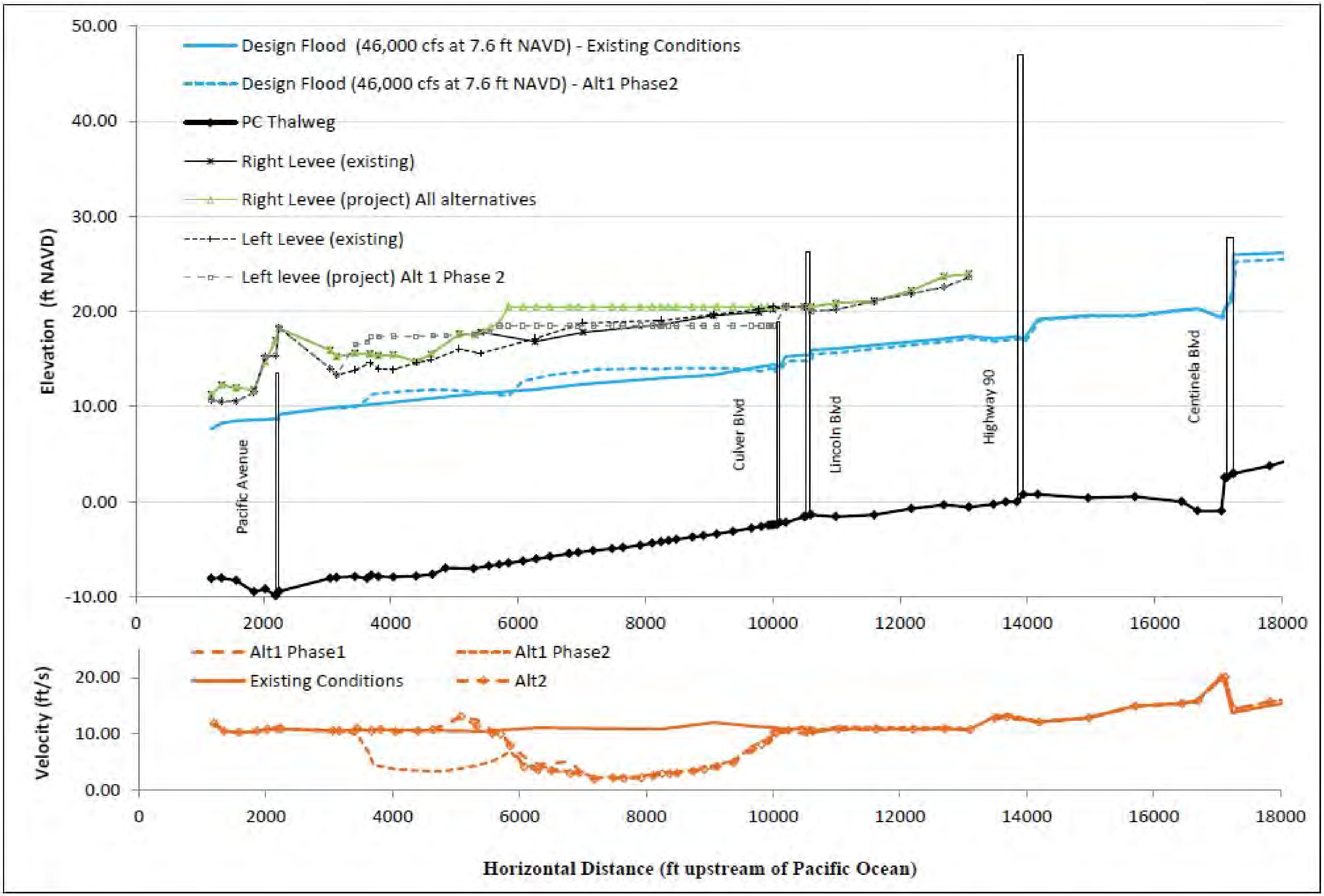


Ballona Wetland Restoration. D120367

Figure 1a

Design Flood and Velocity Profiles
Existing vs. Alt 1 Phase 1 Project Conditions

ESA PWA



Ballona Wetland Restoration. D120367

Figure 1b

Design Flood and Velocity Profiles
Existing vs. Alt 1 Phase 2 Project Conditions

ESA PWA

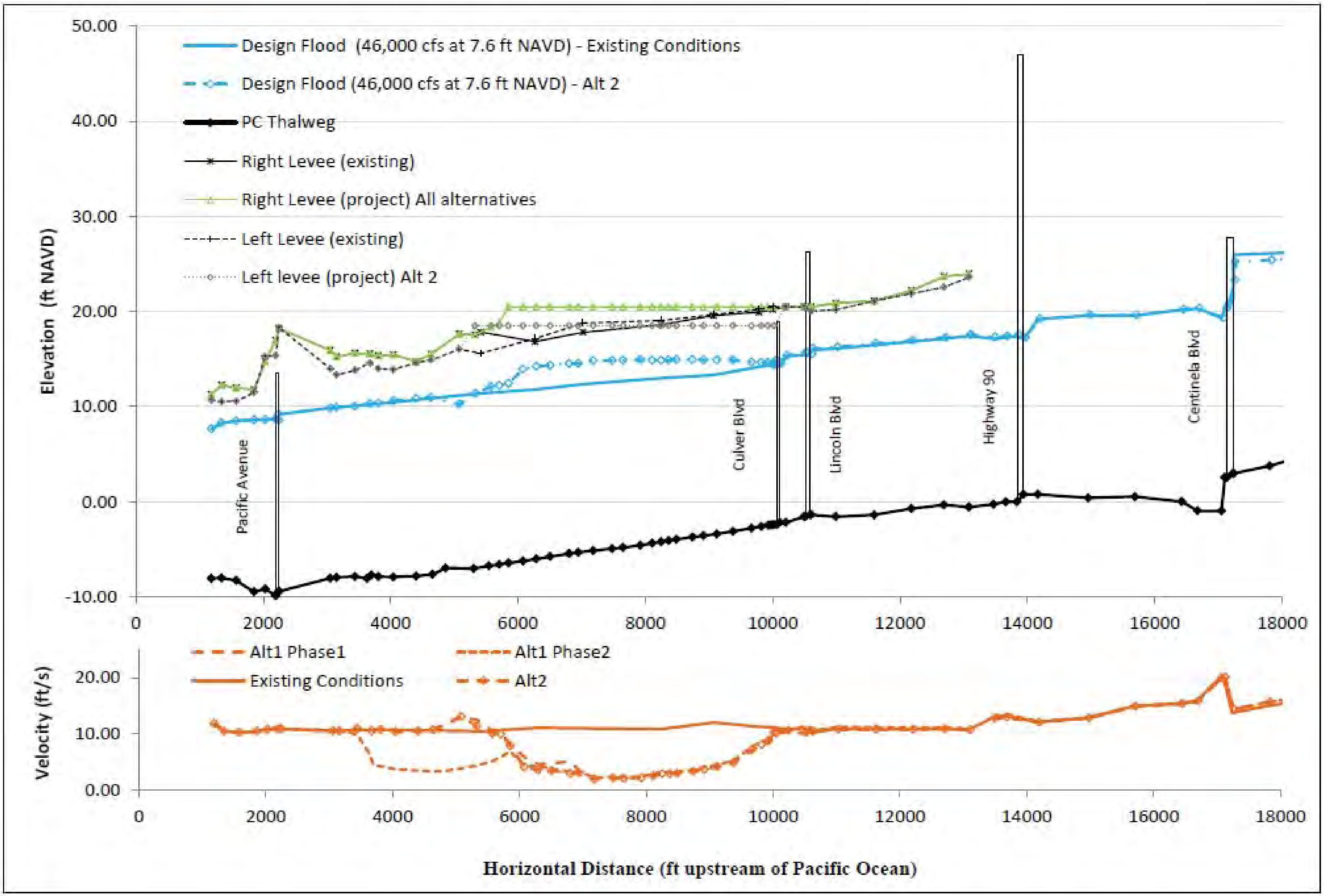


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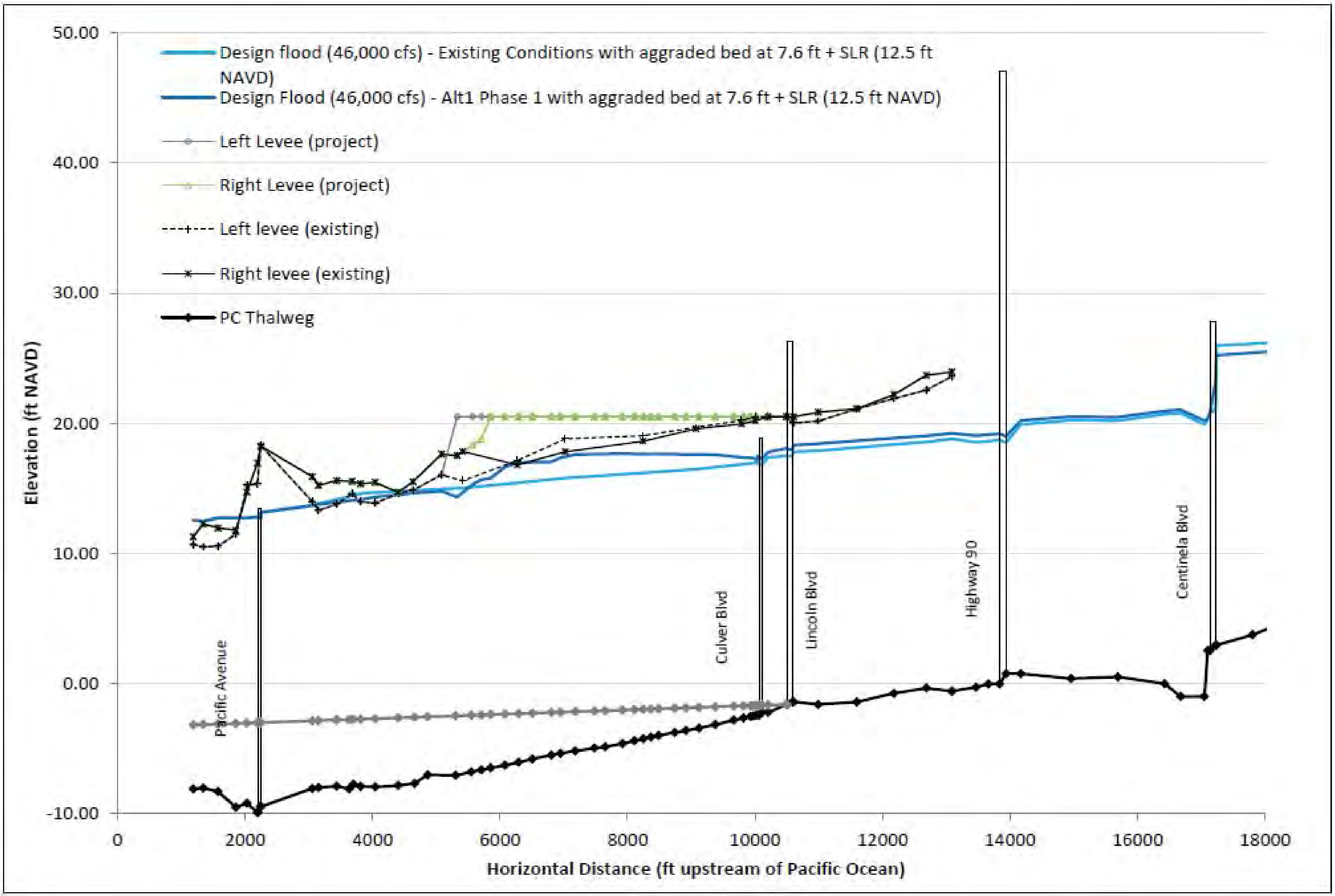
Figure 1c

Design Flood and Velocity Profiles
Existing vs. Alt 2 Project Conditions

ESA PWA



ESA PWA

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Figure 2a

Design Flood Profiles with Sea Level Rise and Bed Aggradation for EC and Alt1 Phase 1

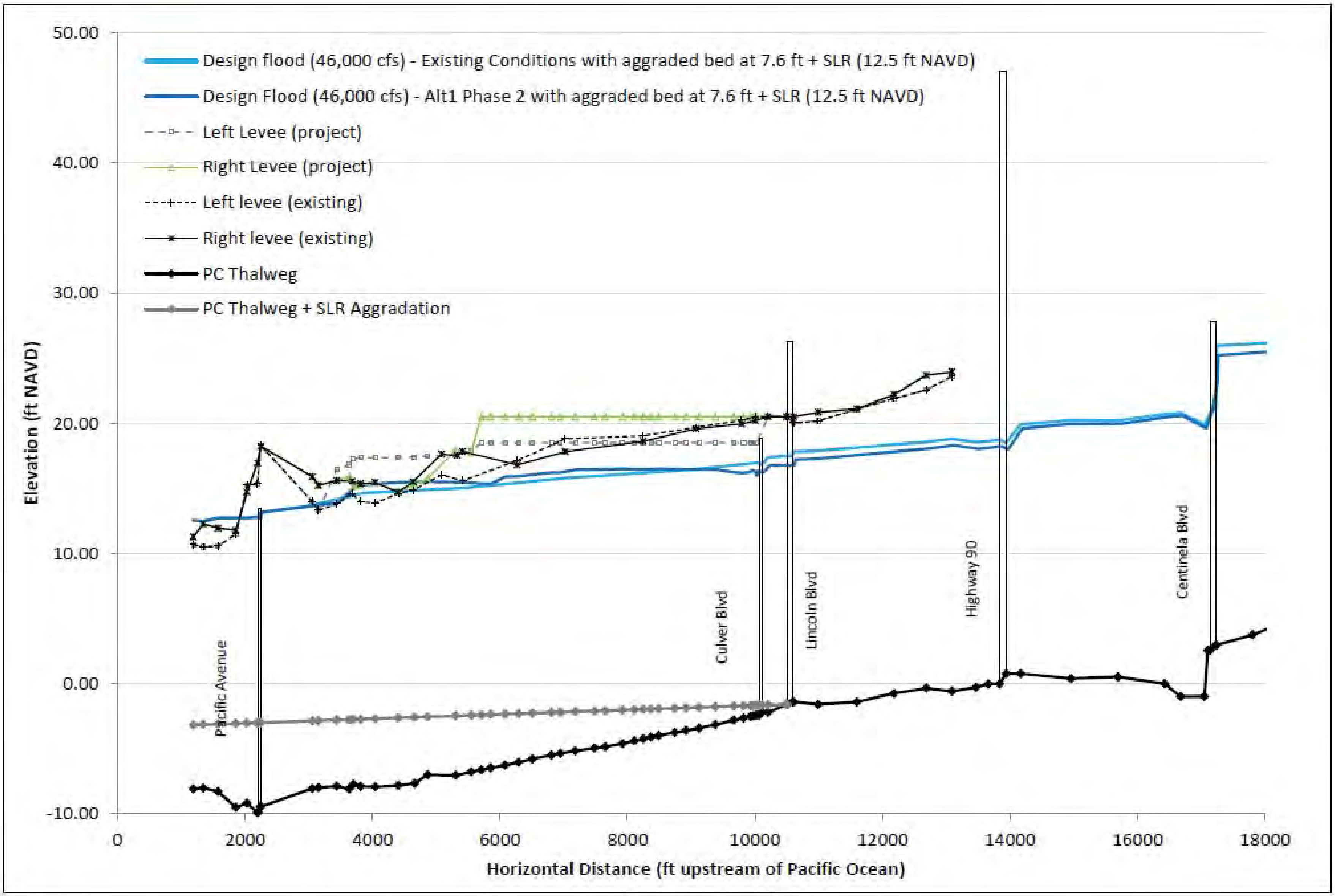

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Figure 2b

Design Flood Profiles with Sea Level Rise
and Bed Aggradation for EC and Alt1 Phase 2

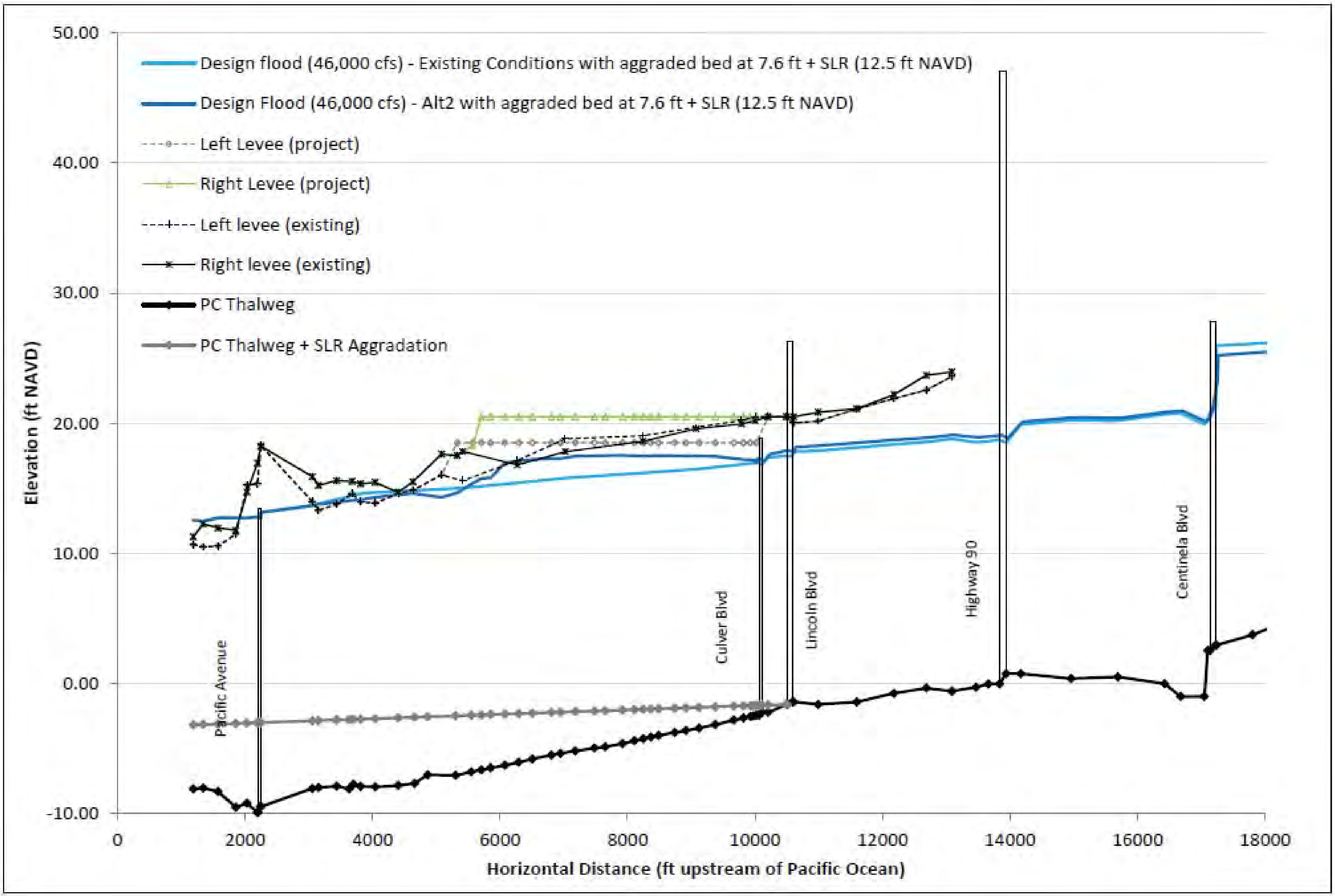

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Figure 2c

Design Flood Profiles with Sea Level Rise and Bed Aggradation for EC and Alt2

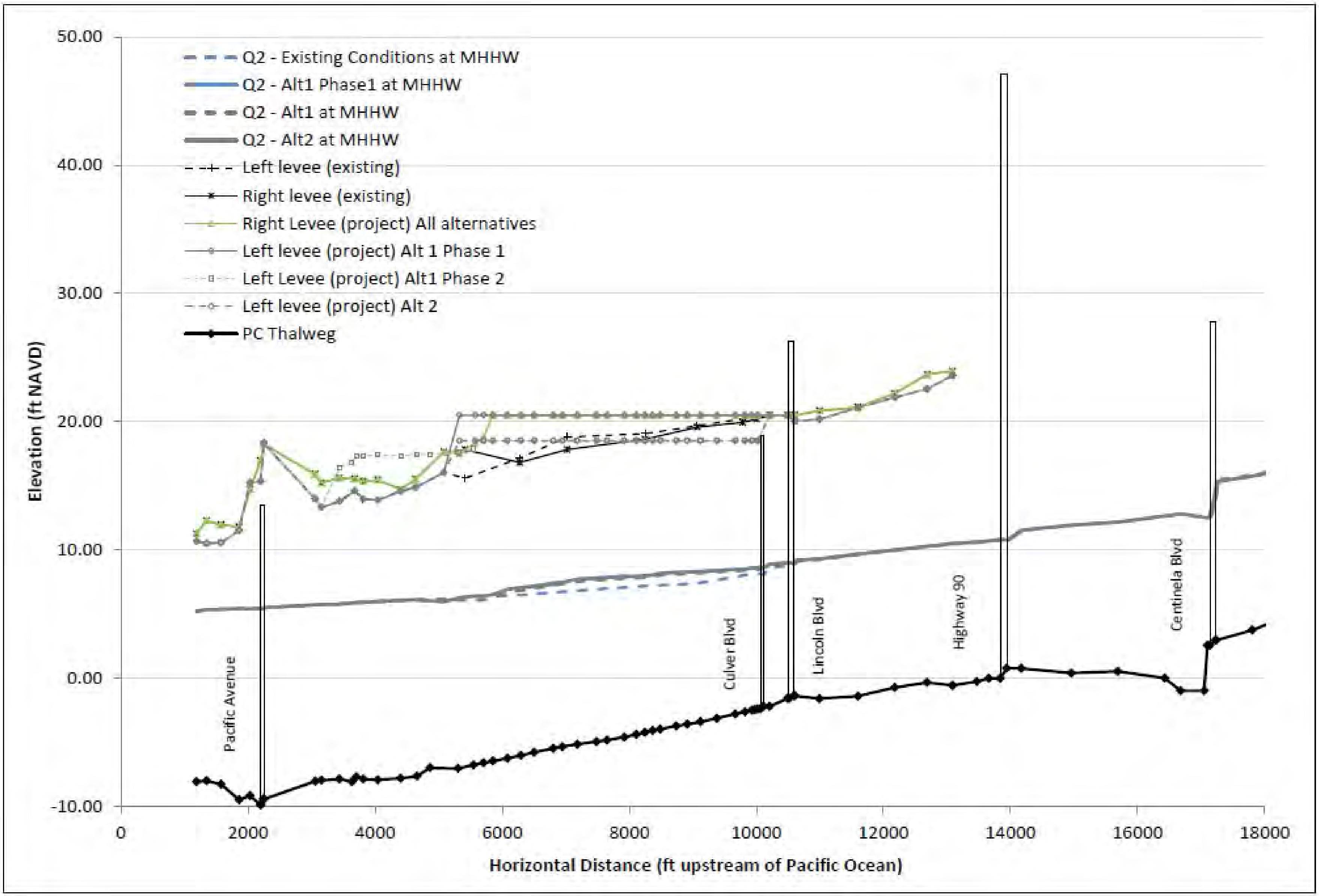

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Figure 3a

Flood Frequency Q2 for EC, Alt1 Phase 1, Alt 1, and Alt2

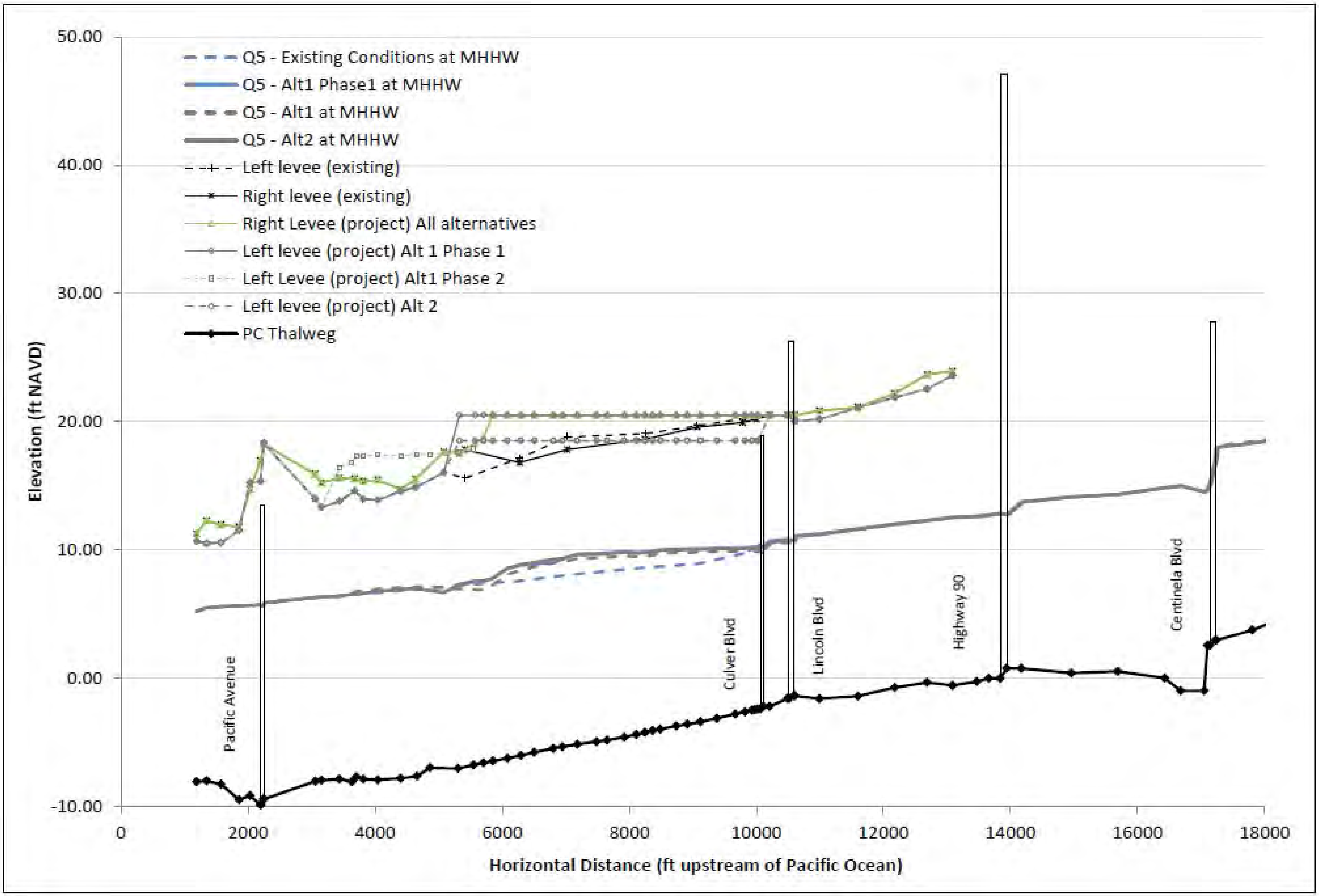

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Figure 3b

Flood Frequency Q5 for EC, Alt1 Phase 1, Alt 1, and Alt2

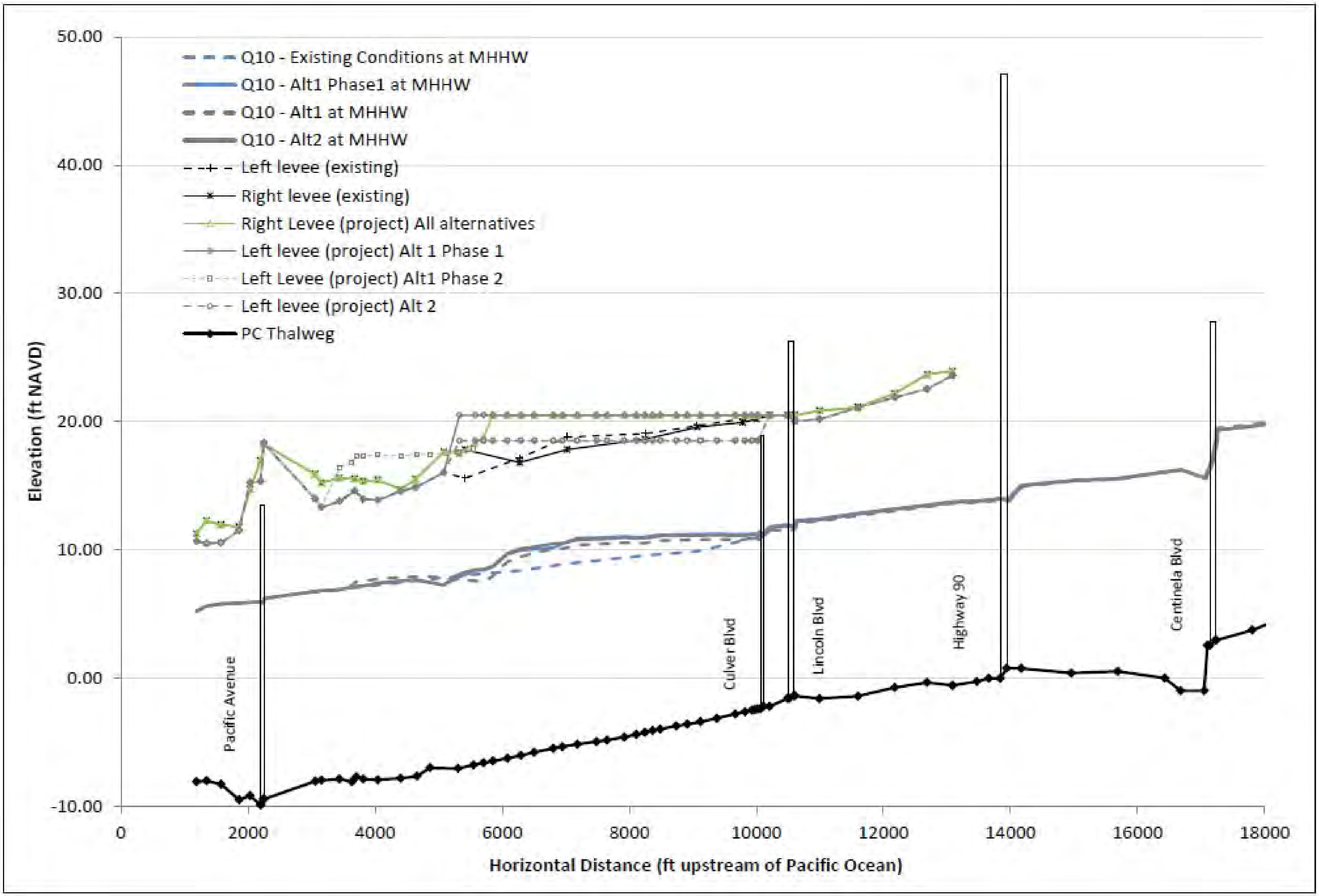

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Figure 3c

Flood Frequency Q10 for EC, Alt1 Phase 1, Alt 1, and Alt2

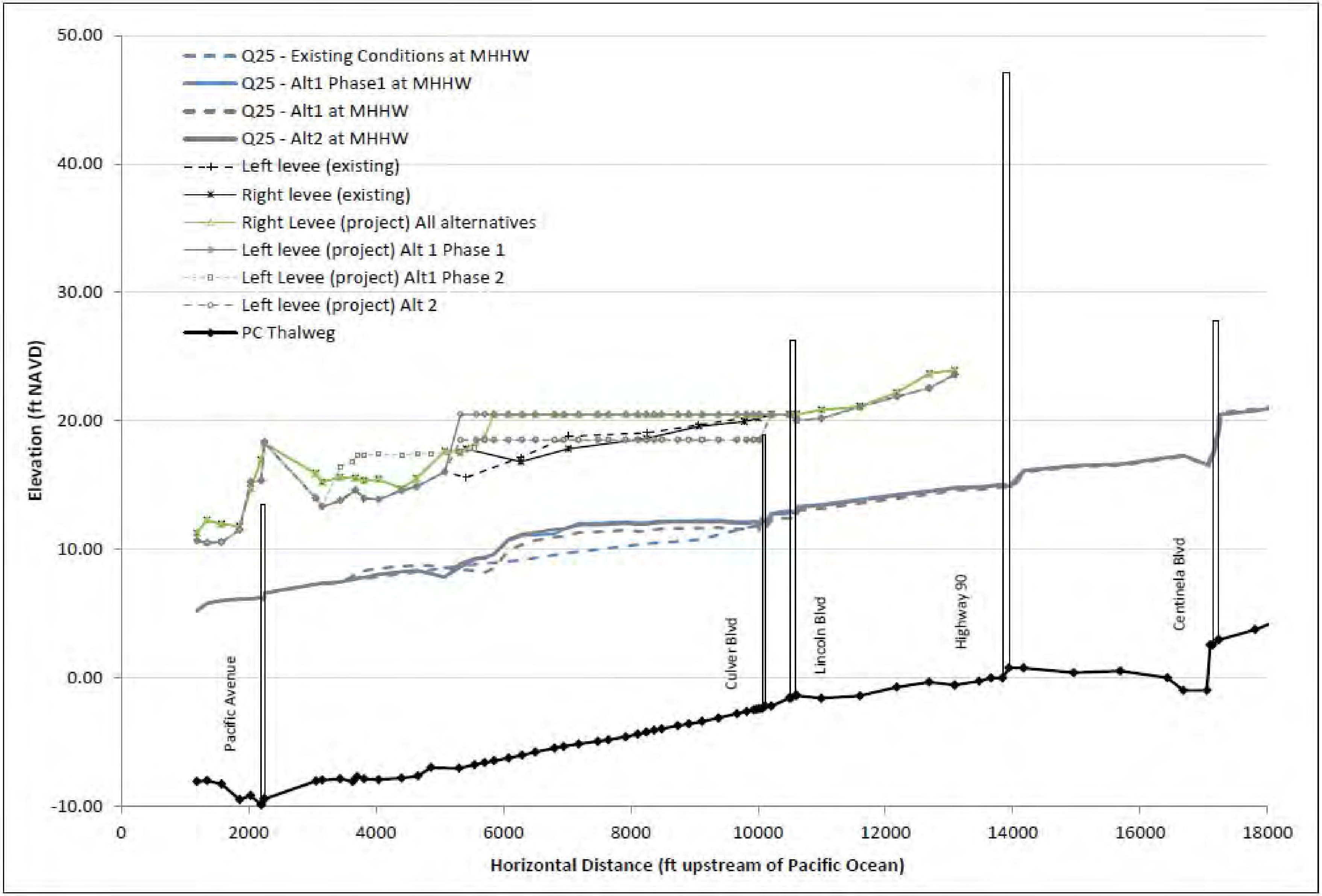

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Figure 3d

Flood Frequency Q25 for EC, Alt1 Phase 1, Alt 1, and Alt2

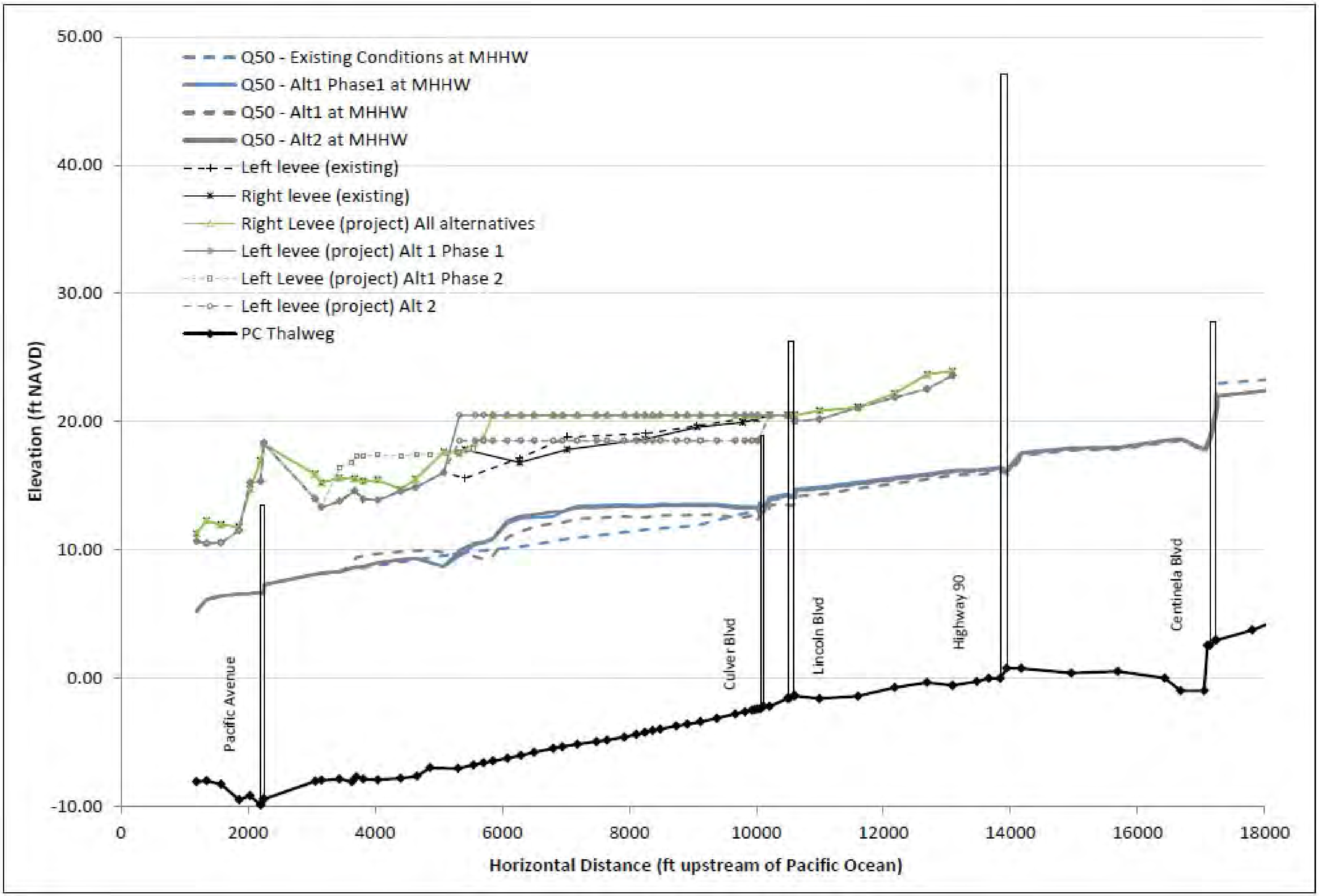

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Figure 3e

Flood Frequency Q50 for EC, Alt1 Phase 1, Alt 1, and Alt2

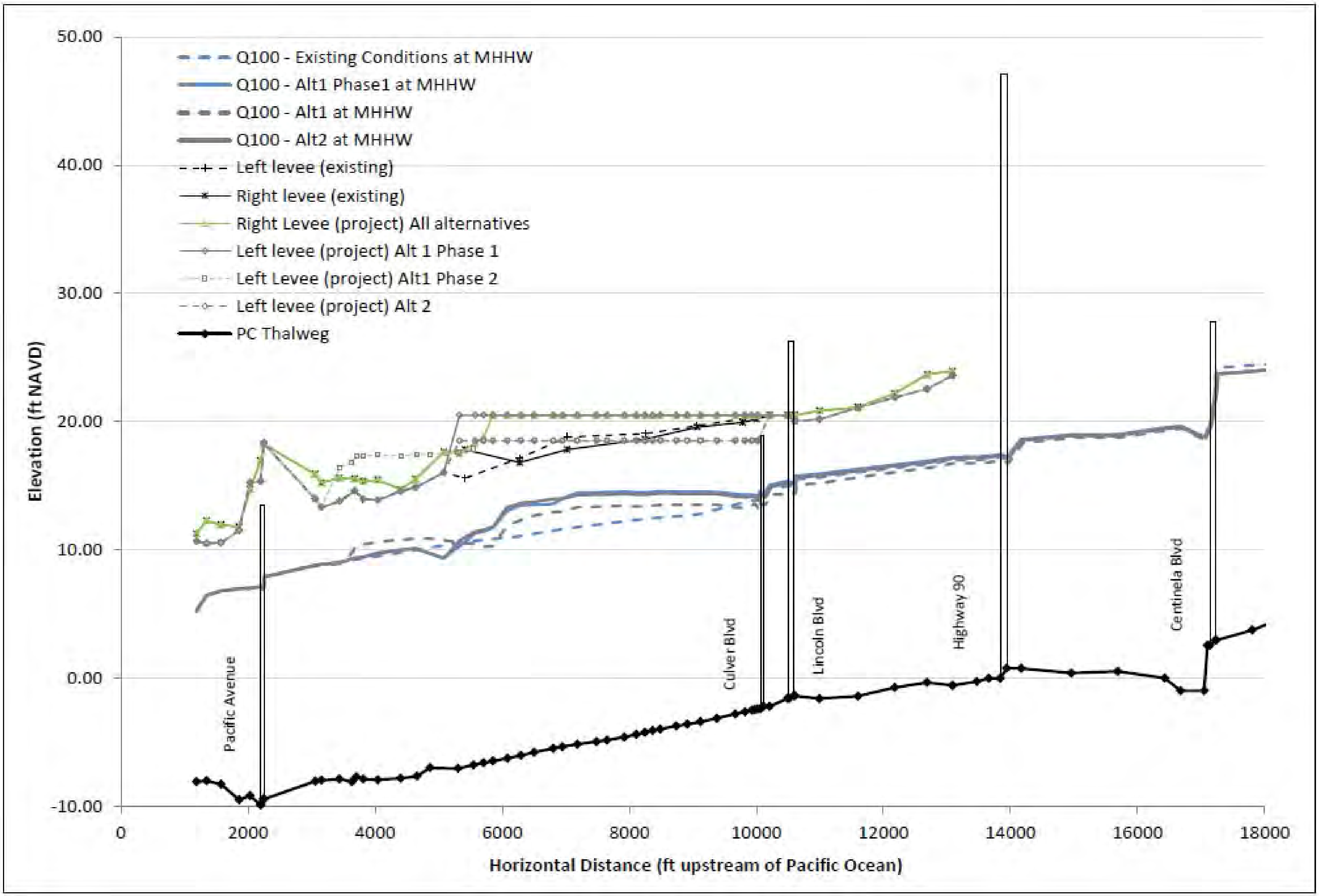

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Figure 3f

Flood Frequency Q100 for EC, Alt1 Phase 1, Alt 1, and Alt2

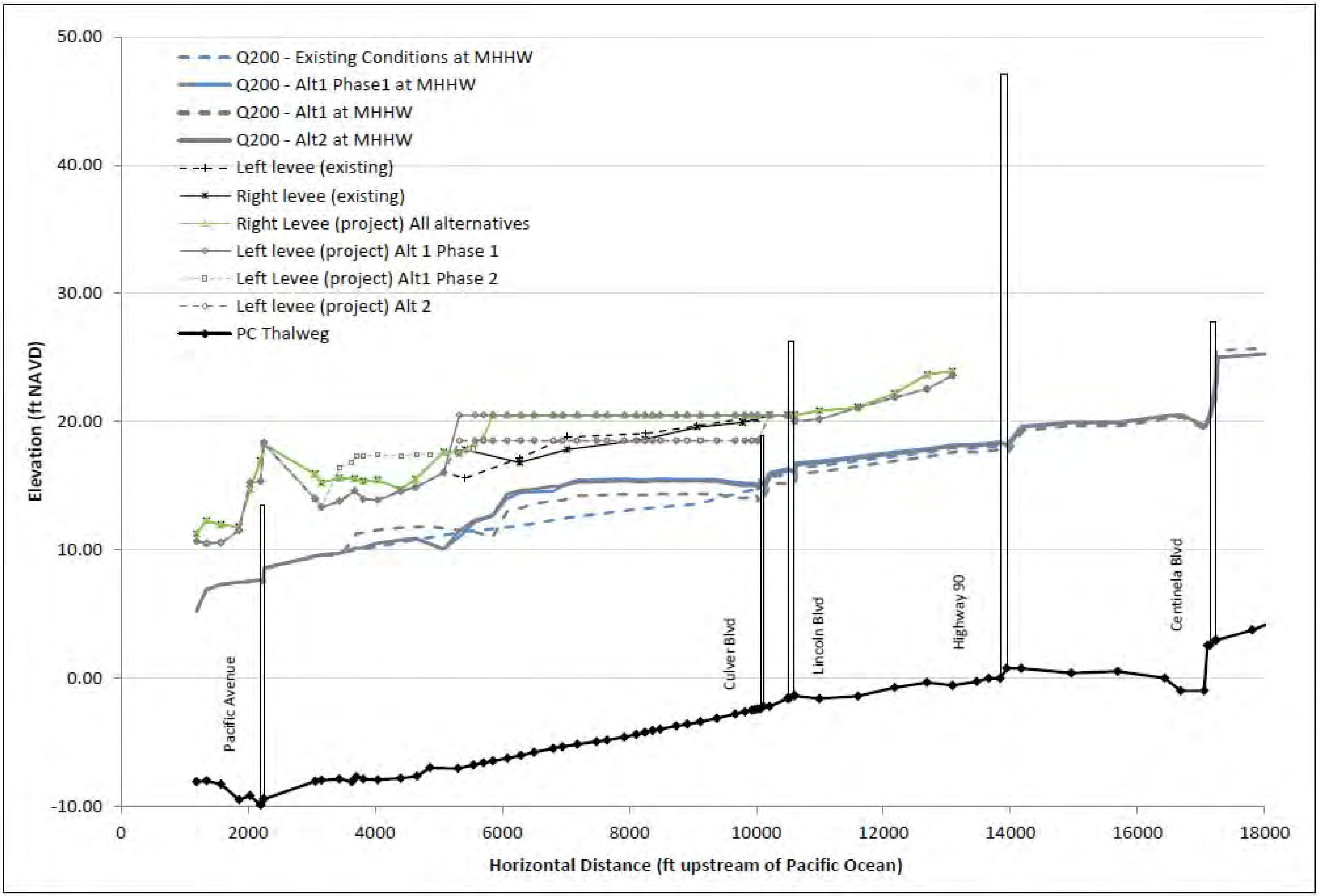

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Figure 3g

Flood Frequency Q200 for EC, Alt1 Phase 1, Alt 1, and Alt2

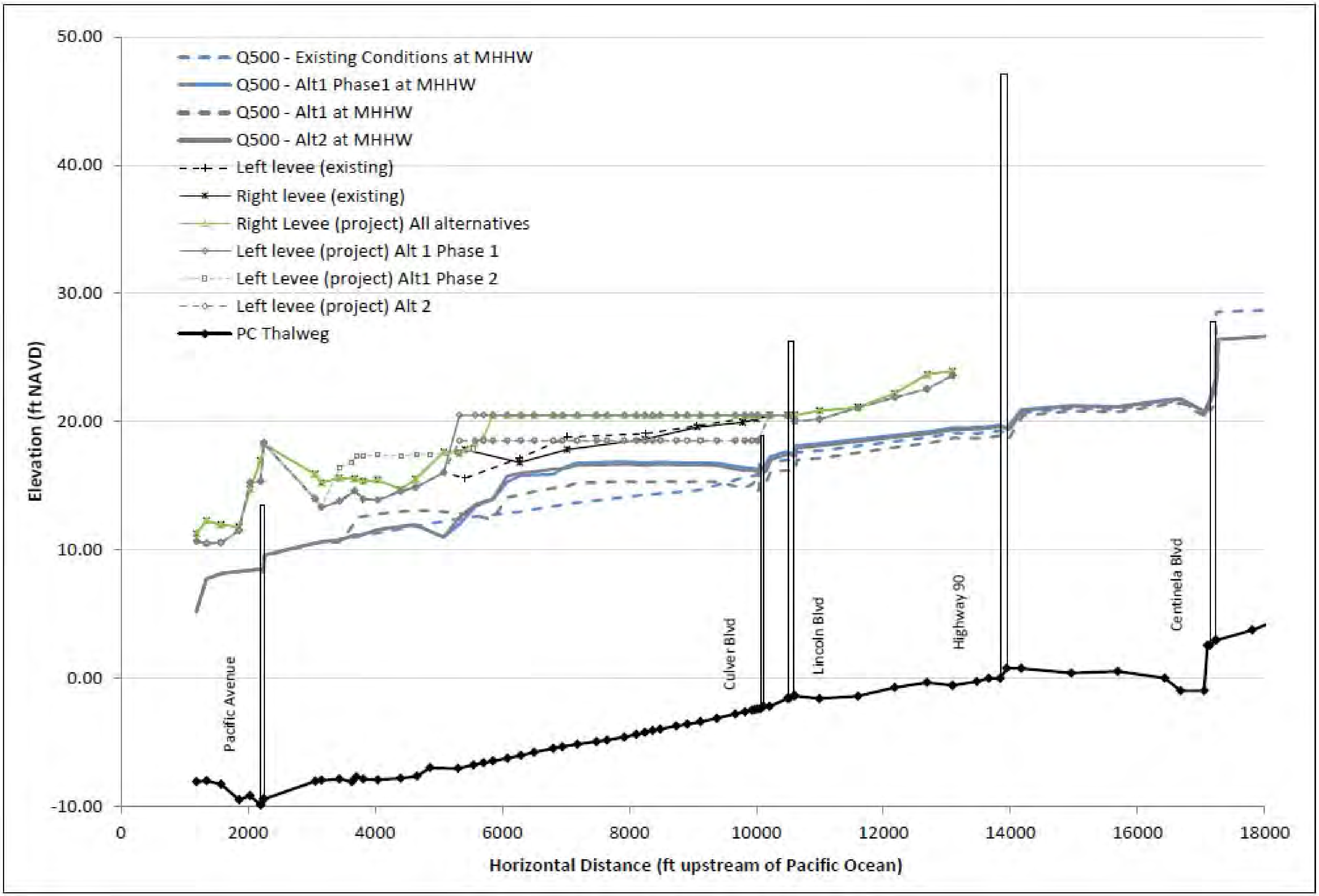

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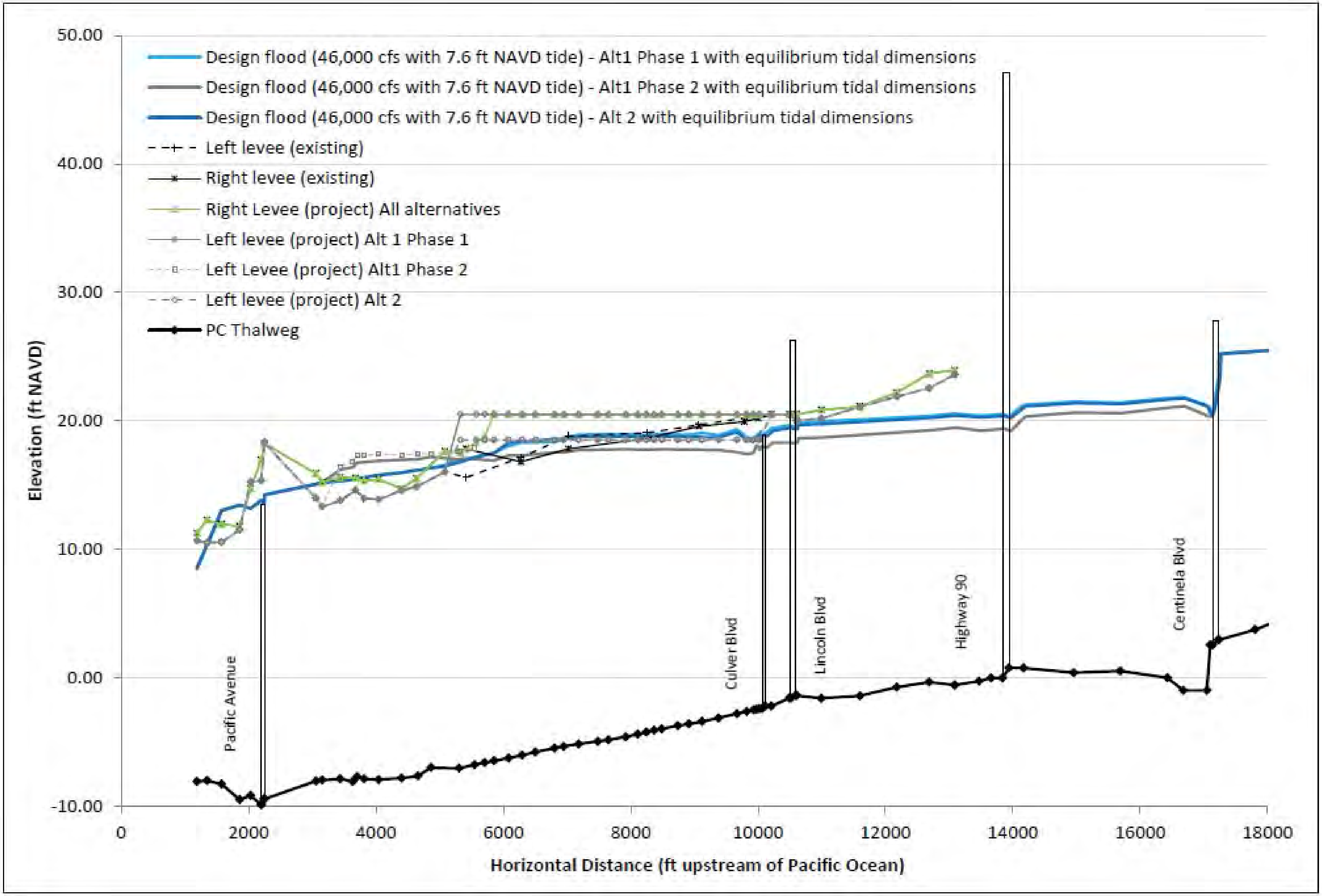
Figure 3h

Flood Frequency Q500 for EC, Alt1 Phase 1, Alt 1, and Alt2



ESA PWA

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Figure 4

Design flood profiles for project alternatives with equilibrium tidal geometry

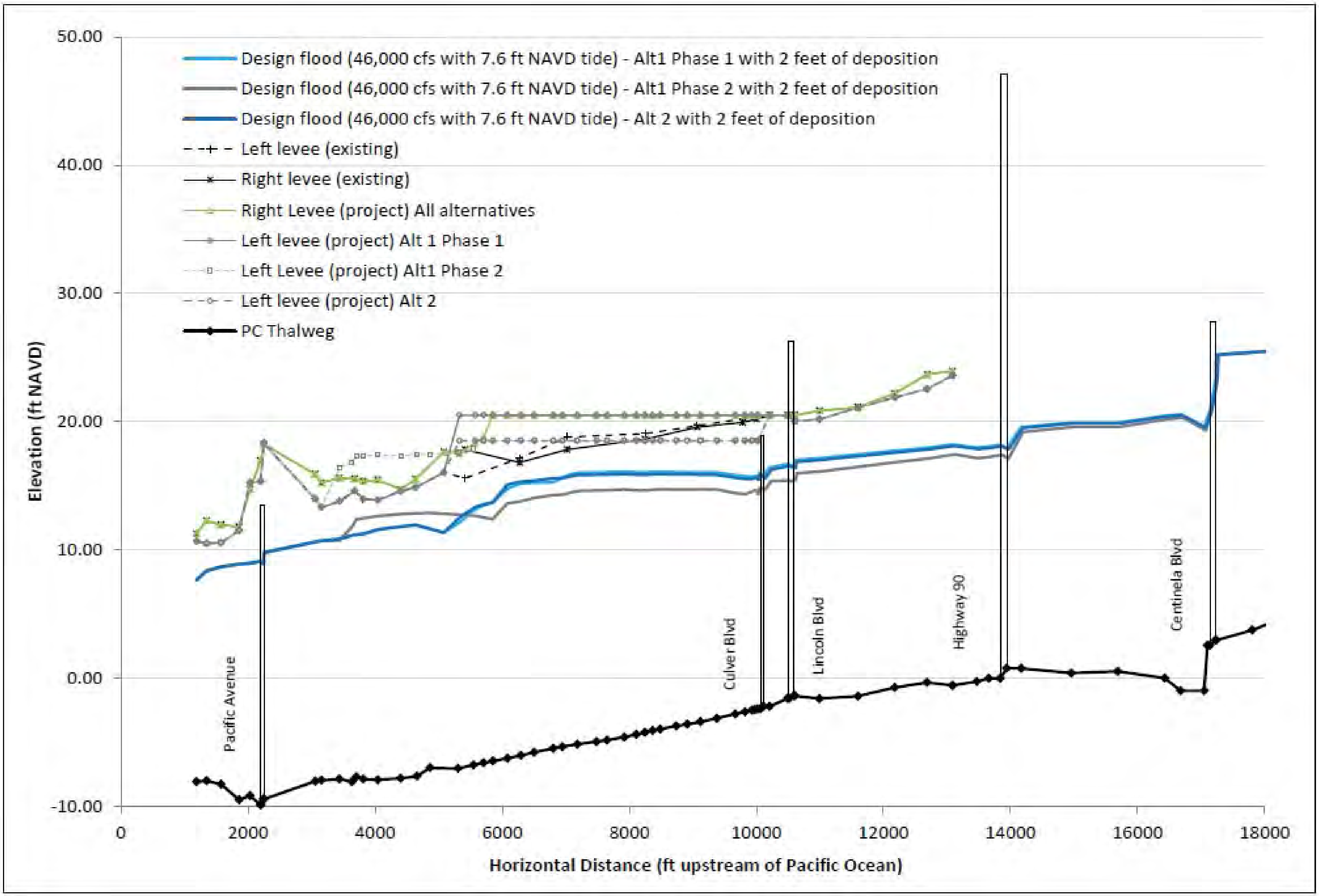

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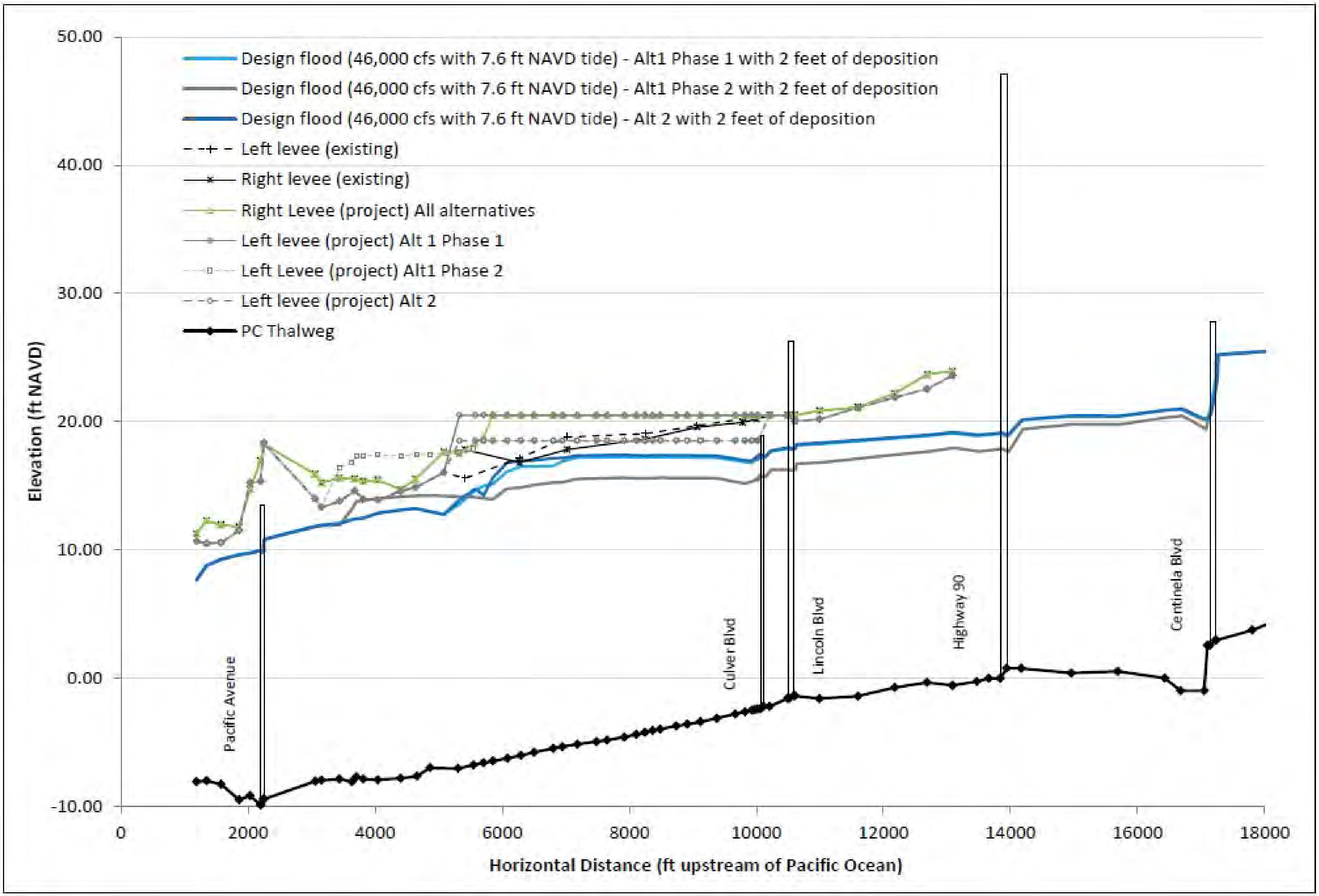
Figure 5

Design flood profiles for project alternatives with 2 feet of deposition



ESA PWA

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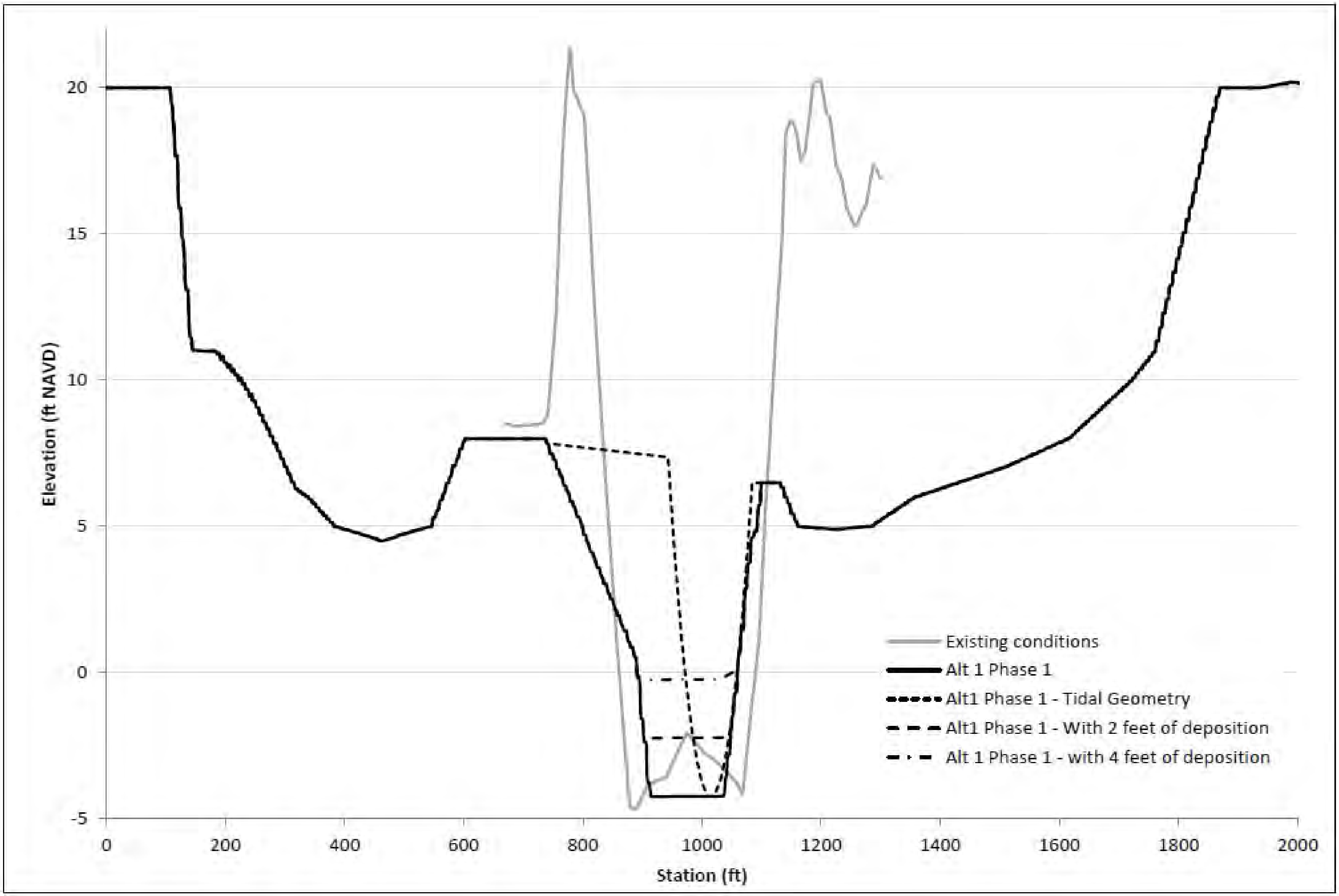
Figure 6

Design flood profiles for project alternatives with 4 feet of deposition



Ballona Wetlands Restoration . D120367

Figure 7

Cross-sections in Area A for existing and project conditions with sedimentation scenarios

APPENDIX F9
Draft Area B Managed Wetlands Preliminary Design

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memorandum

date August 3, 2015 – *updated November 6, 2015*

to Ballona Wetlands Restoration Project Management Team

from Lindsey Sheehan, P.E. and Nick Garrity, P.E.

subject Draft Area B Managed Wetlands Preliminary Design

This memorandum provides the detailed hydrology basis of design for the South and Southeast Area B managed wetlands enhancements, including design criteria for channels, berms, and water control structures as well as hydraulic modeling of existing and project conditions for typical operations and flood scenarios. This memo is an addendum to the September 2015 Preliminary Design Report and the May 2013 Hydraulics and Hydrology Report. This memo provides a discussion of the existing conditions in Section 1, the South and Southeast Area B design features in Section 2, and the model description and results in Section 3. Section 4 notes next steps.

1 Existing Conditions

A brief summary of existing conditions in West, South, and Southeast Area B is included below to provide context for this memo (Figure 1). Other project documents contain more detailed information on existing conditions (e.g., PWA 2006).

1.1 Tidal Connectivity

There are two channels in West Area B that connect to Ballona Creek via culverts through the levee under existing conditions (Figure 1). All of the culverts are equipped with control structures that are designed to limit inflows from Ballona Creek to West Area B. The west channel is connected to the creek with one 36-inch corrugated metal pipe (CMP) which has a one-way flap gate that keeps water from flowing into the marsh (Table 1) from Ballona Creek. The east channel has three 60-inch CMPs, two of which have self-regulating tide gates (SRT gates). The SRT gates are designed to close and prevent inflows when the water surface elevation of Ballona Creek reaches 3.4 ft NAVD, but in practice, they leak and allow water levels to increase in West Area B (LA County 2012). To keep the water levels in the marsh lower than

3.4 ft NAVD, the gates are currently operated to close at 1.4 ft NAVD (LA County 2012). The third CMP has a one-way flap gate intended to keep water from flowing into West Area B.

West Area B is connected to South Area B by three culverts that go under Culver Blvd. A 36-inch reinforced concrete pipe (RCP) connects West Area B to the northern South Area B channel and two 24-inch RCPs connect it to the southern channel (Table 1).

Southeast Area B and South Area B are divided by the Gas Company road, which has three culverts through it. The north channel has two 48-inch CMPs and the south channel has one 48-inch CMP (Table 1).

Southeast Area B also receives overflows from the Freshwater Marsh during storms greater than the mean annual event.

1.2 Existing Topography

The lowest elevations in the vicinity of South and Southeast Area B occur along Culver Blvd, and this is where flooding would occur first during a storm event. In South Area B where Culver Blvd crosses over the existing culvert and channel from West to South Area B, the road drops down and is about even with the surrounding marshplain. For about 300 ft, the middle of the road drops below 7 ft NAVD, with the edges of the road reaching down to below 6.3 ft NAVD. The remainder of Culver Blvd along South Area B is at elevations between 7 to 8 ft NAVD. Where Jefferson Blvd comes off from Culver Blvd, north of Southeast Area B, the road rises to 8 to 9 ft NAVD and then up to 12 ft NAVD when the lanes split. North of the Freshwater Marsh, Jefferson is above 14 ft NAVD. To the south of South and Southeast Area B, the Gas Company is above 7.5 ft NAVD west of the Gas Company Road and above 10 ft NAVD to the east.

The topography is South and Southeast Area B is on the higher end of the range for where salt marsh typically occurs. Generally, pickleweed grows from mean high water (MHW) to the highest high tide level (e.g., Highest Astronomical Tide or HAT). Elevations in South and Southeast Area B are generally conducive to pickleweed marsh (between mean tide level (MTL) and HAT within Ballona Creek), while most of West Area B is lower (between MTL and mean higher high water (MHHW) within Ballona Creek). However, the existing tides are muted by the SRT gates (Section 1.3), so most of the existing habitat does not receive regular tidal inundation. Figure 2 shows how the majority of the area in South and Southeast Area B, of which a portion supports pickleweed, is above the existing high water level, while most of West Area B is much closer to the high water elevation.

1.3 Hydrology and Inundation

West Area B experiences muted tides due to the SRT gates described above. West Area B habitat, which includes a range of marsh habitats, tidal channels, and salt pans, supports the Belding's savannah sparrow and other species. In particular, it has been noted that the current channel layout protects the Belding's savannah sparrow from predators, by limiting access to the marshplain. The muted tidal exchange supports pickleweed at lower elevations than would be found if the area were fully tidal (Section 1.2). In West Area B, the pickleweed is able to grow down to 3.5 ft NAVD, due to the managed water levels. This is a foot below MHW in Ballona Creek (4.5 ft NAVD), so below the lower end of where pickleweed typically occurs (MHW). The muted tides also support a large salt pan at a lower elevation than would occur under full tidal conditions, due to less frequent flooding of the area.

Tides are further muted in South and Southeast Area B due to the culvert connections with West Area B. The muted tidal flow is limited to the existing ditches in these areas and does not inundate the marshplain. However, South and Southeast Area B do support areas of salt marsh vegetation (e.g. pickleweed). The pickleweed grows up to elevations of about 6.75 ft NAVD, which is approximately 2.9 ft higher than the highest managed tide level allowed by the existing culverts and 1.6 ft higher than mean higher high water (MHHW) in Ballona Creek (5.2 ft NAVD). The majority of pickleweed in South and Southeast Area B is considered non-tidal salt marsh, since it is at elevations above the managed tide range and not supported by tidal flows (The Bay Foundation and WRA 2014).

Although construction of the Freshwater Marsh has reduced storm flows to South and Southeast Area B, the pickleweed is likely still supported by residual soil salinity combined with infrequent inundation by stormwater runoff. Historically, storm drainage from the east flowed into the Centinella Ditch, which ran along the southern portion of South and Southeast Area B. Runoff inundated lower elevation areas in South Area B and the western portion of Southeast Area B during extreme rainfall runoff events (Straw 1987). Now, under existing conditions, the Freshwater Marsh intercepts runoff from the east and discharges low flows to Ballona Creek after providing water quality treatment. However, even with this removal of typical storm flows from the east, the flood modeling performed for this memo indicates that portions of South and Southeast Area B are inundated during extreme rainfall runoff events under existing conditions, which likely supports the pickleweed habitat (Section 3.2.2).

Additionally, groundwater elevation data shows that the pickleweed in South and Southeast Area B is likely not reliant on groundwater for survival. Groundwater data is available from July 1987 from a study by Straw, prior to construction of the Freshwater Marsh and installation of the SRT gates. These data indicate that groundwater levels were about 3 to 4 ft below the central portion of Southeast Area B and that the zone of soil saturation was likely about 2 ft below ground throughout the year over much of Southeast Area B except during years of extreme rainfall (Straw 1987). This information and data suggest that the existing salt marsh vegetation in South and Southeast Area B is likely supported by direct precipitation, limited and infrequent inundation by stormwater runoff, and residual soil salinity, but not groundwater.

2 Preliminary Design

The following section supplements PDR Section 3.6. The Preliminary Design for South and Southeast Area B is based on design objectives intended to achieve the goal of enhancing wetland habitat, while avoiding adverse effects to the surrounding properties. The design objectives for the South and Southeast Area B Managed Wetlands enhancements are as follows:

1. Restore and enhance pickleweed-dominant salt marsh habitat for Belding's savannah sparrow nesting habitat. Pickleweed habitat restoration and enhancement includes removal of invasive vegetation, establishment of pickleweed vegetation, and increased tidal inundation to support pickleweed marsh enhancement and function. Increasing tidal inundation involves installing new culverts under Culver Blvd. and enhancing tidal channels.

2. Restore and enhance tidal channels to convey tidal flows and promote marsh inundation. Enhanced tidal channels are also intended to create foraging habitat and to provide protection from predators for the Belding's savannah sparrow. Channel restoration and enhancement would involve excavating tidal channels in the Area B managed wetlands.

3. Maintain the existing level of flood protection for adjacent areas surrounding the Area B managed wetlands, including Culver and Jefferson Boulevards, the Gas Company, and the Freshwater Marsh storm detention and treatment wetland system for Playa Vista and adjacent areas.

4. Allow for management flexibility and adaptive management, including seasonally closed/non-tidal wetland habitat management to mimic certain wetland habitat conditions present at the site in the 1890s, if desirable.

5. Create a managed wetland system that will be resilient to sea level rise within the management constraints.

As part of the EIR/S process, four alternatives are being evaluated for the Ballona Wetlands Restoration. Chapter 2 of the EIR/S describes these alternatives in detail. This memo describes the preliminary design for Alternative 1 only, but is applicable to the other alternatives as well. For example, restoration under Alternative 2 involves a similar design, but without the final phase of restoration. Alternatives 3 and 4 do not involve significant grading south of Ballona Creek or alteration of the flood control features, so they are not included here.

Alternative 1 would use a phased approach to allow for successful evaluation of biologic (including special-status species), hydrologic, and geomorphic performance of early restoration stages prior to the commencement of further phases. Alternative 1 would involve two phases:
1. Phase 1: enhancement of the existing Area B managed wetlands, restoration of Area A and North Area B, new perimeter flood protection levees, and realignment of the Ballona Creek channel (Figure 3).
2. Phase 2: full tidal restoration of West Area B (Figure 4). Note, only the first phase would occur in Alternative 2.

Phase 1. New culverts with adjustable gates would be installed to connect a tidal channel in North Area B with the channels in Southeast Area B under the Culver Blvd levee (Figure 3, Section 2.1). An overflow weir would be installed in South Area B, before the culverts that go under Culver Blvd to West Area B, which would prevent flow from South Area B to West Area B under normal tidal conditions. These connections would allow an increased tidal range south of Culver Blvd to improve pickleweed habitat, without affecting Belding's savannah sparrow existing nesting habitat in West Area B. Additionally, during extreme storm events, water from South Area B could flow over the weir to West Area B, which would provide additional storage area.

The SRT gates would allow for continued flexible management in West Area B. Tidal channels would be excavated in South and Southeast Area B to bring in more water, provide foraging habitat for birds, and offer nesting Belding's savannah sparrows protection from predators (Section 2.3). Berms would be constructed to protect the road to the north and the Gas Company to the south from the higher tide levels and storm flows (Section 2.4). An impoundment berm would be constructed to retain freshwater from the Freshwater Marsh in the southeast of Southeast Area B to encourage the development of brackish marsh habitat in this area and allow for brackish marsh management (Section 2.5).

Phase 2. When the Ballona Creek levee is breached and lowered and West Area B becomes fully tidal, the weir between South and West Area B would be removed and new, larger culverts with adjustable gates would be installed to increase flow between the two areas (Figure 4, Sections 2.1 and 2.2).

The project features and the basis for design are further described below.

2.1 Hydraulic Structures

Phase 1. New culverts with adjustable gates would be installed between Ballona Creek and Southeast Area B to allow an increase in water levels in South and Southeast Area B. Existing hydraulic structures under the Gas Company Rd would be replaced to increase flow capacity between South and Southeast Area B. In both locations, four 60-inch diameter pipe culverts or similar structures would be installed at an elevation of -1 ft NAVD. A new weir box would be added to the existing structure between South to West Area B to manage water levels. The weir would be installed in South Area B to prevent tidal waters from entering West Area B, but to allow stormwater to overflow. The weir would be set to an elevation of 7 ft NAVD.

Phase 2. The weir from South to West Area B would be removed, new, larger culverts (four 60-inch diameter culverts or similar) with adjustable tide gates would be installed. The gates would consist of combination slide/flap gates, SRT gates, or other similar gates or valves, however, tide gates are not required to maintain the existing level of flood protection. Hydraulic modeling results shows that flow through open culverts results in an acceptable range of water levels for typical conditions and the design storm event (Section 3.2); however, the addition of tide gates would provide added safety and design redundancy. The gates would also allow for management flexibility, including the option for managing for habitat seasonally closed to Ballona Creek. As sea level rises, the gates would be used to limit water levels in South and Southeast Area B.

2.2 Long-Term Operation of Hydraulic Structures

Because of the hydraulic connection to Ballona Creek, sea level rise will impact water levels south of Culver Boulevard over time. USACE (2011) estimates 59 inches of sea level rise will occur by 2100, under a high emissions scenario. Since there is substantial variability in the sea level rise estimates, water levels south of Culver Boulevard would be managed to adapt to changing water levels over time.

The hydraulic modeling in this memorandum assumes that there will be 59 inches of sea level rise by 2100. The project is designed so that management, including the addition of flap gates or other controls, can be altered easily in response to changing conditions. SRT gates could be used to limit maximum water levels, or flap gates and slide gates could be used to limit flow in and out of these areas. The project scenarios modeled for this memorandum assume that a flap gate would be added to one culvert at each bank of culverts (between South and West Area B and Southeast Area B and Ballona Creek) about every 25 years, so that by 2100 only one culvert would allow flow into South Area B from Ballona Creek and West Area B, while the other culverts would only provide outflow. This reduction in inflow capacity will limit water levels in the marsh in order to maintain flood protection.

2.3 Tidal Channels

Networks of branching, sinuous tidal channels would be excavated in South and Southeast Area B in Phase 1 and connected to Ballona Creek through a culvert through North Area B. The tidal channel network would extend from and drain to Ballona Creek during Phase 1 (Figure 3), with the flexibility to connect the channels through West Area B in Phase 2. The purpose of the tidal channels is to convey tidal flows and sediment to the restored wetlands, providing tidal circulation (inundation and drainage) to support wetland vegetation and functions. Tidal channels are also expected to provide foraging habitat and protection from predators for the Belding's savannah sparrow. See the PDR for further details on channel sizing and placement.

As described in Section 1.2, groundwater is not thought to be supporting the pickleweed habitat in South and Southeast Area B. This means that the existing channels can be deepened, and any flushing of groundwater should not impact the pickleweed habitat.

2.4 Perimeter Berms

Berms would be constructed along the lower portions of Culver Boulevard, Jefferson Boulevard, and the Gas Company to protect these areas from inundation due to the higher water levels in South and Southeast Area B (Figure 4). The berm crest elevation is set to 9 ft NAVD, in order to increase the existing freeboard during the design flood (see Section 3.2.2 for further discussion). The berm would be offset from the road by 30 ft, and have a top width of 8 ft. The berm would have a slope of 3:1 on the outboard side and a slope of 5:1 on the inboard side down to the marsh. With these dimensions, the berm would require approximately 11,300 cy of fill, which is slightly more than quantity cut from the tidal channels (9,400 cy).

2.5 Brackish Marsh Impoundment Berm

A new low berm would be constructed near the Freshwater Marsh to encourage brackish marsh habitat to establish in the eastern portion of Southeast Area B (Figure 4). This berm would include a weir with adjustable risers designed to allow tidal water into the area and delay drainage of the freshwater that flows into Southeast Area B from the Freshwater Marsh. Overtime, the freshwater impoundment is expected to leach salts from the soil and encourage brackish marsh vegetation to colonize. The berm would also provide transitional habitat and, with sea level rise, high tide refugia.

Adaptive management of the brackish marsh areas is expected to be required to encourage brackish marsh habitat development, and the brackish marsh design is therefore intended to provide management flexibility. Further development of the brackish marsh design will focus on designing water control structures that provide management flexibility rather than precise estimates of salinities.

At a height of 6.8 ft NAVD, the berm would impound freshwater and limit tidal inundation without causing backflow into the Freshwater Marsh with the Freshwater Marsh overflow weir set at the lowest weir elevation (6.9 ft NAVD). The berm would limit tidal inundation of the brackish marsh area until about 2050 (assuming 19 in of sea level rise), when it would be regularly overtopped, at which point the berm would no longer limit tidal inundation. The top width of the berm would be 5 ft and slope to the marsh at 10:1 on both sides. The berm would require approximately 350 cy of fill.

The Freshwater Marsh operation would be adjusted to allow more flow into the brackish marsh. Currently, the Freshwater Marsh can hold up to the annual storm (100% chance of recurrence in an average year or the 1 year storm) by lowering water levels during the summer (down to 4.4 ft NAVD) and allowing water to fill up to the lowest weir setting at 6.9 ft NAVD, before it overflows to Southeast Area B (PSOMAS, 2012). For the brackish marsh to receive freshwater every year, the Freshwater Marsh would need to be managed so that at least the 1 year storm (80 ac-ft) flows into Southeast Area B. A new culvert in the northwest of the Freshwater Marsh would be installed so that treated water would flow into Southeast Area B more frequently, rather than flowing out to Ballona Creek.

3 Hydraulic Modeling

Hydraulic modeling was conducted to evaluate water levels under existing and project conditions and to design the berm elevations and hydraulic structure dimensions. The goal of the modeling and design is to maintain or increase the level of flood protection along Culver Boulevard, Jefferson Boulevard, and the Gas Company property, while increasing tidal elevations to achieve the design objectives described in Section 2.

3.1 Model Setup

3.1.1 Three HEC-RAS hydraulic model geometries were used to represent existing conditions, project conditions under Alternative 1, Phase 1 (which would be the same as Alternative 2), and project conditions under Alternative 1, Phase 2. Model Geometry

The model extent includes the Ballona Creek channel from the Pacific Ocean to just downstream of Centinella Creek (Figure 5). Additionally, the model includes West Area B, South Area B, and Southeast Area B, all modeled as storage areas. The model structures include: Lincoln Blvd, Culver Blvd, and the Pacific Highway bridges, as well as culverts between Ballona Creek and West Area B, between West Area B and South Area B, and between South Area B and Southeast Area B.

3.1.1.1 Topography

A combination of as-built structure data from the USACE model of the Ballona Creek drainage system (USACE 2010) and a digital terrain model (DTM) constructed for the PDR was used to develop existing conditions model geometry for the Ballona Creek system. All elevations are vertically referenced to NAVD88.

3.1.1.2 Storage Areas

West Area B, South Area B, and Southeast Area B were each modeled as individual storage areas for existing conditions, since water surface gradients across the areas are not significant. A stage-storage curve was developed for each area from the topography (Section 3.1.1.1). For Alternative 1, Phase 1 project conditions (Figure 6) model runs, the stage-storage curves that were used for existing conditions were adjusted to account for the tidal channel grading in South and Southeast Area B. For the Alternative 1, Phase 2 project conditions model runs, West Area B was included in the Ballona Creek channel cross-sections and eliminated as a storage area (Figure 7).

3.1.1.3 Structures

Ten culverts were modeled to represent connections between the storage areas and Ballona Creek under existing and project conditions. Table 1 summarizes how each connection was represented in the model geometry.

Under project conditions, the connections between West Area B and Ballona Creek are not modeled since West Area B is included in the channel cross-sections.

3.1.1.4 SRT Calibration

The SRT gates that connect West Area B to Ballona Creek allow water to leak into Area B when they are closed (LA County 2012; Section 1.1). To achieve modeled water levels similar to existing levels in the marsh, the model was run with the SRT gates closing down to a 0.2 ft opening at a rate of 0.2 ft/min when Ballona Creek water levels reach 2.2 ft NAVD. Once channel water levels drop below 2.2 ft NAVD, the gates re-open. Water elevation data from the marsh and the channel, recorded in December 2011, were used to calibrate the SRT gates in the model. The calibration results are shown in Figure 8.

3.1.2 Hydrology

The flood flow rate modeled for the creek is the design flood of 46,000 cfs (USACE 1999) (see H&H report for additional details). A hydrograph based on model runs from the H&H Report was added just downstream of Centinella Creek and included the flows from Centinella, Sepulveda, and Ballona Creeks. This hydrograph is presented in Figure 9.

Stormwater inflow hydrographs were added to South and Southeast Area B to represent 100-year flows from the Freshwater Marsh (with the Ballona Creek outlet gate closed) and the Westchester Bluffs, respectively (PSOMAS 2012). The peak flow into Southeast Area B from the Freshwater Marsh is 174 cfs and the peak flow into South Area B from Westchester Bluffs is 160 cfs (PSOMAS 2012). Figure 9 presents these hydrographs. The 100-year flows result in a peak volume of 17 ac-ft in Southeast Area B and 34 ac-ft in South Area B (PSOMAS 2012).

3.1.3 Downstream Boundary Conditions

An unsteady tidal signal was used for the downstream boundary of the model. For the typical tides scenarios, a two week tide time series from December 2011 was used, in order to include a spring and neap cycle. For the storm runs, a one-day tide time series from February 2007 was used to represent a spring high tide cycle. The peak tidal water level of 6.22 ft NAVD was timed to occur just before the peak flow in Ballona Creek, when water levels in South and Southeast Area B would be at their highest due to the leaking SRT gates. Figure 9 shows these boundary conditions and the timing of the tides in relation to the flow hydrographs. Note that 7.6 ft NAVD, the downstream water level used to design the flood control channel, was not modeled, but may be in future efforts for the 408 Submittal B.

To represent conditions with sea-level rise for the years 2030, 2050, 2070, and 2100, the tidal signals were raised by 9, 19, 32, and 59 inches respectively per the USACE high emissions scenario (2011). To represent the worst-case storm scenario under sea-level rise conditions for the project, the peak flows were timed to coincide with the end of the neap cycle, when water levels in South and Southeast Area B would be at their highest.

Table 1. Model Culvert Data

		Ballona Creek to West Area B		West Area B to South Area B			South Area B to Southeast Area B			Ballona Creek to Southeast Area B
		West channel	East channel	North channel	South channel		North channel		South channel	
					North	South	North	South		
Existing Conditions	Number of culverts	1	3	1	1	1	1	1	1	
	Invert north (ft NAVD)	-1.28	-1.2							
	Invert south (ft NAVD)	-0.11	-1.2							
	Invert west (ft NAVD)			1.61	0.89	0.9	2.82	3.96	2.55	
	Invert east (ft NAVD)			2.56	0.94	1.08	3.2	3.74	2.23	
	Diameter (ft)	3	5 (FG)	3	2	2	4	4	4	
	Height x Width (ft)		5 x 3.93 (SRTs)							
	Length (ft)	58	50 (SRTs), 46 (FG)	77.3	87.5	89.8	30.8	30.1	41.5	
	Shape	Circular	Square (SRTs), Circular (FG)	Circular	Circular	Circular	Circular	Circular	Circular	
	Chart #	2 - CMP	2 - CMP	1 - RCP	1 - RCP	1 - RCP	2 - CMP	2 - CMP	2 - CMP	
	Scale #	1- Headwall	1- Headwall	1- Sq edge	1- Sq edge	1- Sq edge	1- Headwall	1- Headwall	1- Headwall	
	Entrance Loss Coefficient	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
	Exit Loss Coefficient	1	1	1	1	1	1	1	1	
	Manning's n	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	
	Gates	Flap gate	2 SRTs, 1 Flap gate							
	Gate closing elevation (ft NAVD)		3.4							
Alternative 1, Phase 1	Number of culverts	1	3		1	1	4			4
	Invert north (ft NAVD)	-1.28	-1.2							
	Invert south (ft NAVD)	-0.11	-1.2							
	Invert west (ft NAVD)				0.89	0.9	-1			-1
	Invert east (ft NAVD)				0.94	1.08	-1			-1
	Diameter (ft)	3	5 (FG)		2	2	5			5
	Height x Width (ft)		5 x 3.93 (SRTs)							
	Length (ft)	58	50 (SRTs), 46 (FG)		87.5	89.8	40			40
	Shape	Circular	Square (SRTs), Circular (FG)		Circular	Circular	Circular			Circular
	Chart #	2 - CMP	2 - CMP		1 - RCP	1 - RCP	2 - CMP			2 - CMP
	Scale #	1- Headwall	1- Headwall		1- Sq edge	1- Sq edge	1- Headwall			1- Headwall
	Entrance Loss Coefficient	0.5	0.5		0.5	0.5	0.5			0.5
	Exit Loss Coefficient	1	1		1	1	1			1
	Manning's n	0.024	0.024		0.024	0.024	0.024			0.024
	Gates	Flap gate	2 SRTs, 1 Flap gate		Weir structure					
	Gate closing elevation (ft NAVD)		3.4							
Alternative 1, Phase 2	Number of culverts			4			4			4
	Invert west (ft NAVD)			-1			-1			-1
	Invert east (ft NAVD)			-1			-1			-1
	Diameter (ft)			5			5			5
	Length (ft)			900			300			600
	Shape			Circular			Circular			Circular
	Chart #			2 - CMP			2 - CMP			2 - CMP
	Scale #			1- Headwall			1- Headwall			1- Headwall
	Entrance Loss Coefficient			0.5			0.5			0.5
	Exit Loss Coefficient			1			1			1
	Manning's n			0.024			0.024			0.024
	Gates			Flap gates with SLR over time (0 fg initially, 1 fg at 9”, 2 fg at 19”, 3 fg at 32”,3 fg and 1 slide gate at 59”)						Flap gates with SLR over time (0 fg initially, 1 fg at 9”, 2 fg at 19”, 3 fg at 32”,3 fg and 1 slide gate at 59”)

HEC-RAS can model SRT gates as rectangular culverts, but not circular, so dimensions were chosen to match the culvert area and culvert elevations.

3.1.4 Run Catalog

Sixteen scenarios were run. These included existing and project conditions (Alternative 1, Phase 1 and 2), typical tides and the design storm event, and sea-level rise. **Error! Reference source not found.** provides the run catalog.

Table 2. Model Run Catalog

	Run	Scenario	Hydrology	Downstream Boundary Conditions	Sea-Level Rise
Typical tides	Calibration	Existing	-	Two weeks typical tides	-
	1	Existing	-	Two weeks typical tides	-
	2	Alt 1, Phase 1	-	Two weeks typical tides	-
	3	Alt 1, Phase 2	-	Two weeks typical tides	-
Design Event	4	Existing	Design Event	Spring high tide	-
	5	Alt 1, Phase 1	Design Event	Spring high tide	-
	6	Alt 1, Phase 2	Design Event	Spring high tide	-
Sea Level Rise	7	Existing	-	Two weeks typical tides	9” (high)
	8	Existing	-	Two weeks typical tides	19” (high)
	9	Existing	-	Two weeks typical tides	32” (high)
	10	Existing	-	Two weeks typical tides	59” (high)
	11	Alt 1, Phase 2	-	Two weeks typical tides	9” (high)
	12	Alt 1, Phase 2	-	Two weeks typical tides	19” (high)
	13	Alt 1, Phase 2	-	Two weeks typical tides	32” (high)
	14	Alt 1, Phase 2	-	Two weeks typical tides	59” (high)
Design Event with SLR	15	Existing	Design Event	End of neap tides	59” (high)
	16	Alt 1, Phase 2	Design Event	End of neap tides	59” (high)

3.2 Results and Discussion

Model results are presented in Table 3 and Figures 10-16 and discussed in the following sections.

3.2.1 Typical Tides

Figure 10 shows model results for tidal inundation extent during a low tide and spring high tide in Ballona Creek for existing conditions and Alternative 1 (Phase 1 and Phase 2). Under existing conditions, only the remnant channels in South and Southeast Area B are inundated, due to the muted, managed water levels, which have damped high tide levels. Similarly, West Area B experiences a small extent of inundation as well. Under the proposed operations for Phase 1, the new culverts would allow higher water levels, which would increase inundation in South and Southeast Area B. In Phase 2, water levels would increase even more as the culverts to West Area B are expanded. The eucalyptus grove in South Area B near the Gas Company does not experience any inundation under existing conditions. With Alternative 1, the edge of the grove would be tidally inundated. A berm could be

added around the grove to protect it from tidal waters if the inundation is determined to be detrimental.
The elevation-area curves in Figure 11 show inundated acreage under existing, Phase 1, and Phase 2 project conditions. The model results indicate that Phase 1 would inundate an additional 64 acres of marsh in South and Southeast Area B (65 acres total), and Phase 2 would inundate 75 acres.

Figure 12 shows the model results for a typical tidal signal. Under existing conditions, the modeled water level in each area rises with the tide until the water level in Ballona Creek reaches the elevation at which the SRT gates close , and then slowly increases in proportion to the water level in the creek (due to leakage in the SRT gates) until the Creek water levels drops. As the Creek level drops, the areas drain out to the lowest ground surface elevation.

Phase 1 model results show water levels in West Area B would follow the same pattern because the area would be operated the same in Phase 1 as under existing conditions. In South and Southeast Area B model results show some high tide muting despite the increased culvert capacity. With the tidal channel grading, the tidal prism in South and Southeast Area B increases dramatically from 17 ac-ft to 84 ac-ft, and even with the additional and larger culverts, the flow cannot be conveyed quickly enough into the site to raise water levels to the Ballona Creek peak water level before the tide in the Creek starts to drop. This is reflected in the model results, which show peak water level in South and Southeast Area B somewhat lower than the Ballona Creek peak water level.

Under Phase 2, the culvert capacity effectively doubles from Phase 1 (with the removal of the weir from South to West Area B and the new, larger culverts), but model results show the high tide is still slightly muted. However, the muting is not substantial and increasing the culvert dimensions further would offer a decreasing return on investment.

3.2.2 Design Storm Event

During the design storm event under existing conditions, the maximum water level in South and Southeast Area B reaches 5.3 ft NAVD according to model results (Figure 13, **Error! Reference source not found.**). This results in 1.5 ft of freeboard to the low point in Culver Boulevard (6.8 ft NAVD).

In Alternative 1, Phase 1, model results show that the water levels in West Area B are initially lower than under existing conditions because the weir from South to West Area B limits flow. Once the water levels in South Area B overtop the weir (6 ft NAVD), the water levels in West Area B increase and peak to the same level as under existing conditions (4.5 ft NAVD). The weir also limits drainage from South and Southeast Area B. This is reflected in the model results, which show it takes longer (< 1 hour) to drain these areas under Alternative 1, Phase 1 than under existing conditions. Model results show peak water levels in South and Southeast Area B increase to 7.0 and 7.1 ft NAVD respectively under Alternative 1, Phase 1 conditions. However, with the new perimeter berm (9 ft NAVD), freeboard increases to 1.9 ft (Table 3).

In Alternative 1, Phase 2, West Area B would be reconnected to Ballona Creek and the water levels in South and Southeast Area B would increase slightly from Phase 1 according to model results (to 7.3 and 7.4 ft NAVD respectively). The second culvert connection through West Area B allows water to move more quickly into the site, so modeled water levels are higher even before the storm peak passes. However, model results show that the new berm would provide 1.6 ft of freeboard at the peak water level of 7.3 ft NAVD (Table 3).

Since Ballona Creek flow expands and slows in West Area B under Phase 2 project conditions, model results show water levels at the creek side of the tide gates remain elevated for longer than under existing conditions (Figure 13). This would delay drainage in the areas south of Culver Blvd, but the increased culvert capacity allows water to flow out more quickly (2 hours faster than Phase 1, according to model results).

These results demonstrate that flood hazard is not increased under Alternative 1 relative to existing conditions. The modeled project design assumes open culverts without gates; SRT gates or similar types of automatic gates could be added to the culverts under Phase 2 project conditions if more freeboard and lower water levels are desired or for added safety and design redundancy.

3.2.3 Sea-Level Rise

With sea level rise, inundation is expected to increase over time. Without the project, low tide and high tide inundation will be similar, and habitats will convert to lower elevation habitat types (mid marsh to low marsh or low marsh to mudflat). With the project, the tidal signal can be maintained for a longer time. Figure 14 shows the low and high tide inundation with sea level rise over time.

With 59 inches of sea-level rise by 2100 (USACE 2011), MLLW will rise to 4.7 ft NAVD, which is more than two feet above the current SRT closing elevation. Under typical tidal conditions with sea-level rise (i.e., future without project conditions), this means that the water level in all of the managed areas would continually increase (due to the leakage in the SRT gates) except during spring low tides occurring every two weeks when the water can drain out, as shown in the model results in Figure 15. Under project conditions, modeled water levels still show a tidal signal (as opposed to under existing conditions), because the open culverts allow higher tides and are bigger than under existing conditions, so they provide better drainage. While pickleweed in South and Southeast Area B may not survive until 2100 due to the elevations and the increased duration of inundation in South and Southeast Area B, the vegetation would survive longer than it would without the project.

When the design storm event occurs under sea level rise conditions, water levels south of Culver Boulevard would depend largely on whether the event occurs during a spring or neap tide according to the model results. As shown in Figure 15, the modeled water elevations in South and Southeast Area B due to the tides alone can range from 3.6 to 8.2 ft NAVD under project conditions. The worst-case scenario for project conditions would be if the peak flow hit toward the end of the neap tides, when the water levels would already be at their highest south of Culver Boulevard. The model shows that this would result in water levels up to 8.7 ft NAVD (Figure 16, **Error! Reference source not found.**), with 0.3 ft of freeboard for the berm. Under existing conditions, West Area B provides additional storage, and the SRT gates are operated to close at a lower elevation, so the water levels are 2 feet lower (6.7 ft NAVD) than project conditions; however, the freeboard for Culver Blvd under existing conditions is only 0.1 ft. Model results show that the Project would, therefore, maintain or increase the level of flood protection in the future with up to 59 inches of sea level rise.

Table 3. Area B Water Level Results Summary

		Area B	Existing Conditions (EC)	Alternative 1, Phase 1	Change from EC	Alternative 1, Phase 2	Change from EC
Existing Hydrology	Highest Tide Level	All	3.9	5.7	1.8	6.1	2.2
	Design Storm Peak Water Level	West	4.5	4.5	0.0	-	-
		South	5.3	7.0	1.7	7.3	2.0
		Southeast	5.3	7.1	1.8	7.4	2.1
	Freeboard[1]		1.5	1.9	0.4	1.6	0.1
Sea-Level Rise	Highest Tide Level	All	6.3	-	-	8.2	1.9
	Design Storm Peak Water Level	South	6.7	-	-	8.7	2.0
		Southeast	6.7	-	-	8.7	2.0
	Freeboard[1]		0.1	-	-	0.3	0.2

1. Freeboard is to Culver Blvd low point (6.8 ft NAVD) for Existing Conditions and Phase 1, and to the new berm (9.0 ft NAVD) for Phase 2.

3.3 Summary and Conclusions

For the culvert configuration and operation modeled for this preliminary hydraulic design, high tide levels south of Culver Blvd would be increased by 1.8 ft to 5.7 ft NAVD in Phase 1, and increased by 2.2 ft to 6.1 ft NAVD in Phase 2 under typical tidal conditions (**Error! Reference source not found.**). The proposed new perimeter berm would maintain the existing freeboard above high tide for Culver Boulevard in Phase 2, which is approximately 2.9 ft.

With the proposed structure configuration for Phase 1 project conditions, the water levels in South and Southeast Area B during the design storm would increase by 1.8 ft due to the higher starting tidal water levels. In Phase 2, the modeled peak water levels increase further, due to the extra culverts, which allow more flow into the site before the storm peak. During the design storm, the modeled water levels south of Culver Blvd increase by 2.1 ft, but are still 1.6 ft below the proposed new perimeter berm and therefore maintain the existing freeboard (**Error! Reference source not found.**). Subsequent phases of the design will consider the addition of SRT or similar tide gates and hydraulic controls to limit peak water levels and provide added safety and design redundancy. Culvert sizes and designs will also be refined.

With 59 inches of sea-level rise projected in 2100, the project would increase water levels by 1.9 ft under tidal conditions, and 2 ft during the design storm, according to the model results. However, with the proposed new perimeter berm, freeboard is increased by 0.2 ft during the design storm.

Model results for typical tidal conditions demonstrate that Alternative 1 functions to increase the tide range in South and Southeast Area B, therefore enhancing pickleweed-dominant salt marsh, without increasing the tide range in West Area B under Phase 1, in order to protect existing Belding's savannah sparrow nesting habitat. Model results for design storm conditions demonstrate that flood hazard is not increased under Alternative 1 relative to existing conditions. The model results also demonstrate that the design will be more resilient to sea level rise than existing conditions. Additionally, the design allows for management flexibility and adaptive management, thus achieving all of the design objectives.

4 Next Steps

The South Area B managed wetland enhancement design will be further developed in subsequent phases of the design, including:

- Develop gate configuration design. For the new water control structures in the Culver levee in Phase 2, combination slide and flap gates or SRT gates could be used.
- Develop water management design for the brackish marsh area, including the brackish marsh impoundment water control structure design and operation and modifications to the Freshwater Marsh structures.

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6 List of Preparers

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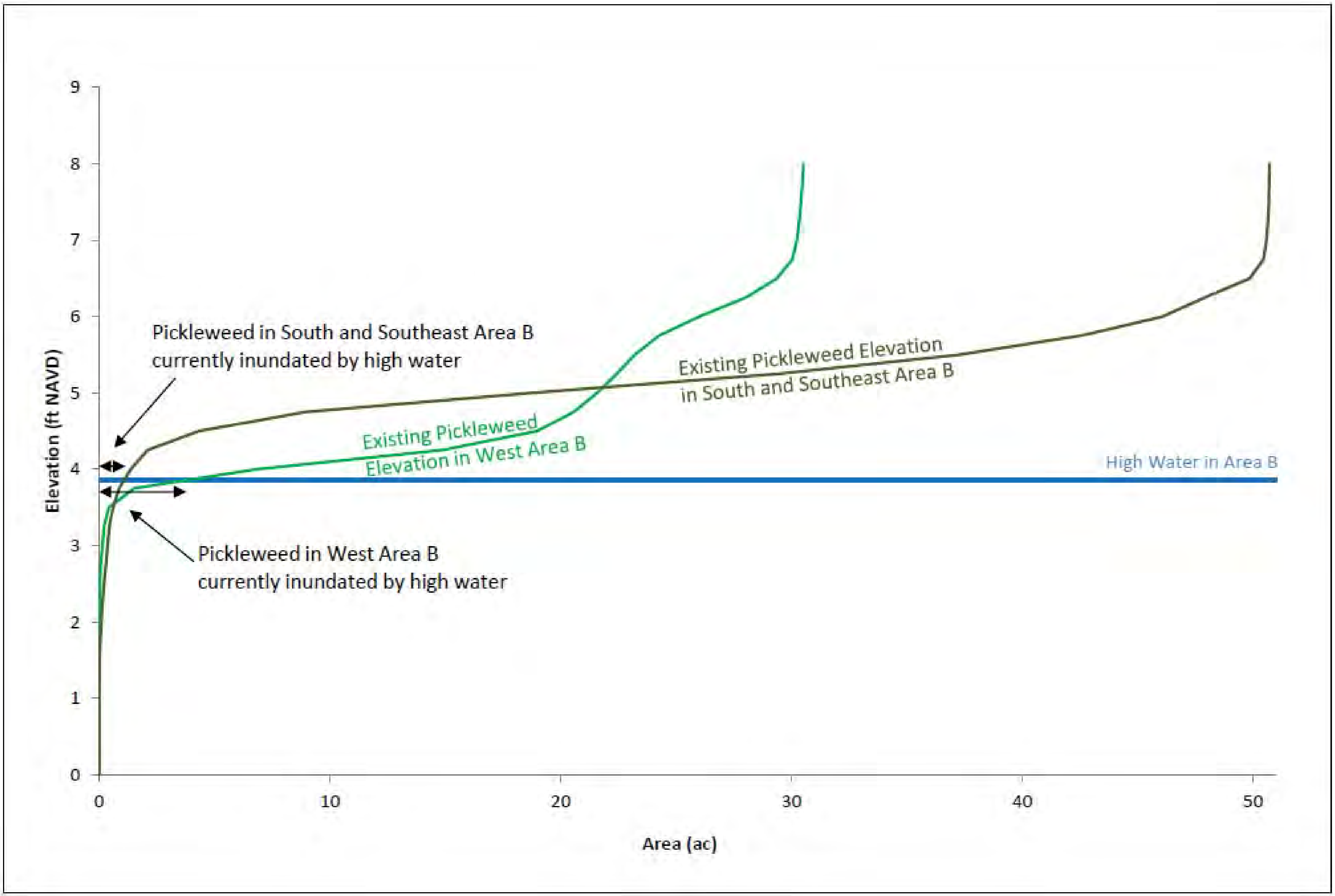
Ballona Wetlands Restoration Project

Figure 1
Site Overview



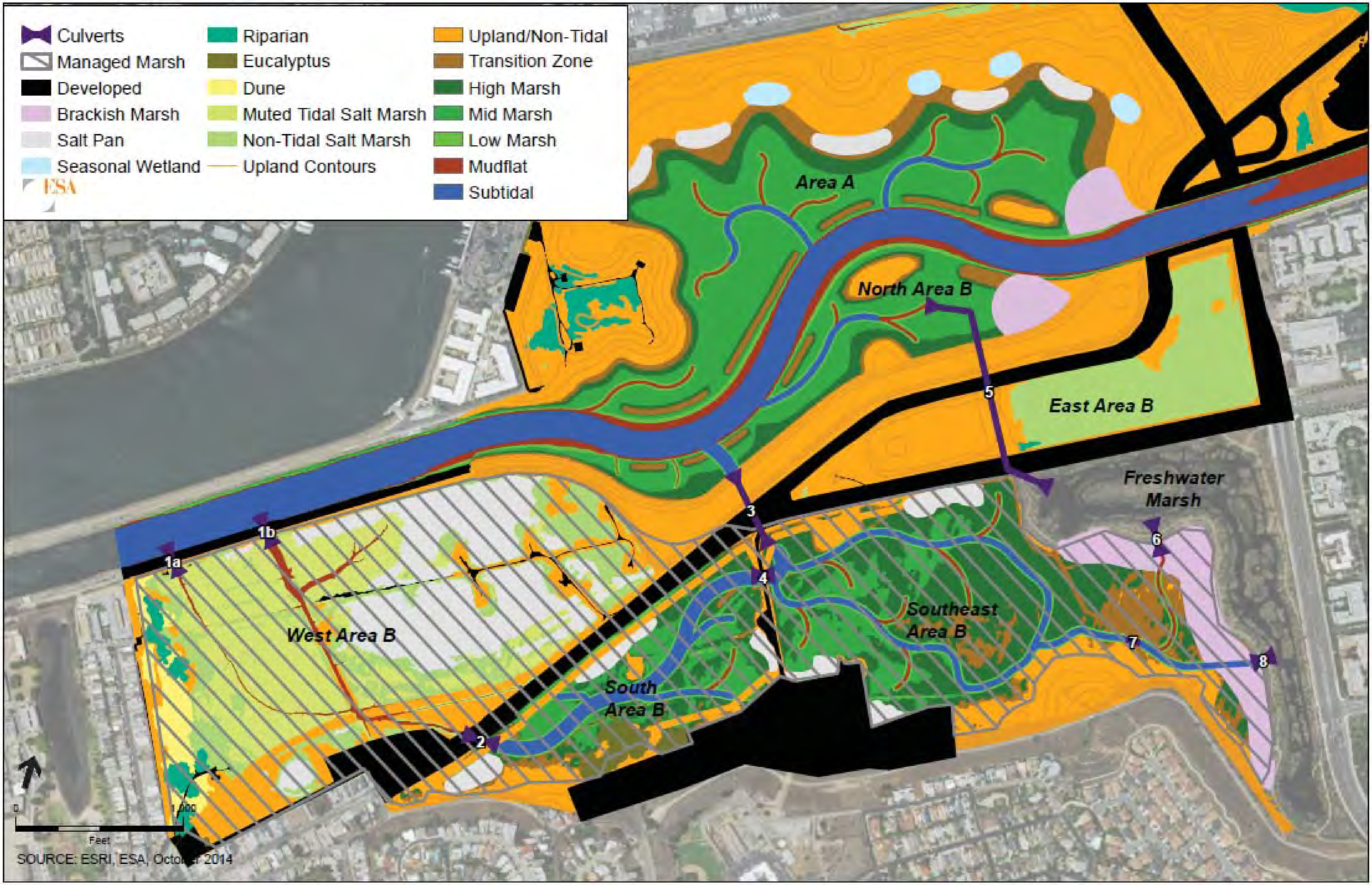
Note: Elevation data from PSOMAS 2013 for PDR. Habitat mapping from the California Department of Fish & Game's (2007) habitat and vegetation mapping.

Ballona Wetlands. D120367

Figure 2

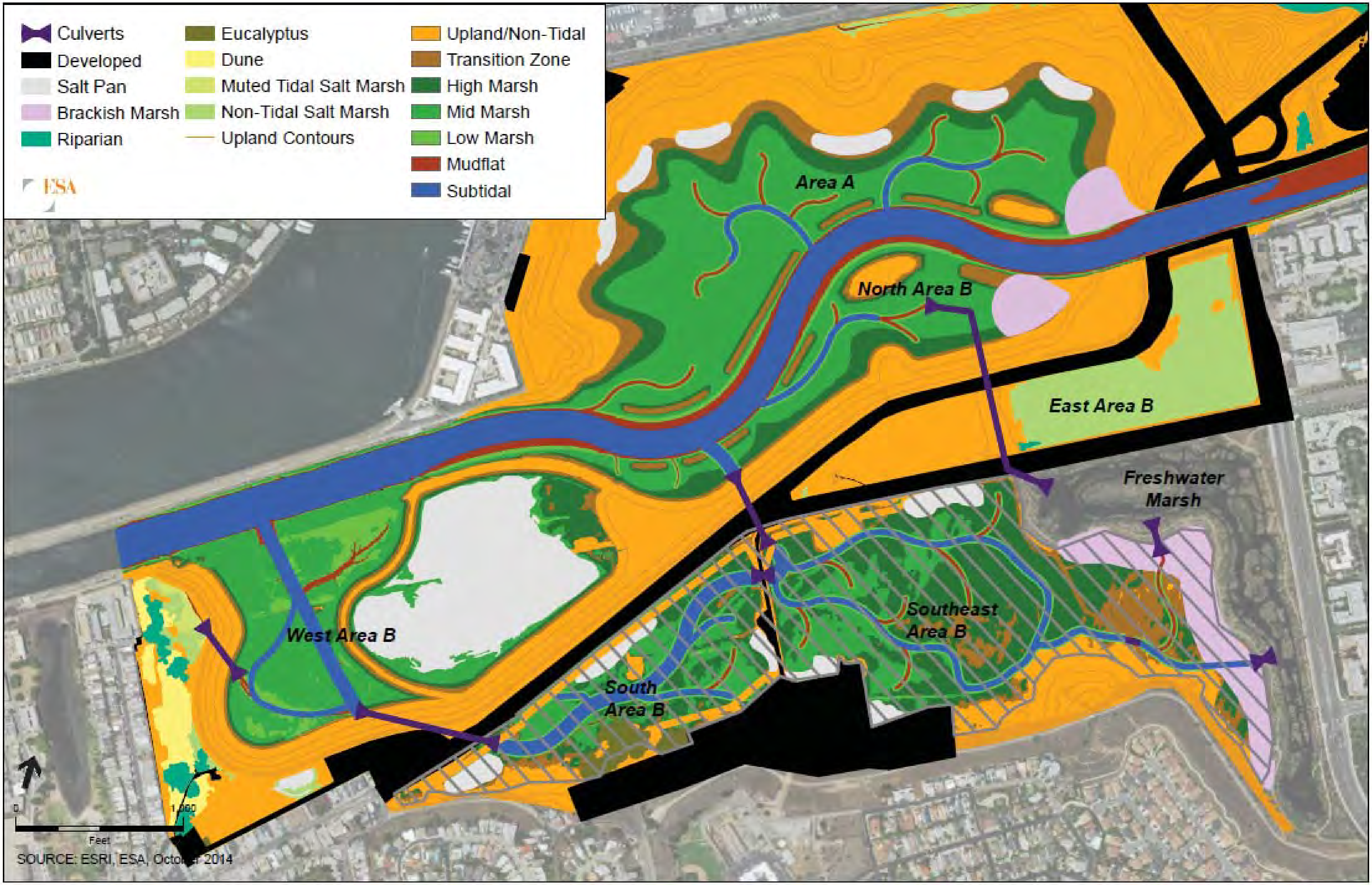
Area B

Existing Pickleweed Elevations



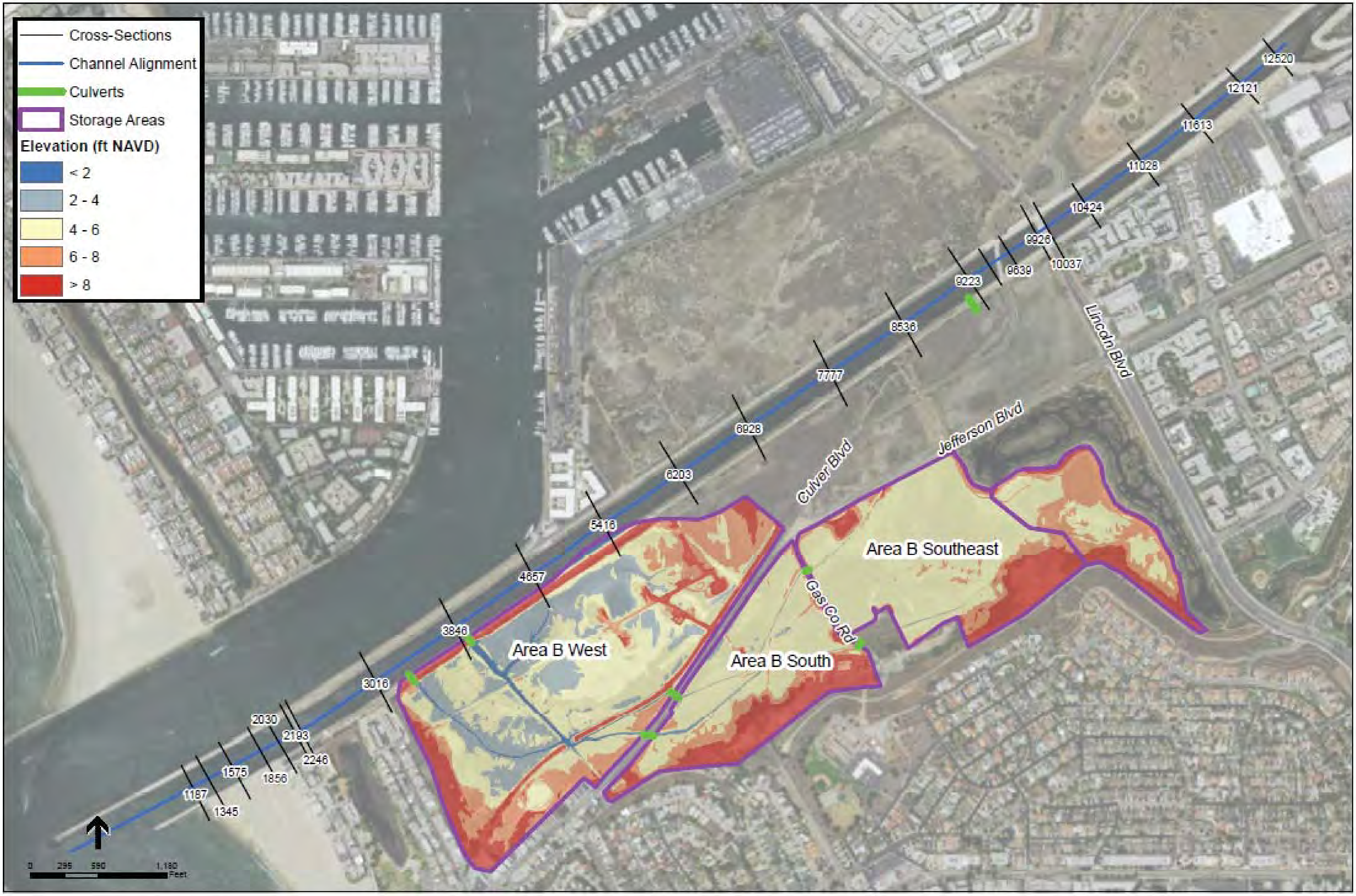
Ballona Wetlands Restoration Project

Figure 3
Alternative 1, Phase 1 Restoration



Ballona Wetlands Restoration Project

Figure 4
Alternative 1, Phase 2 Restoration



Ballona Wetlands Restoration Project

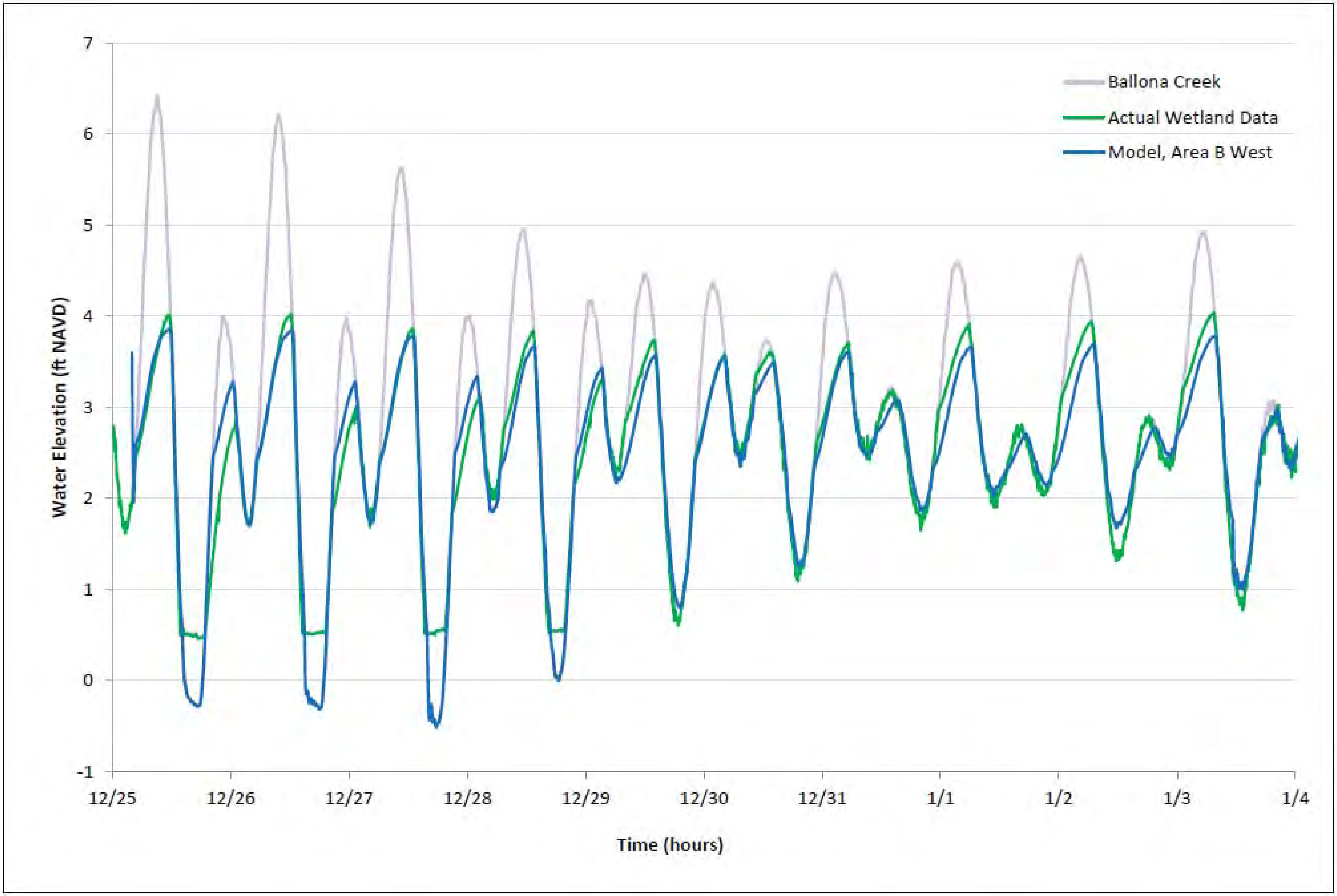
Figure 5
Existing Conditions Model

Ballona Wetlands Restoration Project

Figure 6
Alternative 1, Phase 1,
Project Conditions Model

Ballona Wetlands Restoration Project

Figure 7
Alternative 1, Phase 2,
Project Conditions Model



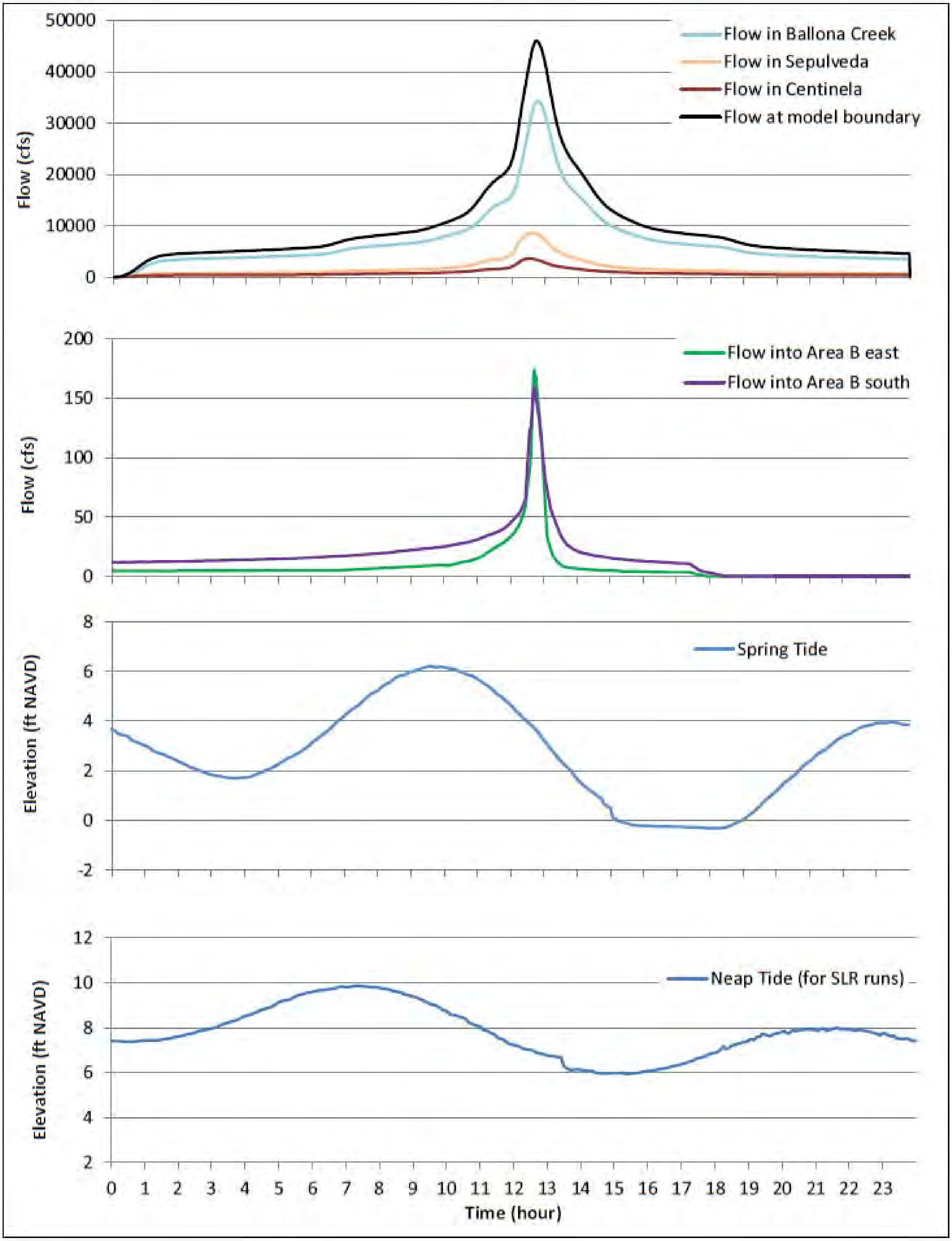
Note: Ballona Creek water levels taken just outside Area B

Ballona Wetlands. D120367

Figure 8

Area B

SRT Gates Calibration



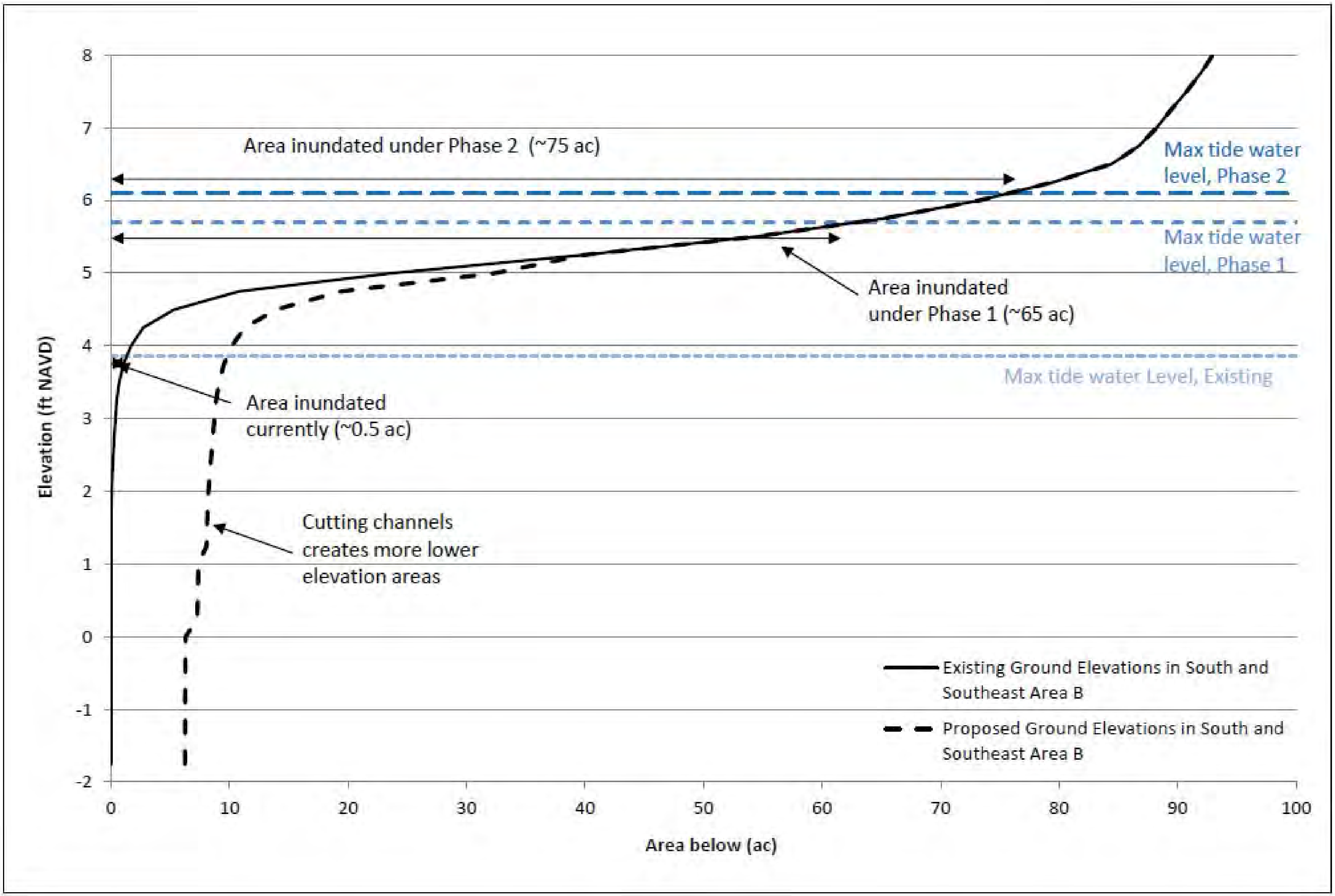
Ballona Wetlands
Restoration Project

Figure 9
Model Hydrographs and Tidal Signals

SOURCE: Channel hydrographs from USACE HMS model; Area B hydrographs from PSOMAS 2012; Tide data from NOAA at the Santa Monica gage.
NOTES: Channel hydrographs represent the design flood event; Storage area hydrographs represent the Q100.

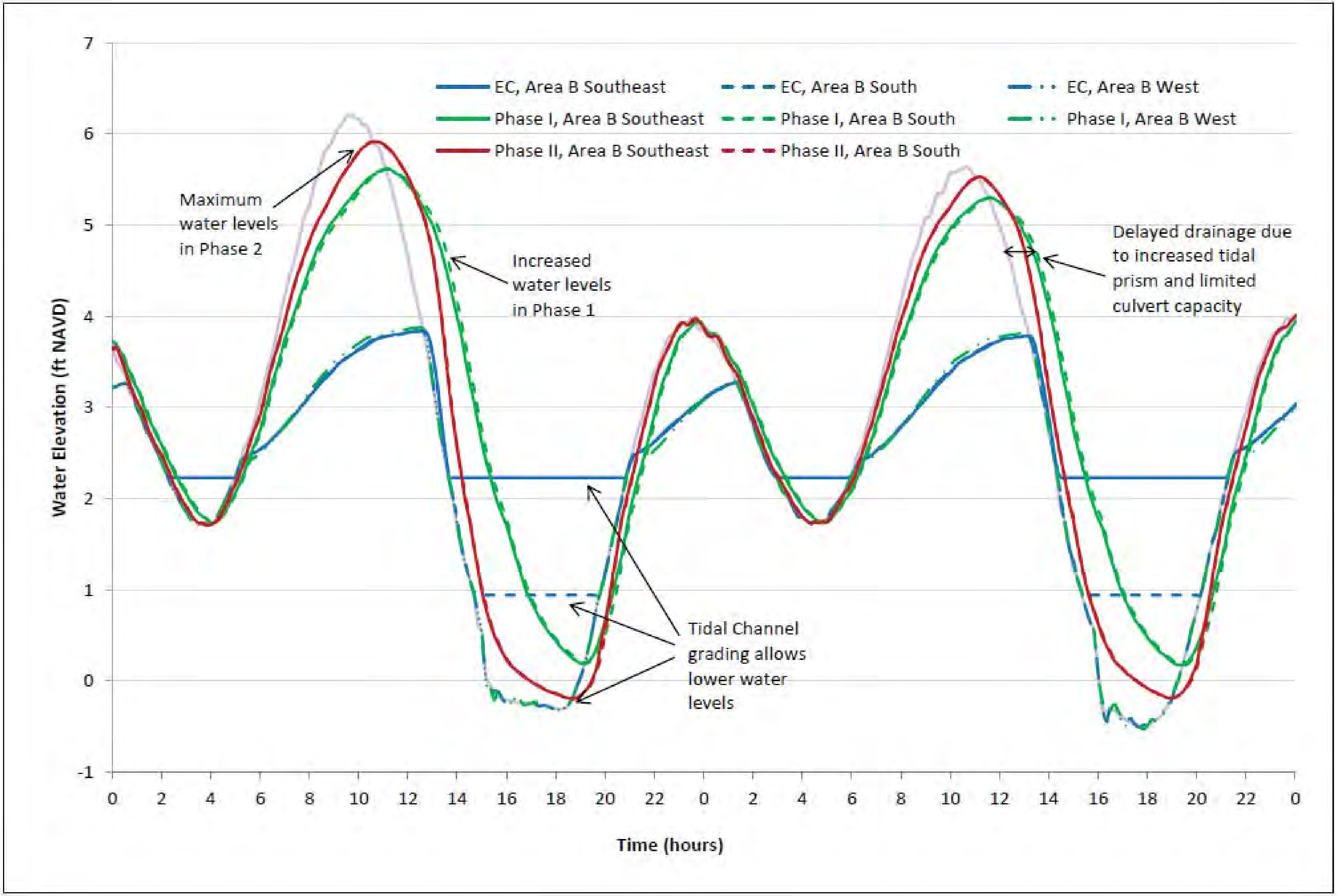
Ballona Wetlands Restoration Project

Figure 10
Increased Inundation Under Alternative 1, Plan View



Ballona Wetlands Restoration Project

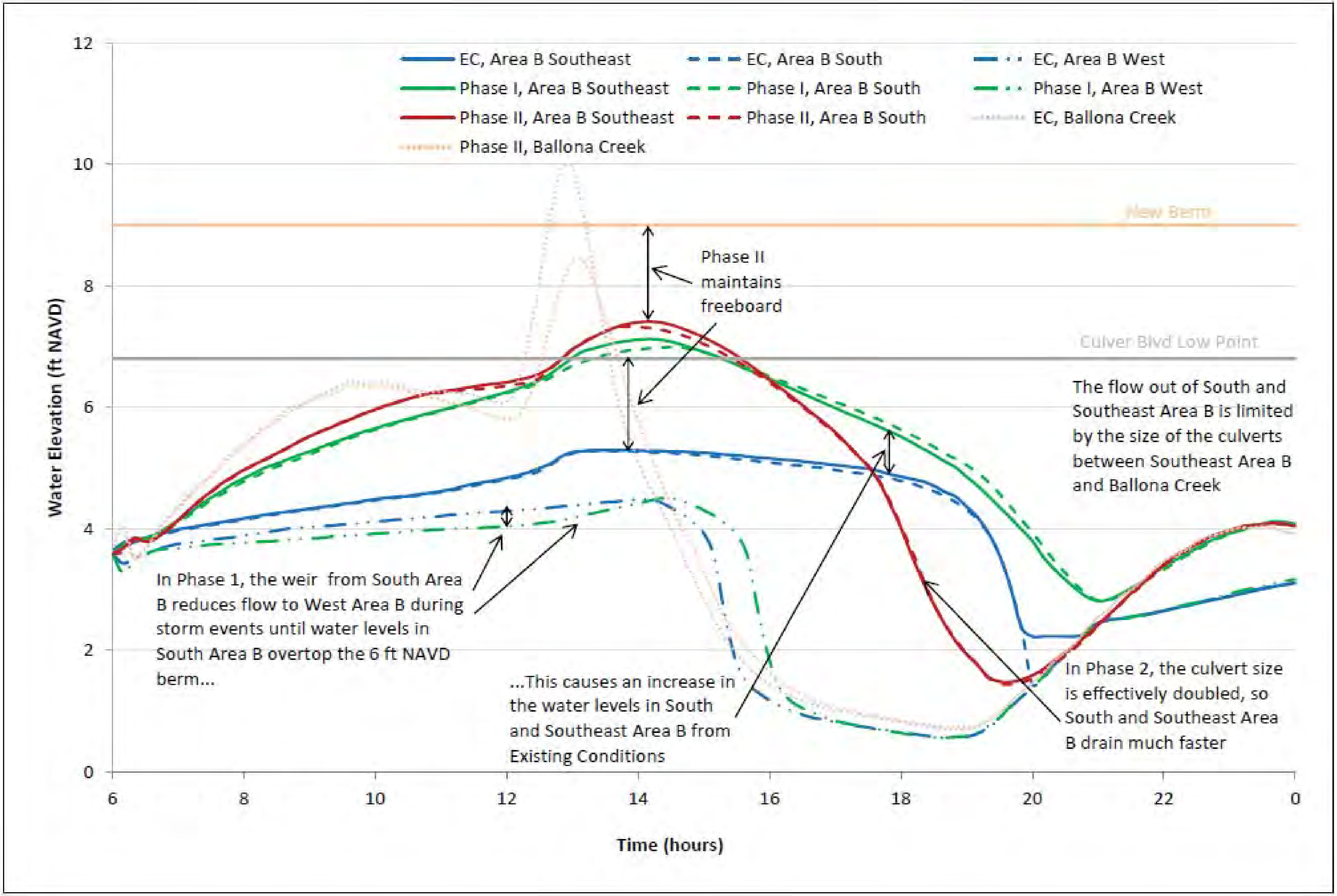
Figure 11
Increased Inundation Under Alternative 1, by Elevation



Ballona Wetlands Restoration Project

Figure 12
Typical Tides Model Results

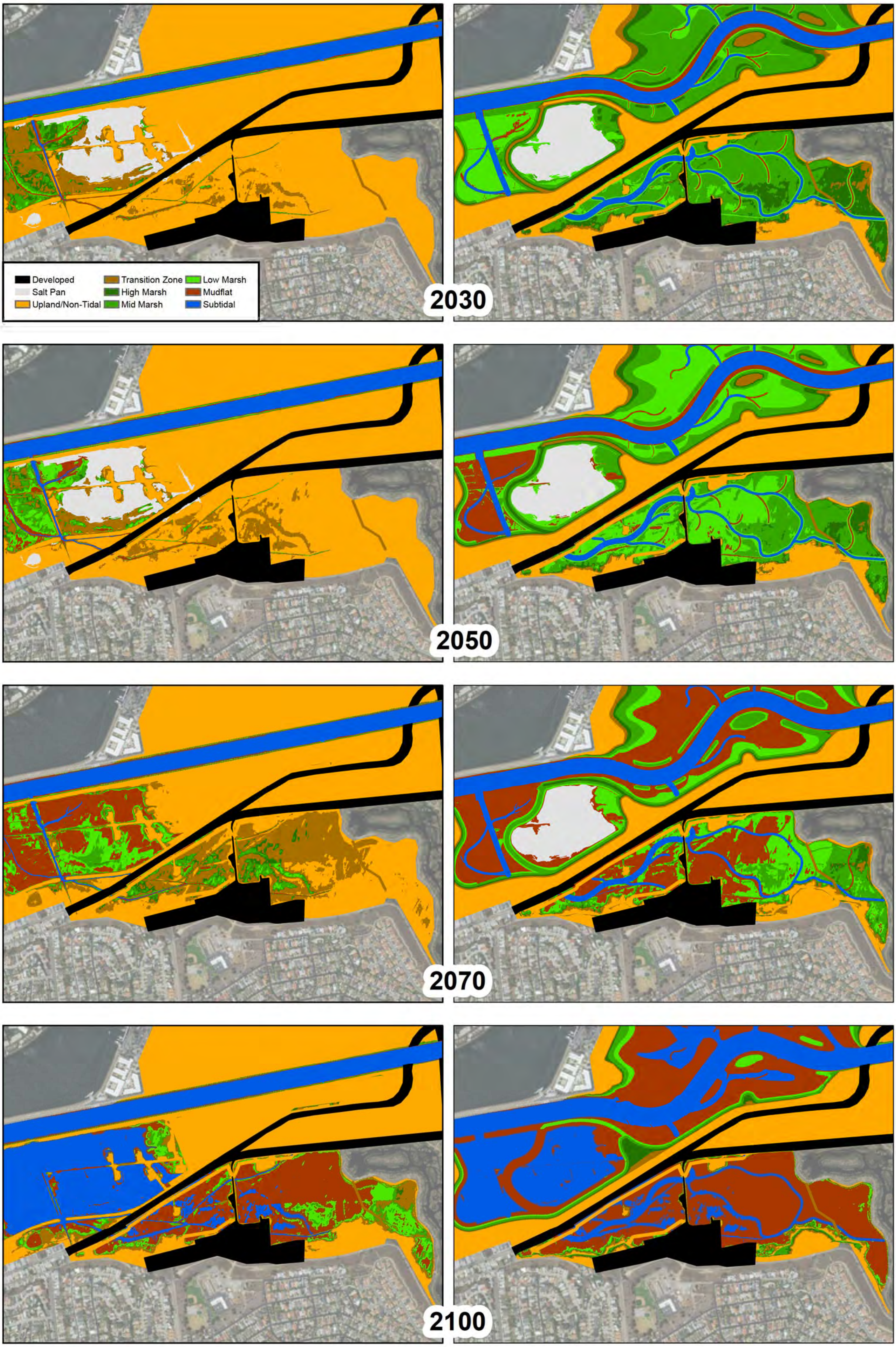
Note: Ballona Creek water levels taken just outside Area B



Ballona Wetlands Restoration Project

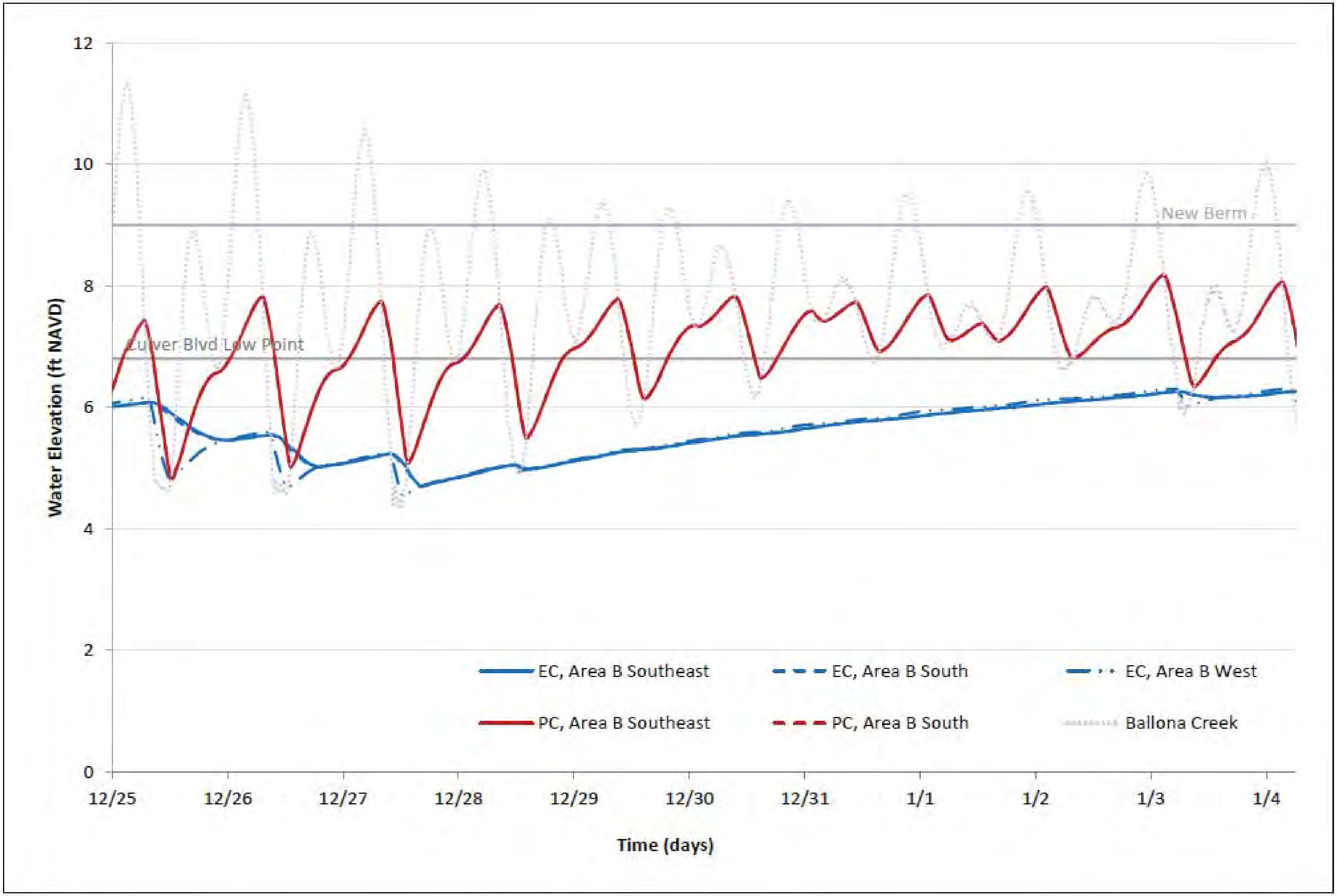
Figure 13
Design Flood Model Results

Note: Ballona Creek water levels taken just outside Area B



Ballona Wetlands Restoration Project

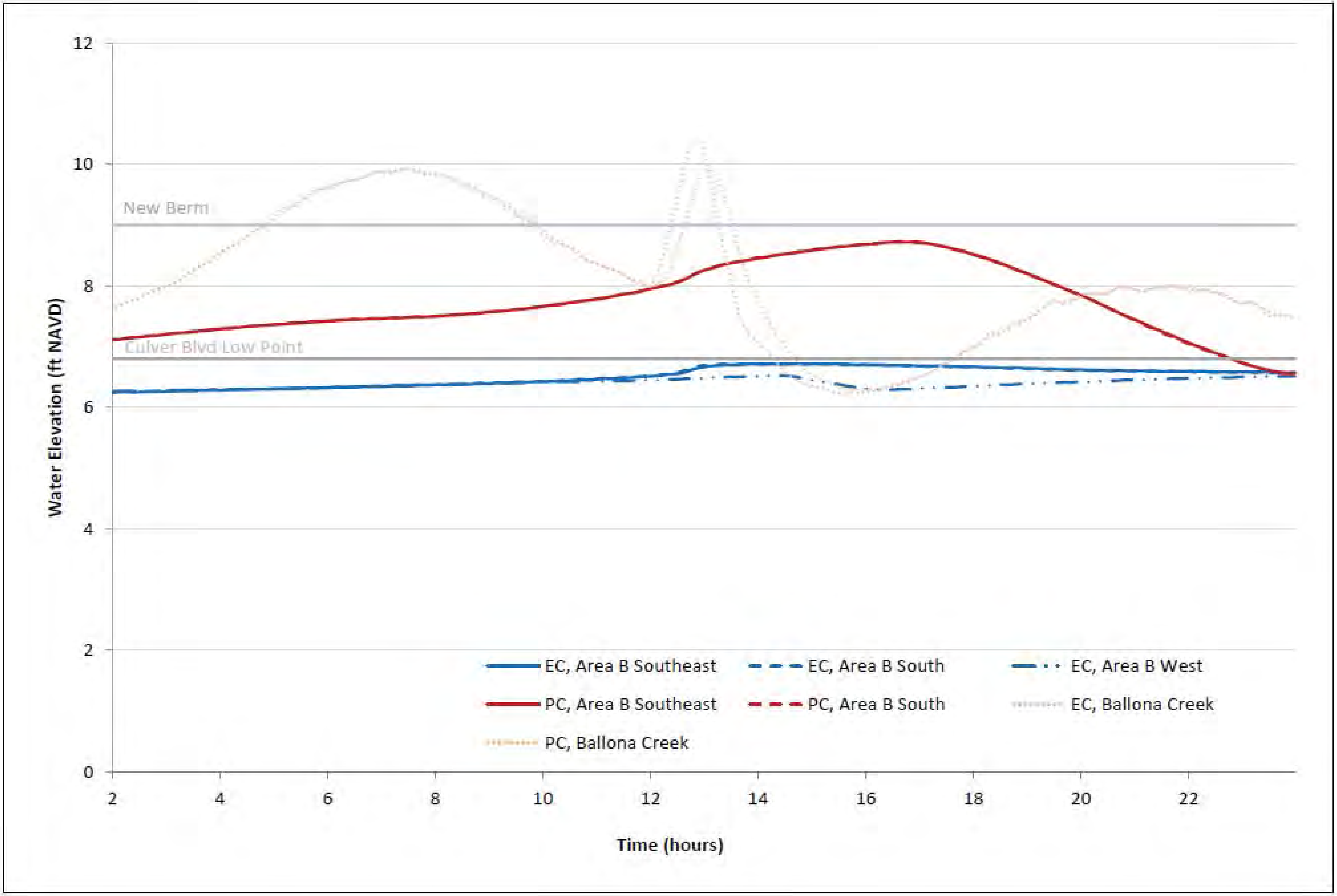
Figure 14
Inundation Under Existing Conditions and Alternative 1 with Sea Level Rise



Ballona Wetlands Restoration Project

Figure 15
Typical Tides with Sea Level Rise Model Results

Note: Ballona Creek water levels taken just outside Area B



Ballona Wetlands Restoration Project

Figure 16
Design Flood with Sea Level Rise
Model Results

Note: Ballona Creek water levels taken just outside Area B.

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APPENDIX F10
Addendum 1. Sediment Transport Analysis

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Memorandum

date December 6, 2013 Administrative Draft – *revised 2/18/2014, 4/21/2014*

to Mary Small, California State Coastal Conservancy

from Nick Garrity, P.E., James Gregory, P.E., and Christie Beeman, P.E.

subject *Draft Ballona Wetlands Restoration Project, Preliminary Hydrology and Hydraulics Report*
Addendum 1. Sediment Transport Analysis

EXECUTIVE SUMMARY

This document is Addendum 1, Sediment Transport Analysis, to the Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report (H&H Report, ESA PWA 2013a) prepared for the U.S. Army Corps of Engineers (USACE) Section 408 Initial Submittal A. To refine the representative sediment transport model simulations conducted for Submittal A, ESA PWA conducted sensitivity analyses on several sediment transport parameters and modeling of design flood events. The model used is the USACE's Hydraulic Engineering Center's River Analysis System (HEC-RAS), version 4.1.0. The purpose of the sensitivity testing was to identify the relative influence of each parameter and to adjust the parameters to which the model is most sensitive in order to improve model agreement with the historic scour and deposition as reflected in the channel profile. The sensitivity results of the sensitivity analysis will also inform the Risk and Uncertainty (R&U) analysis required for Submittal B of the Corps 408 permit application. Preliminary results indicate that the sediment transport model is sensitive to variation in some sediment parameters such as grain size distribution; however, the flood levels simulated in HEC-RAS are not sensitive to the differences in the channel profile that result from varying grain size and sediment load parameters.

Sediment transport modeling of the 100-year discharge (Q100) and design flood event were performed to inform subsequent design refinement and assessment of long-term erosion and deposition patterns for the restored wetlands. Project conditions model results demonstrate local increases in shear and erosion may be caused by channel expansion and contraction at the upstream and downstream ends of the project reach. This result will be used to inform the next phase of project design development, including design refinement for scour protection features.

1. INTRODUCTION

This document is Addendum 1, Sediment Transport Analysis, to the Ballona Wetlands Restoration Preliminary Hydrology and Hydraulics Report (H&H Report, ESA PWA 2013a) prepared for the U.S. Army Corps of Engineers (USACE) Section 408 Initial Submittal A. This Sediment Transport Analysis Addendum includes additional fluvial sediment transport model sensitivity analyses and sediment transport model runs to support Submittal A and inform subsequent design refinement and preparation of Section 408 Submittal B. A complete discussion of data sources and the technical approach for sediment transport modeling is provided in the H&H Report (ESA PWA 2013a).

To refine the representative sediment transport model simulations included in the H&H Report, this Sediment Transport Analysis includes sensitivity analyses on several sediment transport parameters. The purpose of the sensitivity testing is to identify the relative influence of each parameter and to adjust the parameters to which the model is most sensitive in order to improve model agreement with the historic scour and deposition patterns as reflected in channel profile surveys over time. Results of the sensitivity analysis will also inform the Risk and Uncertainty (R&U) analysis required for Submittal B. The sensitivity analysis was structured to lead directly into the R&U analysis, using upper and lower bounds for key parameters per the guidelines laid out in EM 1110-2-1619 (USACE, 1996). Preliminary results indicate that the sediment transport model is sensitive to variation in some sediment parameters such as grain size distribution; however, the flood levels simulated in HEC-RAS are not sensitive to the differences in the channel profile that result from varying sediment transport parameters.

As described in Submittal A, results of the sediment transport analysis also inform design development for the wetland restoration project. For example, the design for scour protection features (discussed in the Ballona Wetlands Restoration Preliminary Design Report, ESA PWA 2013b) will be refined considering sediment transport model results. This Sediment Transport Analysis Addendum includes sediment transport model runs for the estimated effective discharge (Q_{eff}), 5-year discharge (Q5), 100-year discharge (Q100), and the channel design event (46,000 cubic feet per second (cfs) with a 7.63 ft NAVD tide boundary condition) to inform further design development and for consistency with hydraulic and sediment transport analyses included in the H&H Report. The Q_{eff} (the discharge responsible for transporting the majority of sediment in the channel, based on magnitude-frequency analysis) and Q5 runs were chosen to reflect channel-forming flow conditions, while Q100 and the design event were selected to evaluate the erosion and sedimentation risk of large flood events. The hydrographs for these events were adapted from the USACE's HEC-HMS hydrology (USACE, 2010) which included hydrographs for 2-, 5-, 10-, 25-, 50-, 100-, 150-, 100-, 200- and 500-year flood events. The Qeff hydrograph was scaled down from the 2-year HMS hydrographs, and the design event was scaled up from the 100-year HMS hydrographs.

Note that the results from this Sediment Transport Analysis will be incorporated into a sediment budget assessment to further characterize long-term erosion and deposition patterns and equilibrium conditions for the restored wetlands.

2. SEDIMENT TRANSPORT PARAMETERS

The following parameters were tested to evaluate the sensitivity of sediment transport modeling results to the values selected:

1. Bed material grain size distribution (GSD)
2. Tidal boundary condition
3. Incoming sediment load
    a. GSD
    b. Total load (rating curve)

The analyses conducted to evaluate the model sensitivity for these parameters are discussed in the following sections.

2.1 Bed material grain size distribution

The sediment gradation in the channel bed affects the amount of sediment that can be mobilized from the bed material. Coarse sediments require more energy to mobilize than fine sediments and thus a coarser bed material composition will be less susceptible to bed scour. Previous sediment transport analysis (H&H Report, ESA PWA 2013a) applied an "average" (composite) GSD developed by the U. S. Army Corps of Engineers' from data shown in Figure 1 (USACE 2003). To refine our understanding of GSD in the project reach, bed sediment samples were collected by ESA PWA at three discrete locations in the Ballona Creek channel downstream of Lincoln Boulevard. The three sample locations were:

1. Downstream of Lincoln Boulevard at approximately river station 9800
2. Within the project reach at approximately station 4400
3. Downstream of Pacific Ave on the shoal near the river mouth at approximately station 1800

Two samples were collected at location 3 to better characterize the sediment size gradation in the shoal at the mouth of the channel, for a total of 4 samples. The GSD of these collected samples was analyzed and provided to ESA PWA by Wallace Labs. Table 1 shows mean diameter (D_{50}) for the collected samples, reflecting the expected pattern of sediment fining in the downstream direction. Table 1 also shows D_{50} for the USACE composite GSD, which is similar to the downstream-most sample collected by ESA PWA. Visual inspection of the channel confirmed that the sediment composition at the upstream end of the study reach is coarser than that of the composite USACE curve.

Table 1. D_{50} for USACE sample composite and ESA PWA bed material samples

	ESA PWA Samples (approximate station)			USACE composite
	1. (9800)	2. (4400)	3. (1800)	
D50 (mm)	0.80	0.53	0.36	0.39

To identify an appropriate range of GSD curves for sensitivity testing, a subset of the 20 sediment samples collected by the USACE on Ballona Creek and its tributaries (USACE 2003) were used in combination with the sediment samples collected by ESA PWA to estimate a mean and standard deviation of percentages for each sediment class. Based on comparison to ESA PWA samples, visual observations and previous modeling results, five of the USACE samples were identified as outliers with atypically high fine concentrations and excluded from the statistical analysis. The percent-finer value was estimated for each sediment class size from the USACE graph (Figure 1). The lowest sediment size was estimated by projecting the end of each curve onto the x-axis. The USACE samples and highlighted outliers are shown in Figure 2.

For each sediment class represented in the HEC-RAS sediment transport module (i.e. coarse sand, fine sand, etc) the percent of the bed material in that class was identified for the 15 USACE samples and the 4 ESA PWA samples. The average and standard deviation of the sediment class percentages were estimated for the 19 samples. The full set of sediment samples are presented with average and standard deviation curves in Figure 3. The standard deviation curves were computed by adding or subtracting the standard deviation estimate of percent to each sediment class for the average GSD resulting in a respectively finer or coarser GSD curve. The values for the average and standard deviation curves are summarized in Table 2.

Table 2. Average and standard deviation GSD curves for Ballona Creek sediment

	Particle Diameter (mm)	Average	Standard Deviation	1SD Coarser[1]	1SD Finer	2SD Coarser	2SD Finer
Clay	0.004	1%	1%	0%	2%	0.0%	3%
VFM	0.008	1%	2%	0%	3%	0.0%	5%
FM	0.016	2%	2%	0%	4%	0.0%	7%
MM	0.035	3%	4%	0%	7%	0.0%	11%
CM	0.0625	5%	6%	0%	11%	0.0%	16%
VFS	0.125	11%	10%	1%	21%	0.0%	30%
FS	0.25	22%	18%	4%	40%	0.0%	58%
MS	0.5	44%	27%	16%	71%	0.0%	99%
CS	1	67%	22%	45%	89%	22.5%	100%
VCS	2	86%	12%	74%	98%	61.6%	100%
VFG	4	95%	6%	89%	100%	82.3%	100%
FG	8	99%	3%	96%	100%	92.5%	100%
MG	16	100%	0%	100%	100%	100.0%	100%
CG	32	100%	0%	100%	100%	100.0%	100%
VCG	64	100%	0%	100%	100%	100.0%	100%

[1]Negative values were converted to zero and values exceeding 100% were fixed at 100% to create the standard deviation GSD curves

For sediment transport modeling, ESA PWA processed the sample data into the grain size classes utilized in HEC-RAS. The baseline bed sediment conditions were set up in the model using the GSD for each of the samples at the model cross section nearest the sample location. The model was set to interpolate the GSDs for cross-sections between sampling locations. The sediment sample collected at Lincoln was used for the GSD upstream of Lincoln Blvd to the concrete to earthen channel transition. Upstream of the transition, the channel is concrete lined and the bed was assumed to be immobile. To capture the model sensitivity to bed sediment grain size, model runs were also conducted with the average GSD shifted into the coarse range by 2 standard deviations and into the fine range by 2 standard deviations. A shift of two standard deviations above and below the mean captures the 95% and 5% confidence interval on the available grain size data and was therefore used to calculate upper and lower bound parameter values for GSD.

2.2 Tidal Boundary Condition

The tide level has a substantial influence on flow velocities and, consequently, sediment transport capacity in the project reach of the existing Ballona Creek channel. Higher tides create backwater conditions that slow incoming floodwaters and reduce the sediment transport capacity in the channel. Inversely, lower tidal conditions provide less of a barrier to incoming flow which leads to more efficient transport conditions. Three tidal conditions were evaluated in the sensitivity analysis (1) mean tide level (MTL, 2.6-ft NAVD) representing average downstream boundary conditions, and (2) mean higher high water (MHHW, 5.2-ft NAVD) representing a high downstream boundary condition, and (3) mean lower low water (MLLW, -0.2-ft NAVD) representing a low downstream boundary condition. The MTL boundary condition represents the baseline parameter.

2.3 Incoming Sediment Load

In addition to the sediment composition of the channel bed discussed above, the sediment load carried by creek flows will affect sediment transport conditions in the channel. Higher sediment loading may lead to increased deposition in cases where the transport capacity of the channel is less than the sediment delivered to the system. In a sediment-limited environment, flows may cause a net sediment export leading to degradational conditions. In evaluating the incoming sediment load, we evaluated the model sensitivity to both GSD of the incoming sediment load as well as the magnitude of the load.

2.3.1 Sediment Load GSD

The GSD of the sediment load is not necessarily the same as the GSD of the bed material discussed above. No GSD data have been measured for the sediment load. Therefore the “hydraulic design” module in HEC-RAS was used to estimate the GSD for the load for each flow on the rating curve. The module computes the size fraction based on a user defined baseline GSD and a theoretical transport function. As described in the previous sediment transport modeling conducted for the H&H Report (ESA PWA 2013a), the Yang transport function was selected as the most representative function for the Ballona Creek sediment transport regime. A coarser grain size distribution will correspond to a coarser load composition. Baseline load composition was estimated based on the USACE sample average bed material GSD described above. To evaluate model sensitivity, the average bed material GSD was shifted toward the coarser end of the sediment size spectrum by two standard deviations and to the finer end of the spectrum by two standard deviations to represent the 95% and 5% confidence intervals (upper and lower bound). Because GSD data were not available for the sediment load, the standard deviation of each sediment class was assumed to be equal to the standard deviation derived from the bed material data. The upper and lower bound bed material curves and corresponding sediment load compositions are presented in Figure 4.

2.3.2 Sediment Load Rating Curve

The sediment supply rating curve was also varied to test the model sensitivity to assumptions about the total amount of sediment delivered to the project reach by creek flows. As described in Submittal A, the baseline sediment rating curve was developed using 148 suspended sediment measurements from the LACDPW and SCCWRP with an added factor of 10% to represent bed load (ESA PWA 2013a). We estimated the 5% and 95% confidence intervals to identify a range of rating curves for use in sensitivity testing. The 5% and 95% confidence intervals (CI) were calculated using the following statistical relationship between a predicted value for a given value of the independent variable x_i.

$$CI = \underline{+}t(\alpha, df)S_{yx}\sqrt{1+\frac{1}{n}+\frac{(x_i-\overline{x})^2}{\sum_{i-1}^{n}(x_i-\overline{x})^2}}$$

Where $\overline{x}$ is the sample average, n is the number of samples collected, S_{yx} is the standard error in the estimate, and *t* is the critical t statistic, a statistical function of α, the confidence interval desired (in this case the 0.05, and 0.95 interval), and the degrees of freedom in the sample set *df*. Note that in this case the relationship between discharge and sediment is linearized by taking the logarithm of both, thus *x* refers to the logarithm of the independent variable (in this case, discharge). This equation for estimating confidence intervals around a linear regression fitted to the logarithms of the independent variable has been applied in various applications for evaluating sediment load sensitivity (Lee and Bhowmik, 1979).

The confidence intervals around the sediment rating curve are shown in Figure 5. Model runs were conducted using the sediment rating curve representing the 5% and 95% confidence intervals to evaluate model sensitivity to sediment loading.

3. SENSITIVITY ANALYSIS

To evaluate the sensitivity of model results to each of the four identified sediment transport parameters, each parameter was varied individually using a Q_5 discharge event (24,500 cfs at the river mouth) in the HEC-RAS existing conditions sediment transport model. The Q_5 flood event was selected as a representative event likely to generate sediment mobilization yet frequent enough to reflect expected trends of deposition and scour. Channel profiles resulting from the model simulations were compared to historic sedimentation trends estimated by comparing contemporary topography (PSOMAS 2012) with Ballona Creek as-built channel drawings (LA County FCD 1959).

3.1 Baseline Conditions

We first ran the model using baseline parameter values for bed material GSD, sediment load magnitude and sediment load composition combined with MTL. This model run is identical to the existing conditions run included in the H&H Report (ESA PWA 2013a), with the exception that the bed material, previously characterized using the USACE composite GSD, was replaced with the sample data collected by ESA PWA. Relative to the results presented in Submittal A, this adjustment was found to have negligible effects on the overall model results.

As described in the H&H Report (ESA PWA 2013a), the study area can be divided into three reaches between the concrete to earthen channel bottom transition and the jetties at the river mouth based on historic changes in the channel bathymetry as follows and as shown in Figure 6a:

1. An erosional reach immediately downstream of the terminus of the concrete channel lining (Station 16,500 to 14,350), which includes a scour hole at the transition from the concrete to earthen channel bottom;
2. An aggradational reach (Station 14,350 to 7,850); and
3. A slightly net aggradational reach exhibiting both erosion and aggradation at the downstream end of the study reach (Station 7,850 to 1,200). Though this reach is net aggradational, the thalweg has lowered slightly over time.

The historic trend in sediment transport conditions can be summarized as exhibiting erosion for approximately 2000 ft downstream of the concrete to soft bottom transition, aggradation for another 7000 ft downstream, and slight net aggradation for another 5,000 ft downstream to the jetties at the river mouth. A shoal has developed at the river mouth, which appears to be influenced by coastal/tidal sediment sources. Besides baseline conditions, the sensitivity results were evaluated relative to this understanding of historic sediment transport trends for the fluvial sediment transport.

The baseline parameter simulations predicted significant channel scour relative to the existing channel profile in two locations:

1. Station 14,000 to 16,000, immediately downstream of the concrete-lined channel.
2. Near station 10,000 at the Lincoln and Culver Blvd. bridges.

The existing channel profile represents the thalweg from the 2012 topography developed by PSOMAS. Comparison between the 1959 as-built and 2012 surveyed channel profiles (Figure 6b) indicates that significant channel erosion has not occurred between station 13,000 and 14,000 or at the bridges since the channel was constructed. This suggests that the sediment transport model baseline parameters may over-represent scour potential at these locations under existing conditions. Note that the profile comparison in Figure 6b shows a lower elevation thalweg in 2012 compared to the 1959 as-builts for the downstream reach (station 7,850 to 1,200), but Figure 6a shows some net accretion when accounting for apparent change in the channel cross-section (i.e., channel scour adjacent to the levees and deposition in the channel center). This indicates that the thalweg has lowered over time but that deposition in other areas has led to net accretion in this reach. The topographic changes shown in Figure 6a and the thalweg profiles shown in Figure 6b were both developed using the USACE as-built drawings and the 2012 topography collected by PSOMAS. Profiles in Figure 6b represent the lowest point in the channel which is not necessarily at the center of the channel.

3.2 Sensitivity Runs

Adjustments to the model parameters were grouped according to whether they would tend to simulate more depositional or more erosional conditions relative to the baseline parameters. The "upper bound" (i.e. those that would tend to simulate more depositional conditions) and “lower bound” (i.e. those that would tend to simulate more erosional conditions) parameter adjustments are listed below and summarized in Table 3. The upper bound parameter adjustments were:

1. Bed material GSD shifted 2 standard deviation towards coarser sediment, with baseline load and load composition conditions and a tidal boundary condition at MTL
2. Baseline sediment conditions with a tidal boundary condition at MHHW
3. Sediment load GSD 2 standard deviations above the baseline load GSD, with the baseline load and baseline bed material GSD conditions at MTL
4. Sediment rating curve loading conditions for the 95% confidence interval, with baseline GSD and load composition at MTL

Similarly the lower bound parameter adjustments were:

1. Bed material GSD shifted 2 standard deviation towards finer sediment, with baseline load and load composition conditions at MTL
2. Baseline sediment conditions with a tidal boundary condition at MLLW
3. Sediment load GSD 2 standard deviations below the baseline load GSD, with the baseline load and bed material GSD conditions at MTL
4. Sediment rating curve loading conditions for the 5% confidence interval, with baseline GSD and load composition at MTL

Table 3. Sediment transport model parameter groupings for sensitivity runs.

		Bed material GSD	Sediment load GSD	Sediment load	Tidal boundary condition	Short ID
Upper bound	1	+2 SD	baseline	baseline	MTL	Bed GSD + 2SD at MTL
	2	baseline	baseline	baseline	MHHW	Baseline parameters at MHHW
	3	baseline	+2 SD	baseline	MTL	Sediment load GSD + 2SD at MTL
	4	baseline	baseline	95% CI	MTL	95%CI Sediment load at MTL
Lower bound	1	-2 SD	baseline	baseline	MTL	Bed GSD - 2SD at MTL
	2	baseline	baseline	baseline	MLLW	Baseline parameters at MLLW
	3	baseline	-2 SD	baseline	MTL	Sediment load GSD - 2SD at MTL
	4	baseline	baseline	5% CI	MTL	5%CI Sediment load at MTL

Notes: 2 SD = two standard deviations, CI = confidence interval.

3.2.1 Upper Bound Sensitivity Runs

Channel profiles resulting from the upper bound sensitivity runs and the baseline run are shown in Figure 7. Historic trends for the three channel segments are shown at the top of the figure. The baseline run indicates scour potential at the profile break where the channel bottom transitions from concrete to earthen material. There is an existing scour hole at this transition (reflected in the existing channel profile from the 2012 PSOMAS topography data), but the baseline simulation over-predicted the extent of channel scour at this location. Adjusting the composition of the incoming sediment supply and raising the downstream boundary had little effect on this result; however, simulations using coarser bed material GSD and higher sediment load both resulted in less scour.

Results from all upper bound simulations indicate minor deposition from river station 4,000 to 8,000, a pattern which generally matches with the historic trend. None of the parameter adjustments have a significant impact on sediment transport conditions downstream of the Culver Boulevard bridge at station 10,000.

3.2.2 Lower Bound Sensitivity Runs

Channel profiles resulting from the lower bound sensitivity and baseline runs are shown in Figure 8. As noted above, the baseline run indicates scour potential at the profile break where the channel bottom transitions from concrete to earthen material. As expected, each of the lower bound sensitivity runs shows similar or higher scour potential extending from the channel bottom transition downstream to approximately station 13,000 ft. With MLLW conditions, this scour persists to approximately station 8000 ft. All of the lower bound runs show slight aggradation from river station 4000 ft to 8000 ft and generally over-predict scour potential relative to the historic changes to the channel profile.

3.3 Results

Figure 7 and Figure 8 show the average bed change for each of the model runs. As shown for the upper bound runs, increasing the sediment load has the largest impact on scour and deposition rates, followed by the coarser bed material. The model results indicate relatively little sensitivity to the coarser bed material and coarser sediment load. For the lower bound runs, lowering the downstream tidal boundary had the greatest impact on average bed change, largely as a result of the increased scour at the river mouth. The degree of scour shown at the concrete to soft bottom transition point is likely exaggerated in these runs as the model does not account for bed armoring and sediment consolidation which would limit scour depth at this location. On average, the bed change is within 0.5 feet for the lower bound sediment sensitivity runs. The average bed change as well as the bed change for each run is summarized in Table 4.

Table 4. Modeled bed change for sediment transport sensitivity analysis runs

Run		Bed Change for Q5 (ft)			
		Upper Reach (historically erosive)	Middle Reach (historically aggradational)	Lower Reach (historically net aggradational)	Average
Baseline parameters at MTL		-0.53	-0.42	-0.12	-0.36
Upper bound sediment parameter sensitivity runs	Sediment load GSD + 2SD at MTL	-0.57	-0.36	-0.05	-0.33
	Baseline parameters at MHHW	-0.51	-0.23	0.1	-0.21
	Bed GSD + 2SD at MTL	-0.19	-0.13	0.08	-0.08
	95%CI Sediment load at MTL	-0.19	-0.02	0.09	-0.04
Lower bound sediment parameter sensitivity runs	5%CI Sediment load at MTL	-0.60	-0.46	-0.13	-0.40
	Sediment load GSD - 2SD at MTL	-0.68	-0.48	-0.04	-0.40
	Bed GSD - 2SD at MTL	-1.15	-0.47	0.15	-0.49
	Baseline parameters at MLLW	-0.55	-0.68	-0.86	-0.70

The modeled bed change for each of the sediment transport sensitivity runs relative to the existing profile is shown by reach in Table 4. All runs show net scour in the upper reach and in the middle reach under a Q5 event. In the middle reach, a coarser grain size distribution and higher sediment load have the largest impact on reducing the predicted scour and bringing the transport behavior more in line with observed conditions. For the lower reach, model results vary within a relatively minor bed change of +/- 0.2-feet, with the exception of the lower boundary condition which results in a large potential for scour at the mouth of the channel.

All model runs over-predict scour potential at the profile inflection point where the channel bottom transitions from concrete to earthen material (upper reach) and at the existing bridge crossings (middle reach), relative to the observed channel profile. The over-prediction of scour may indicate that sediment load is higher than the estimated baseline rating curve, bed material GSD is coarser than the sample average, and/or sub-surface conditions limit the extent of scour. The ESA PWA bed samples were collected from a kayak with a petite Ponar grab sampler, which has the potential to lose material during sampling. Field observation of the bed material prior to laboratory testing suggested a higher content of coarse grains than was present in the ESA PWA samples. Therefore, we adjusted the bed material GSD to evaluate whether a coarser GSD would bring the model results in line with the current channel profile.

Results of model runs shifting the baseline bed material GSD by 2 standard deviations and raising sediment loading rates to the 95% confidence interval both produced deposition through the historically erosive reach downstream of the channel bottom transition. Therefore, an additional run with a 1 standard deviation shift on the GSD was performed. The results of this run show moderate scour downstream of the channel bottom transition attenuating at approximately station 13500. This result is more similar to the observed scour pattern than any of the other runs (Figure 9). This analysis indicates that either the

GSD at this location is coarser than the sample that was analyzed, or that factors not accounted for in the model such as an armor layer of coarse sediment, or rubble or riprap below the surface, may limit the depth of scour at this location. For future analyses, we will investigate options for evaluating vertical variation of the in-situ material to further refine the sediment transport model.

4. EFFECT ON WATER SURFACE ELEVATION

The impact of model parameter adjustments on the water surface elevations will inform the risk and uncertainty analysis which will be conducted in the next phase of this project. Two additional model runs were conducted using combinations of these parameter changes to get an initial sense of water level response to different parameter combinations. As identified in the Corps R&U guidance, sensitivity analysis can either be done for each parameter individually or for "reasonable likely combinations of upper and lower bound estimates of model parameter values" (Section 5-7, USACE, 1996). The first model run contains an upper bound combination of parameters which will tend to result in increased depositional conditions, and the second model run contains a lower bound combination of parameters which will all result in increased erosional conditions.

1. Bed GSD + 2SD, sediment load at the 95% CI, sediment load GSD + 2SD, tide level at MHHW.
2. Bed GSD - 2SD, sediment load at the 5% CI, sediment load GSD - 2SD, tide level at MLLW.

These two runs are intended to capture the range of reasonable likely combinations in sediment transport parameters. The resultant water surfaces for the upper and lower bound runs are shown for a 5-year flood event in Figure 10. These results are compared to a run with GSD + 1 standard deviation which was found to more closely reflect historic sediment dynamics as described in the previous section.

4.1 Results

The model results indicate a water surface change averaged over the downstream limit of the model and Centinella Ave (station 1,100 to 17,200) of -0.5 feet for the lower-bound run and +0.6 feet for the upper-bound run relative to the baseline parameter run. When these runs were repeated with a consistent tidal boundary of MTL, there was no difference in water surface results relative to baseline conditions (Figure 10). This indicates that, over a reasonable range of parameter combinations, the water surface profile is not sensitive to the selection of bed GSD, sediment load, and sediment load GSD parameters. The range of deposition and scour incurred under the parameter combinations does not affect the water surface profiles. The water surface is, however, inherently a function of the downstream boundary tide level and thus is sensitive to this parameter. Water surface sensitivity to the tide level, including the effects of sea level rise, will be explored further in the R&U analysis for Submittal B.

5. COMPARISON OF PROJECT AND EXISTING CONDITIONS

Both existing and project conditions runs were conducted for the effective discharge (Q_{eff}) estimated to be 4,650 cfs (ESA PWA H&H Report, Appendix 3), Q_5 (24,500 cfs), and Q_{100} (44,270 cfs), at MTL. Additionally, a model run was conducted for the design event (46,000 cfs discharging against a tailwater of 7.6 ft NAVD). The set of model runs and sediment transport parameters used for each run are summarized in Table 5.

Table 5. Existing and project conditions sediment transport model runs and parameters

	Run	Discharge		Tidal boundary condition		Bed material GSD	Sediment load GSD	Sediment load
		Event	Discharge (cfs)	Tide level	El (ft NAVD)			
Existing conditions	1	Q_{eff}	4,500	MTL	2.6	GSD + 1SD	Baseline	Baseline
	2	Q_5	24,500	MTL	2.6			
	3	Design flow	46,000	Design water level	7.6			
	4	Q_{100}	44,270	MLLW	-0.2			
	5			MTL	2.6			
	6			MHHW	5.2			
	7			MHHW+SLR	10.1			
Project conditions	8	Q_{eff}	4,500	MTL	2.6	GSD + 1SD	Baseline	Baseline
	9	Q_5	24,500	MTL	2.6			
	10	Design flow	46,000	Design water level	7.6			
	11	Q_{100}	44,270	MLLW	-0.2			
	12			MTL	2.6			
	13			MHHW	5.2			
	14			MHHW+SLR	10.1			

For each of these runs, the sediment load and load GSD were kept at baseline conditions and the bed material GSD was raised by 1SD to better reflect observed sediment dynamics. The tide level was set at MTL for Q_{eff}, and Q_5, and at the design water level of 7.6ft for the design flow. Additionally, Q_{100} runs were conducted with tide levels at MLLW, MTL, MHHW, and MHHW with sea level rise (SLR).

The bed change and average cross-section shear stress for existing and project conditions for Q_{eff}, Q_5, and the design flow are shown in Figure 11. This figure indicates that shear stresses and sediment transport under project conditions are similar to existing conditions upstream of around station 12,000 (approximately 2,000 feet upstream of the entrance to the project site), with some regions of increased shear stress and scour relative to existing conditions for larger flood events. Downstream of station 12,000 model results indicate that changes in the channel shape at the entrance to and exit from the project site under proposed conditions lead to local flow accelerations, increased shear stresses, and increased potential for local erosion at expansion and contraction points. This result will be used to inform the next phase of design development, which will incorporate measures to address local erosion potential.

At the entrance to the project site, the flow area expansion leads to a local acceleration increasing shear stresses from around station 10,000 to 11,000. The flow acceleration occurs due to the steepening of the water surface at the channel expansion transition. Downstream of this transition, velocities are reduced due to the expanded flow area. Under existing conditions, model results for this channel reach reflected energy losses as a result of flow contact with the Culver and Lincoln bridge piers. With project conditions, the bridge losses and the acceleration due to changing channel shape may increase erosion potential under high flow conditions. Under these conditions, model results show some of the material scoured from the bridge vicinity being deposited just downstream; however the deposition is not extensive enough to impact channel capacity. Further analysis will be conducted for final project design to evaluate the potential for scour- and deposition-related impacts to bridge piers and the adjacent levees.

Model results for the downstream reach of the project near the point of reconvergence between the project area and existing channel reflect another occurrence of local acceleration leading to increased scour potential under high flows. Sediment transport model results for Q_{eff} suggest this reach is generally stable (i.e. minimal net change in bed elevation) to slightly aggradational, suggesting that under average conditions sediment deposition through this channel segment would likely balance out some of the scour that may be incurred under larger flood events. This result will be evaluated further during the next phase of design development.

Additional runs were conducted to evaluate the channel scour and deposition behavior under the 100-year discharge event (Q100) for tailwater conditions at MLLW, MTL, MHHW, and MHHW+SLR. These runs, the results of which are shown in Figure 12, exhibit similar sediment transport trends as the design event. Significant scour potential present under existing conditions continues for project conditions between river station 14,350 and 16,500 where the channel bed transitions from concrete-lined to earthen conditions. The historically aggradational reach from station 7,850 to 14,350 shows some scour and deposition of scoured material, as would be expected under a large flood event, but shows less scour than the upstream reach. The reach between station 1,200 and 7,850 shows net scour under project conditions, primarily as a result of increased shear stresses where flows reconverge with the existing confined channel. Some deposition occurs near the entrance to the project site at approximately station 10,000 ranging from 0.2 ft under MLLW, to 0.9 ft under MHHW+SLR. The potential impact of this deposition on water levels will be evaluated for the final design and R&U analysis in the next phase.

A quasi-two-dimensional depiction of shear stress and velocity model results for the 100-year discharge with project conditions is presented in Figure 13. This graphic was generated using the GeoRAS toolbar in ArcGIS which apportions overbank velocities and shear stresses over the depth along a coincident 2D surface. Model results reflect similar velocity and shear stress patterns for the other flow events discussed above. High velocity regions are found at the upstream and downstream boundaries of the project site as well as near the peninsula between Area A and Area B where flow reconvergence causes local acceleration and increased shear stress. Ineffective flow areas were used in HEC-RAS to account for areas where water is stored but not contributing to conveyance. Preliminary results from 2D modeling described in the Submittal A report (ESA PWA, 2013) indicate that the ineffective flow area in Area B may be larger than what is currently reflected in the HEC-RAS model. The ineffective flow area extents will be revised for future model iterations to more closely reflect the velocity conditions suggested by the 2D modeling results.

As described in this report, the project consists of significantly expanding the channel and overbank conveyance area downstream of Culver Boulevard and then reconverging the flow back into the flood control channel approximately 1000-feet upstream of Pacific Avenue. This increase in conveyance area leads to significant reductions in flow velocities; however, as described in this section, model results indicate local increases in channel shear and bed change under project conditions. The locations of increased shear are a function of large changes in conveyance area over short distances required to expand the channel through the project reach and contract the channel back into the flood control channel before it reaches the Pacific Ocean. Figure 14 contains plots of water surface elevation, flow velocity, flow area, friction slope[1], shear stress, and bed change for the 100-year discharge. Model results indicate two primary locations where increased shear stress may lead to bed erosion under project conditions, as shown in Figure 14: (1) just upstream of the project area between station 10,000 and station 11,000, and (2) near the channel contraction from station 5,000 to 7,200. The increase in conveyance area at the upstream end of the project lowers and steepens the water surface profile just upstream of the project area. This steeper water surface profile increases shear stress which increases the potential for scour at this location. Between stations 5,000 and 7,000, the flow area is reduced from approximately 18,000 ft^2 to 5,600 ft^2 (30%) over a 1,200-foot reach. Though the velocity is lower through this constriction than under existing conditions, the flow area is larger and the shear stress is equivalent. Additionally, over the full hydrograph, shear stresses in this reach are generally higher under project conditions as shown in Figure 15. Model results indicate that the conditions in this reach have the potential to cause local scour under a large flood event. The design for the channel (cross-section) and scour protection will be refined based on these results.

6. SUMMARY AND CONCLUSIONS

To refine the representative sediment transport model simulations conducted for Submittal A, ESA PWA conducted sensitivity analyses on several sediment transport parameters. The purpose of the sensitivity testing was to identify the relative influence of each parameter and to adjust the parameters to which the model is most sensitive in order to improve model agreement with the historic scour and deposition as reflected in the channel profile. Results of the sensitivity analysis will also inform the Risk and Uncertainty (R&U) analysis required for Submittal B of the Corps 408 permit application. The key findings of this analysis are summarized as follows:

- As discussed in the H&H Report (ESA PWA 2013a), sediment supply to the study area is low relative to the sediment transport capacity and the site can be characterized as generally sediment supply-limited. Sediment transport model results support this conclusion, with all sensitivity runs

[1] Friction slope, also known as the energy grade line, is the energy (head) loss per unit length which is a measure of the rate of energy dissipated by flowing water. Shear stress is directly proportional to the friction slope thus a higher slope, or higher rate of head loss, corresponds to higher shear stress.

generally showing more potential for scour than for sediment deposition under existing conditions.

- Since the channel was constructed, the profile has been relatively stable, although some scour is observed immediately downstream of the terminus of the concrete channel lining.
- Baseline conditions model results over-predicted scour relative to the observed channel profile at the concrete to earthen channel bottom transition as well as in the vicinity of the existing bridges. This result suggests that either the GSD of bed sediments is higher than what was sampled, or that other factors such as channel armoring and/or buried coarse sediments have historically mitigated scour potential during flood events.
- Model results indicate that over a reasonable range of combinations, the water surface profile is not sensitive to bed material GSD, sediment load GSD, or total sediment load parameters. Of the four parameters analyzed, the water surface is only sensitive to the tidal boundary condition. This result will be explored further as part of the R&U analysis.
- Initial project conditions model results show that at the channel bottom transition from concrete to earthen the change in scour relative to existing conditions is within 0.1 ft for a 100-year event suggesting minimal changes in the historically scoured reach.
- Project conditions model results demonstrate local increases in shear and erosion may be caused by channel expansion and contraction at the upstream and downstream ends of the project reach. This result will be used to inform the next phase of project design development.

7. REFERENCES

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ESA PWA, 2013b. Ballona Wetlands Restoration Preliminary Design Report. May 8 Draft. Prepared for the California State Coastal Conservancy.

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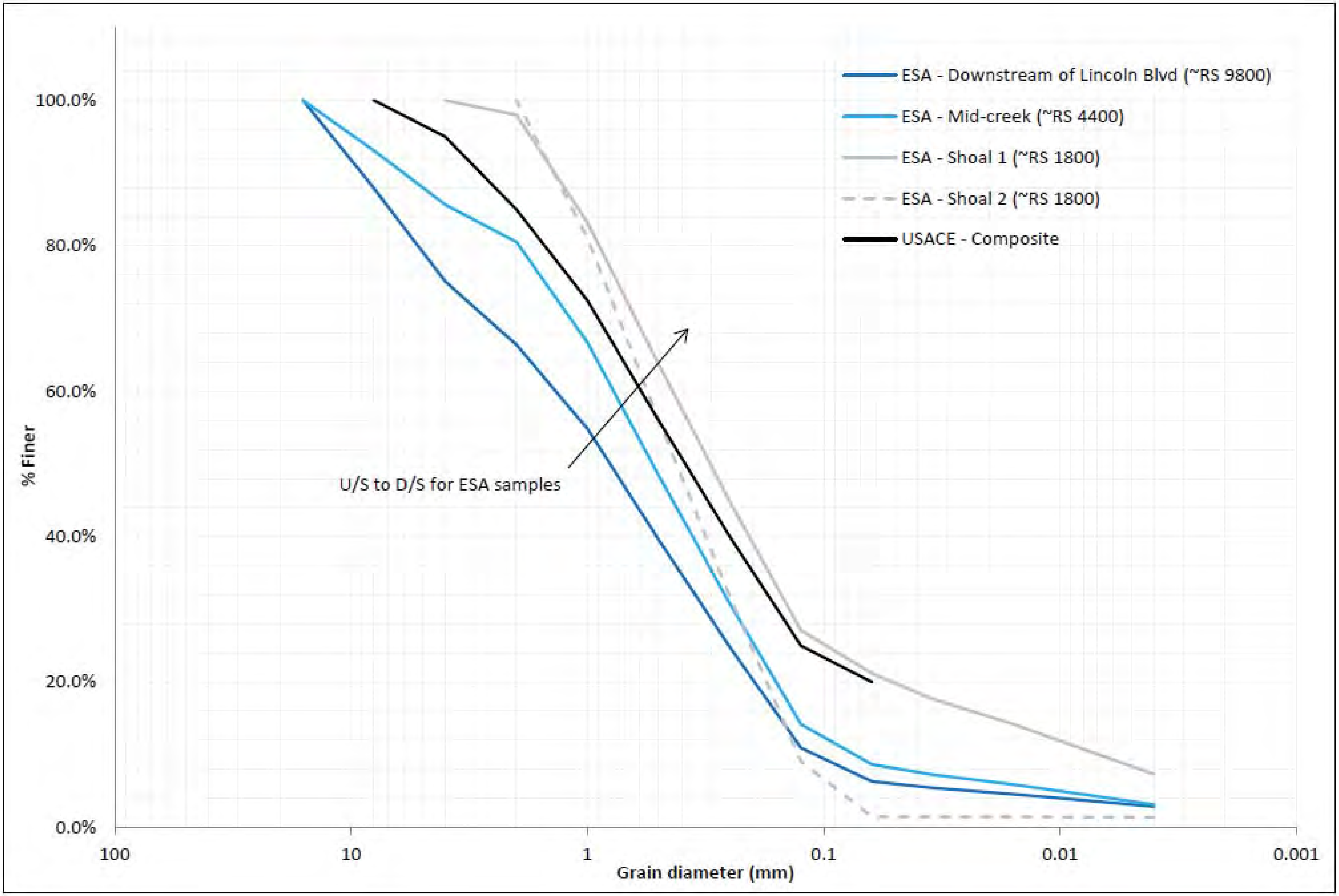
LIST OF FIGURES

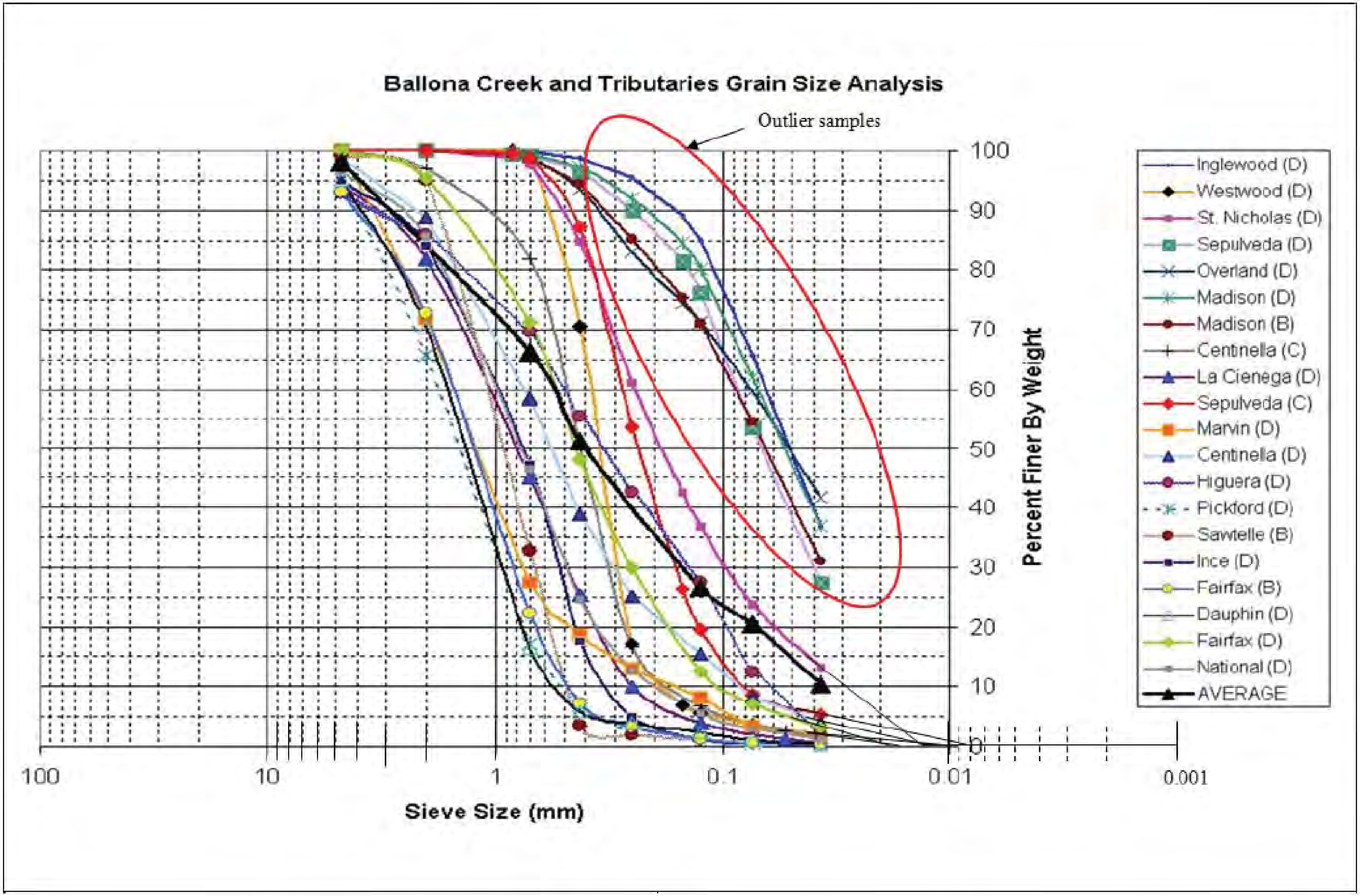


SOURCE: USACE (2003), Wallace Labs (2013)

Ballona Creek Wetlands . D120367

Figure 1

Ballona Creek Grain Size Distribution Curves

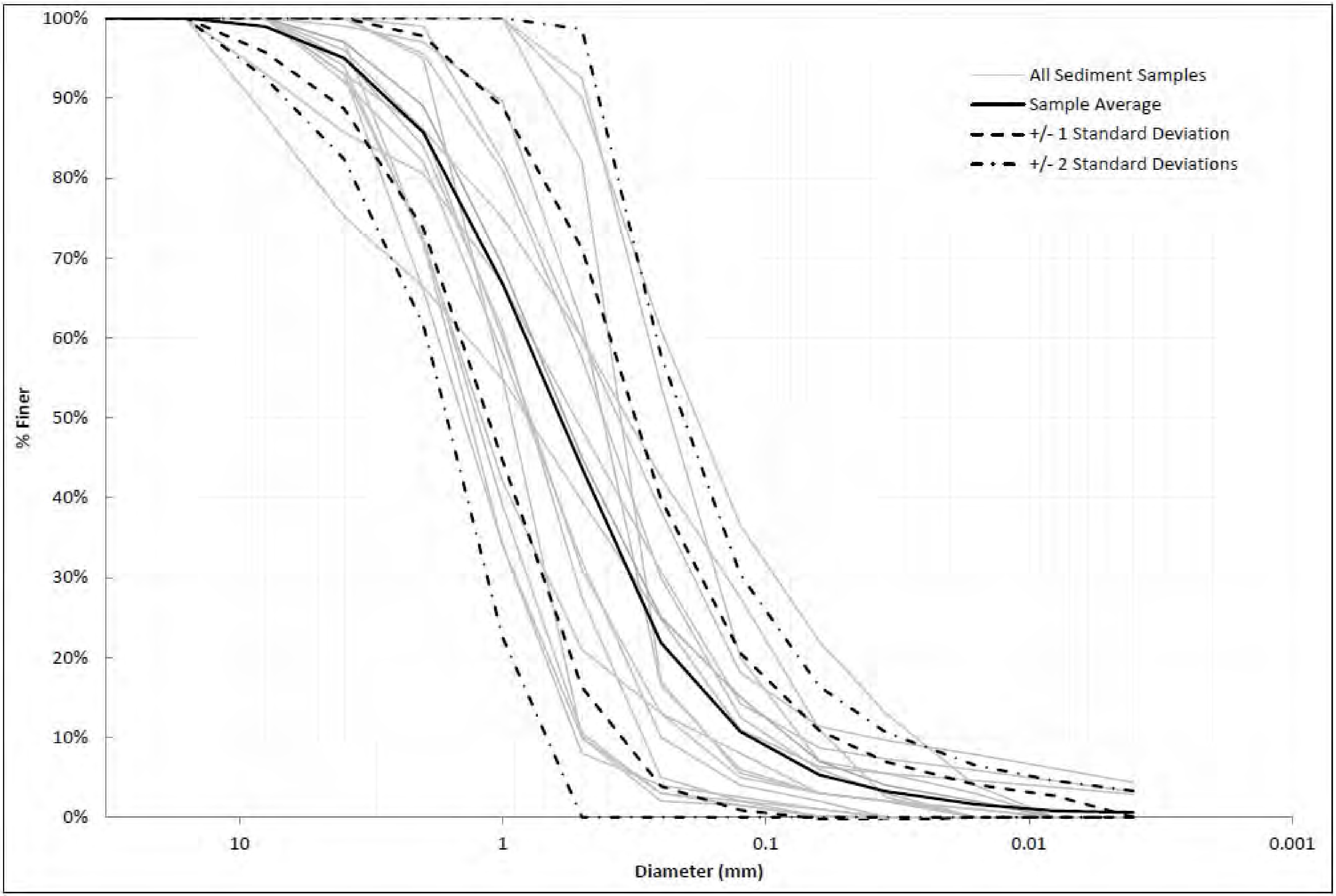


SOURCE: USACE 2003

Ballona Wetlands . 120367.00

Figure 2

Corps Grain Size Distribution Curves for Samples on Ballona Creek



SOURCE: USACE sediment samples F4 documentation (2003), ESA sediment samples (2012-2013)

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Figure 3
Grain Size Distribution Sensitivity

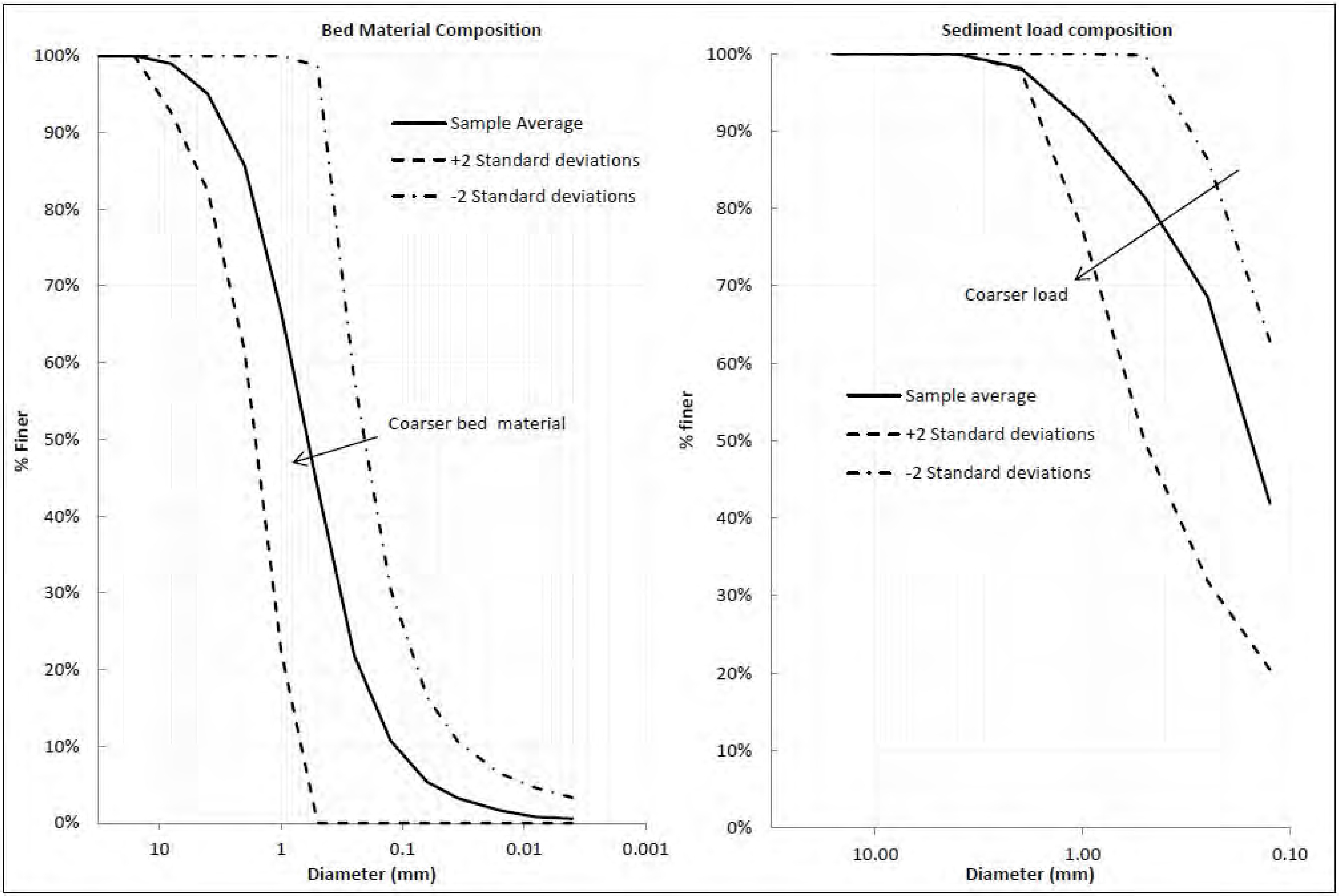

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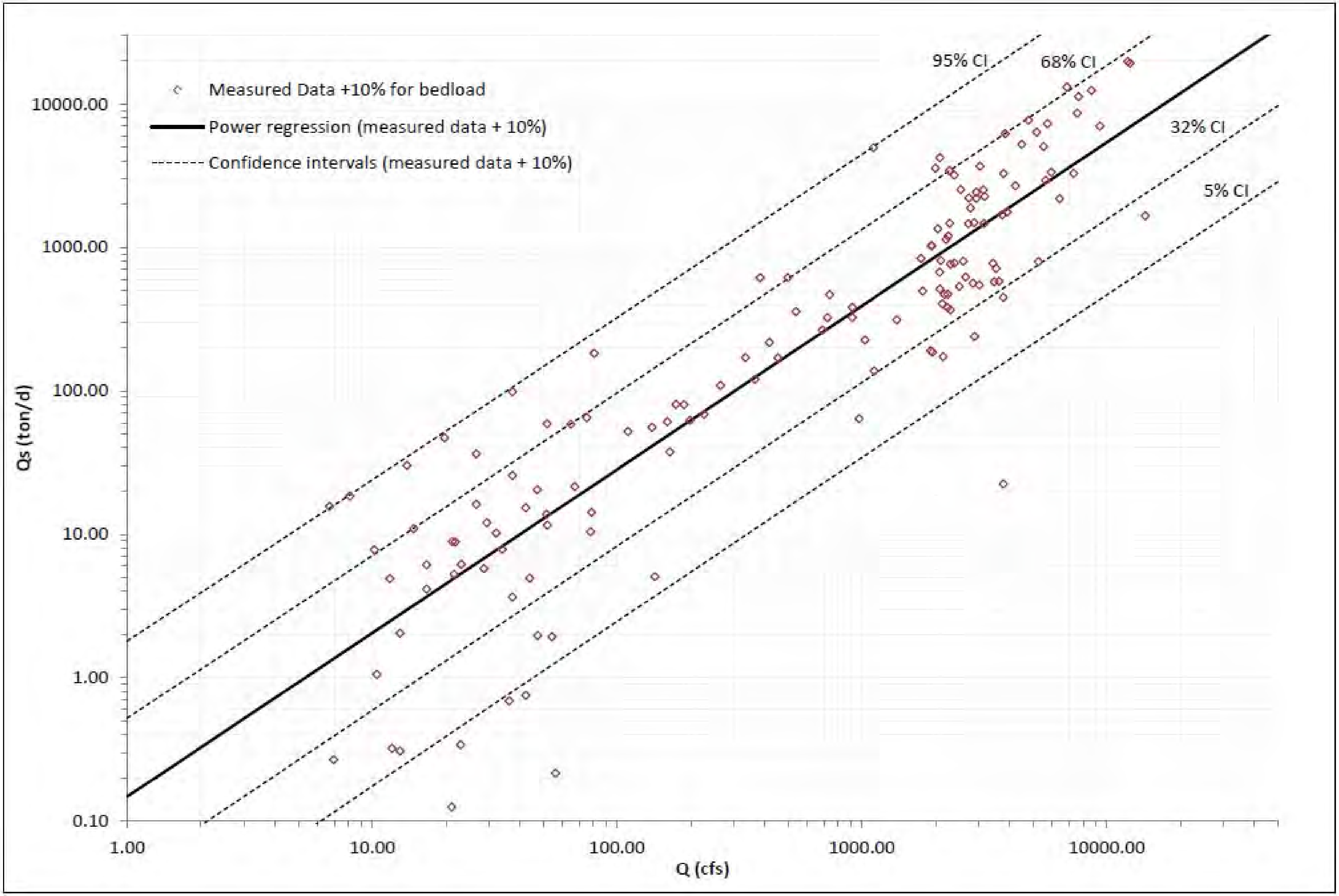
Figure 4

Sediment Load Composition Sensitivity



SOURCE: LACDPW, SCCWRP

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Figure 5

Sediment Rating Curve Sensitivity

J:\1793_Ballona\Accretion.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community; USACE (2003), PSOMAS (2012)
Notes: Figure shows net change from 1961 to 2012.

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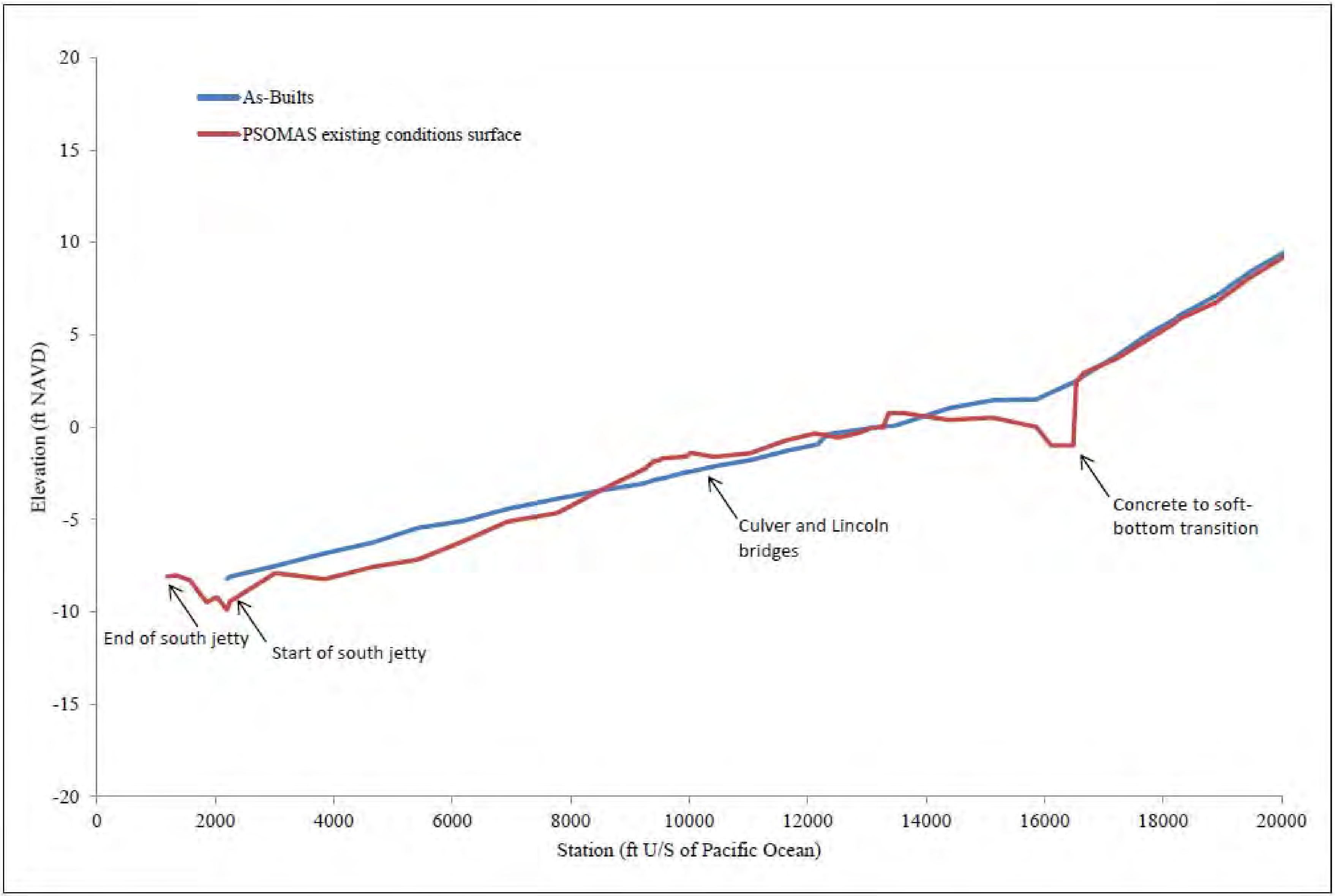
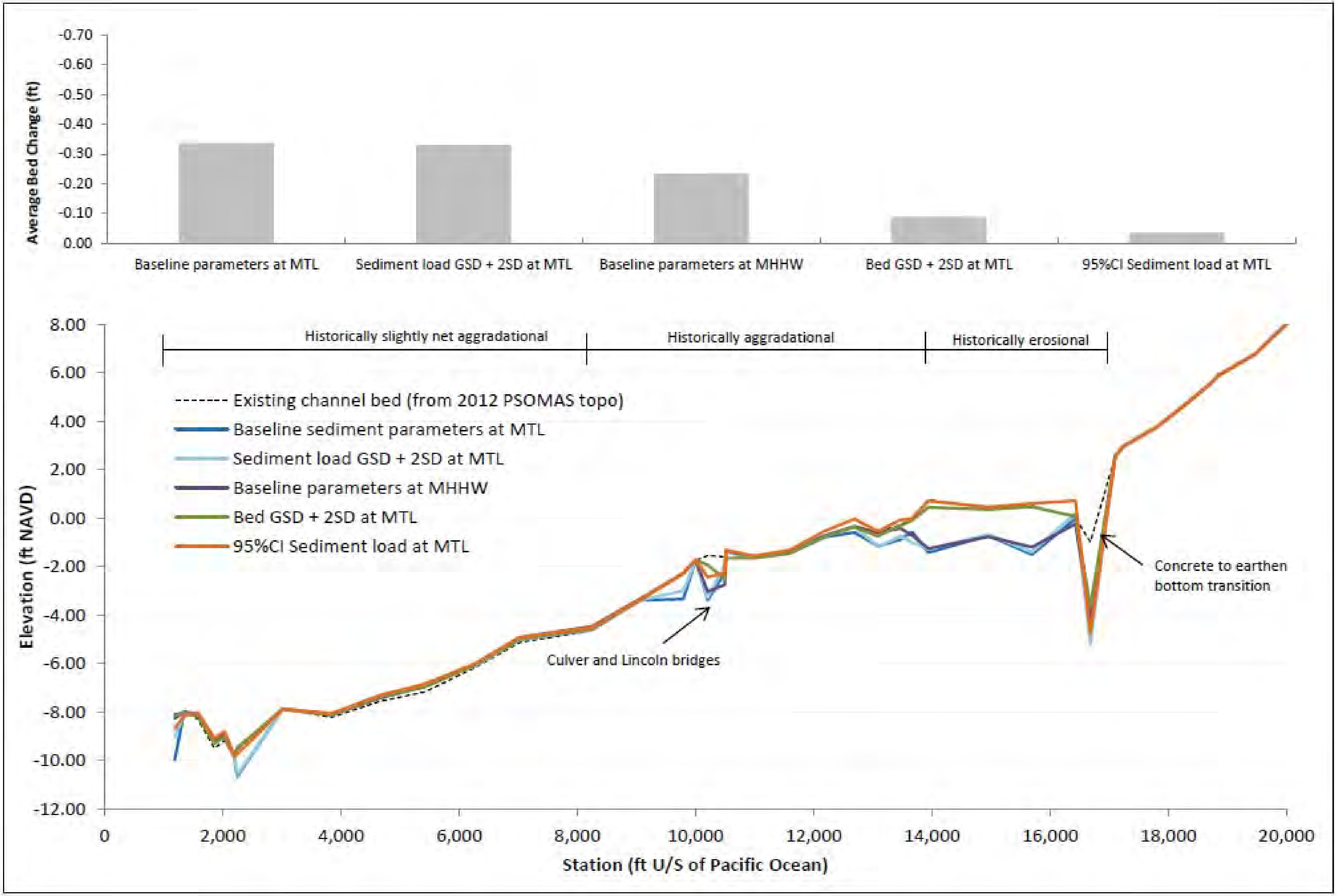
Figure 6a
Ballona Creek Accretion between 1961 and 2012



SOURCE: USACE (2003); PSOMAS (2012)
NOTE: Figure shows net change from 1961 to 2012

Ballona Wetlands. D2110367
Figure 6b
Thalweg Profiles
1961 and 2012



NOTE: Results represent model runs conducted using Yang transport function for a Q5 event. Historic patterns (net aggradation and erosion between 1961 and 2012 from Figure 6a) are shown above for reference.

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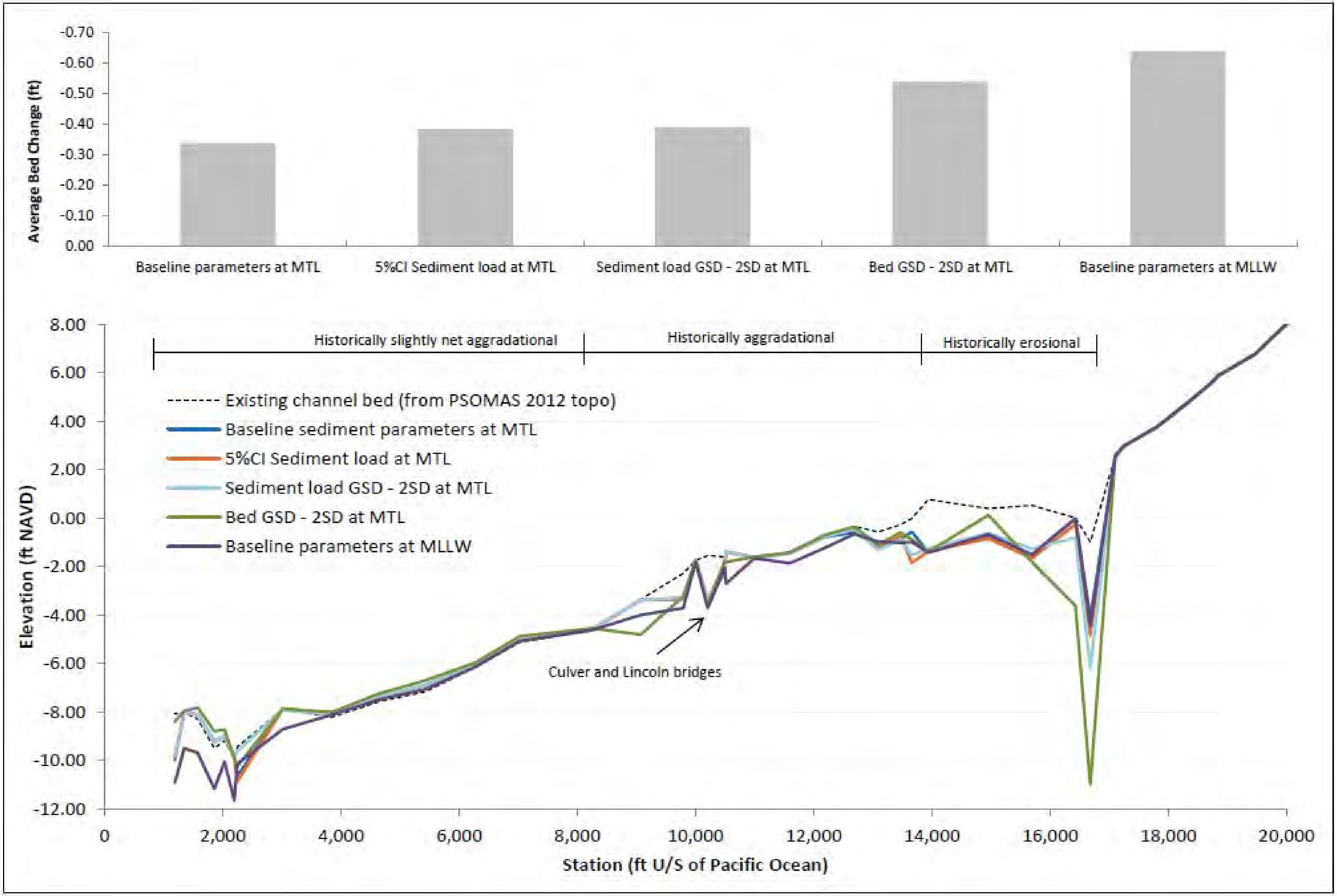
Figure 7

Q5 Channel Profiles for Upper Bound Sediment Transport Parameter Sensitivity Runs



NOTE: Results represent model runs conducted using Yang transport function for a Q5 event. Historic patterns (net aggradation and erosion between 1961 and 2012 from Figure 6a) are shown above for reference.

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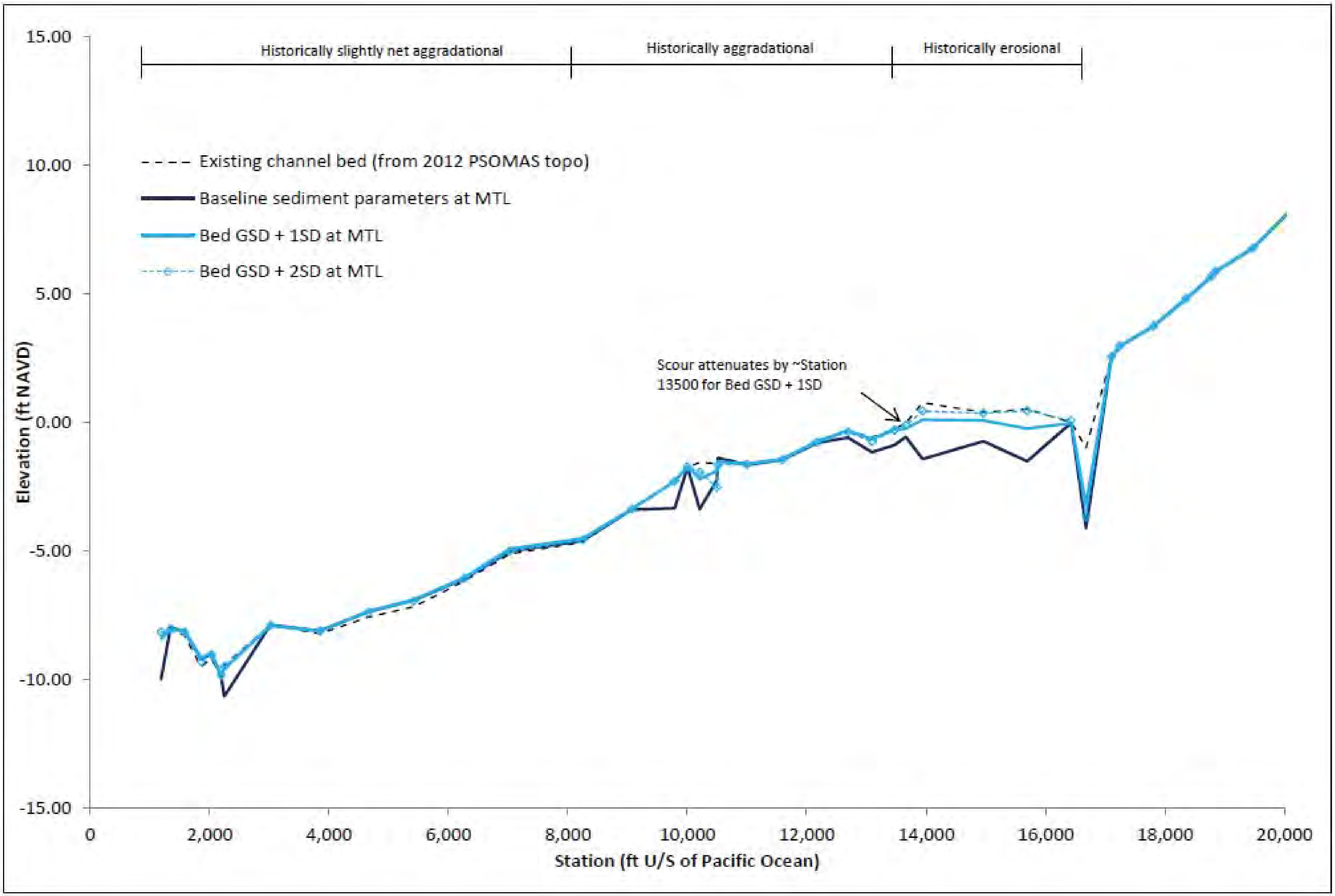
Figure 8

Q5 Channel Profiles for Lower Bound Sediment Transport Parameter Sensitivity Runs



NOTE: Results represent model runs conducted using Yang transport function for a Q5 event. Historic patterns (net aggradation and erosion between 1961 and 2012 from Figure 6a) are shown above for reference.

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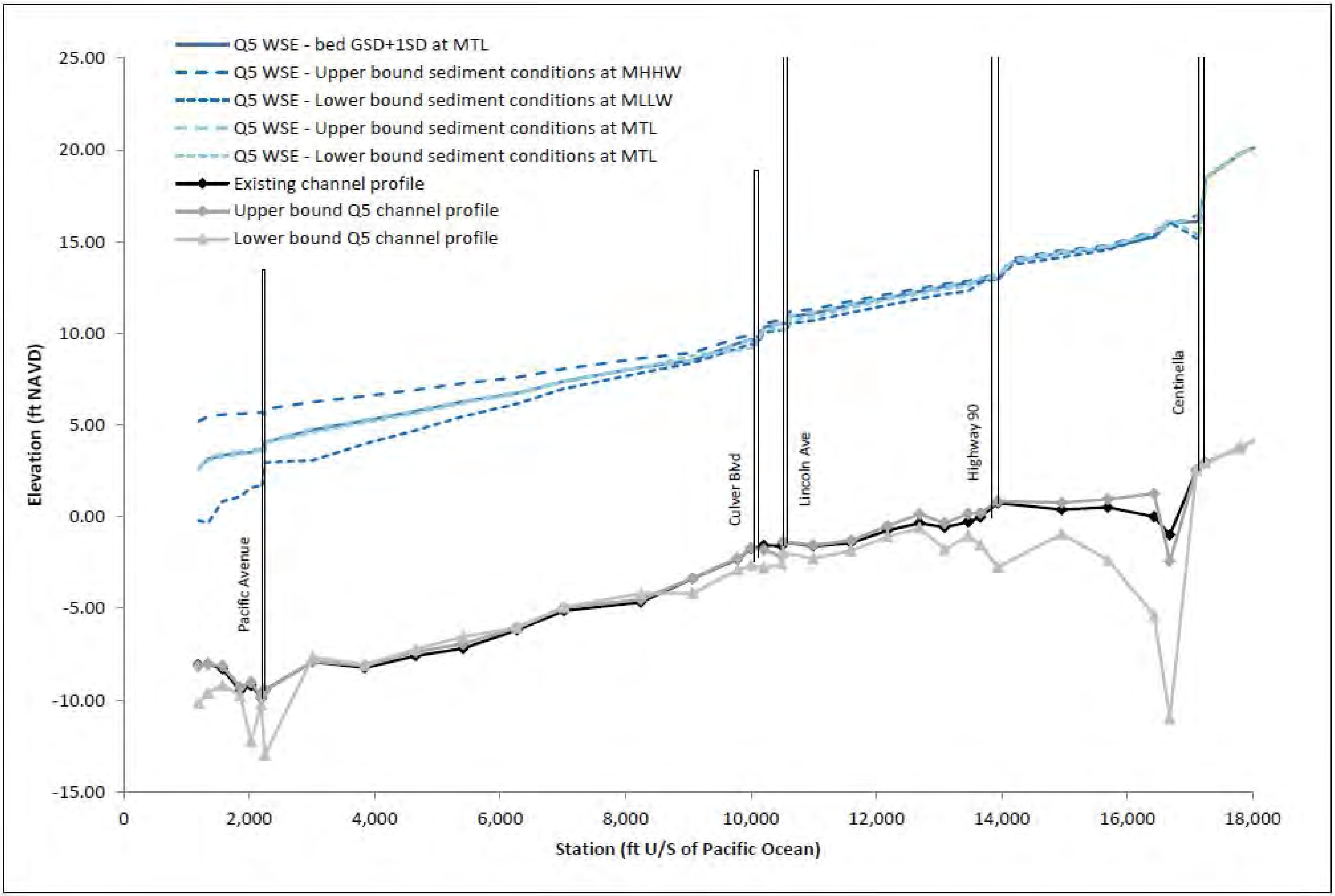
Figure 9

Q5 Channel Profiles with Initial and Modified Baseline Sediment Parameters



NOTE: Results represent model runs conducted using Yang transport function for a Q5 event.

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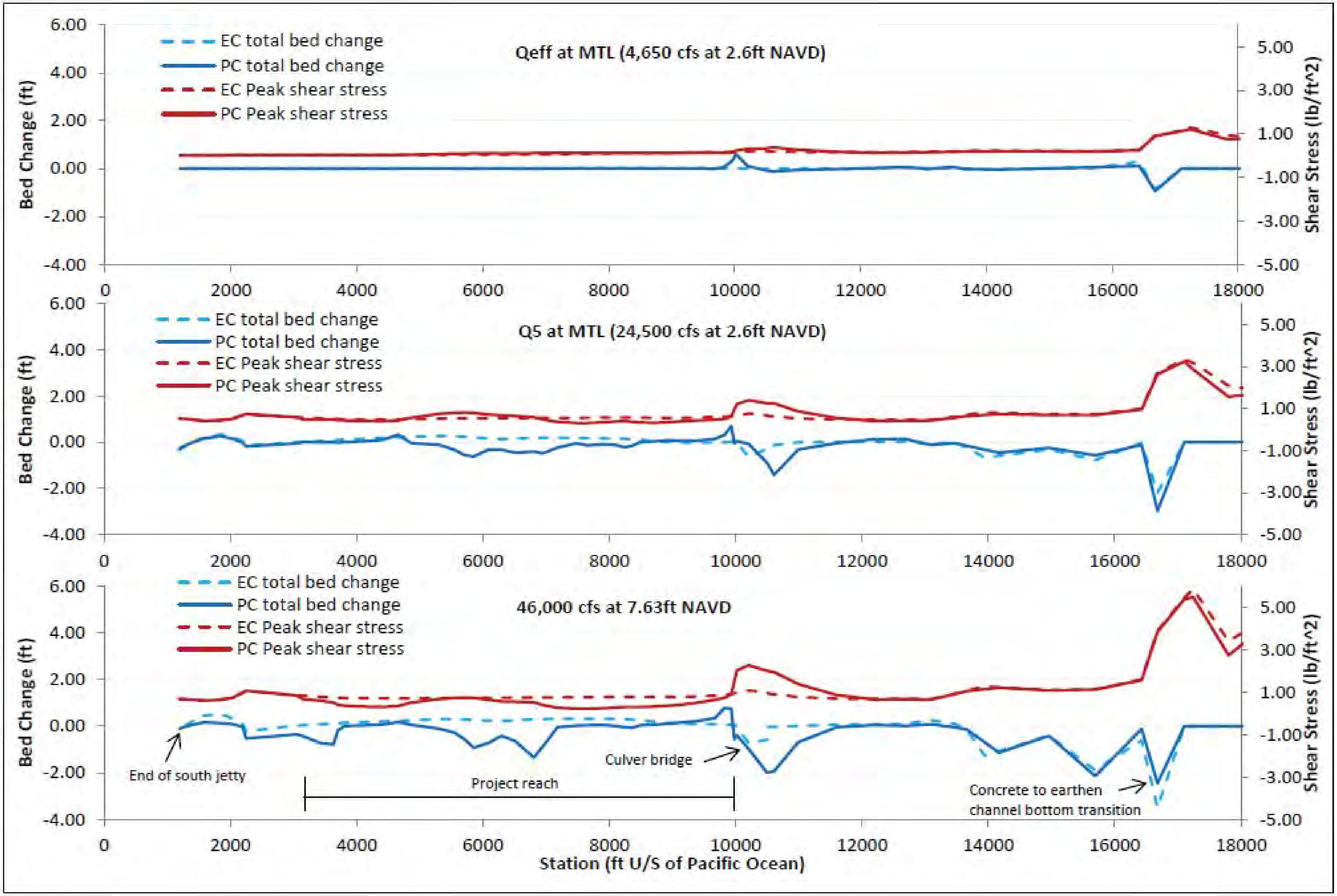
Figure 10

Existing Conditions Q5 Water Surface Profiles with Upper and Lower Bound Sediment Parameter Combinations



NOTE: Bed change results for existing and project conditions are the same upstream of station 16,500

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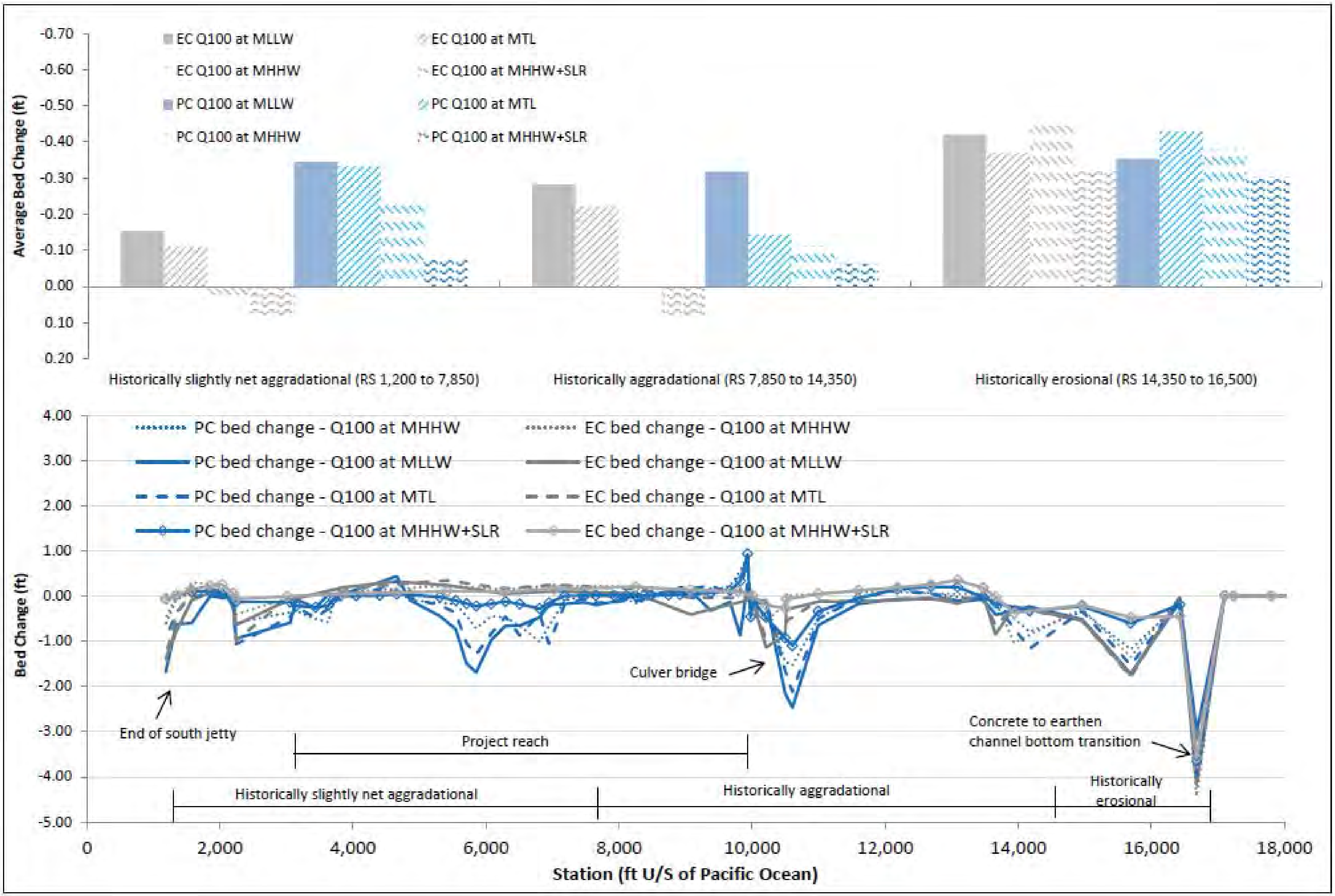
Figure 11

Existing and project conditions sediment transport results



NOTE: Bed change results for existing and project conditions are the same upstream of station 16,500. Simulation results are for a Q100 event. Historic patterns (net aggradation and erosion between 1961 and 2012 from Figure 6a) are shown above for reference.

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Figure 12

Bed change for Q100 event

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User

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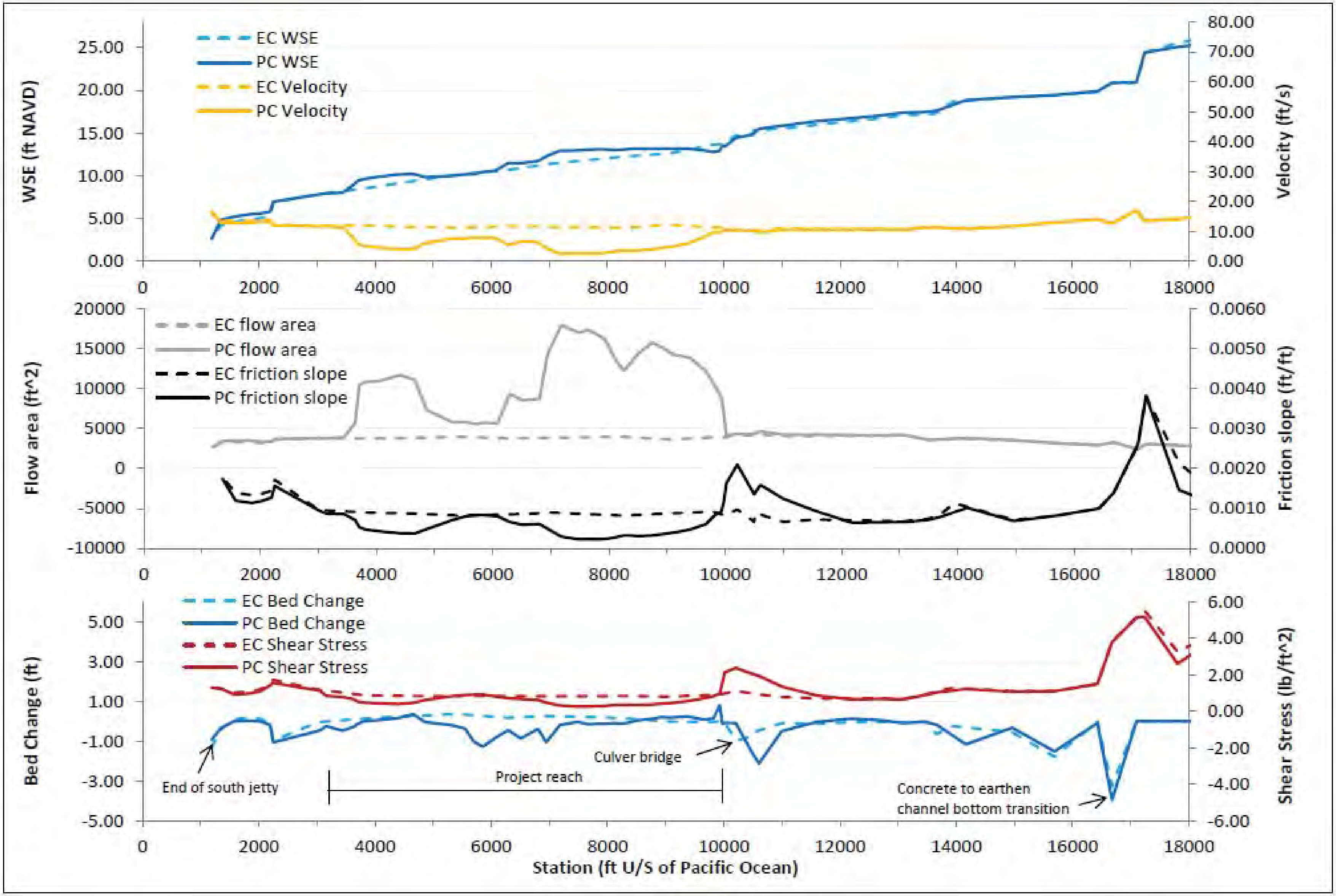
Figure 13
Q100 Shear Stress and Velocity Map



NOTE: Results for existing and project conditions are the same upstream of station 16,500

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Figure 14

Q100 Existing and project conditions model results

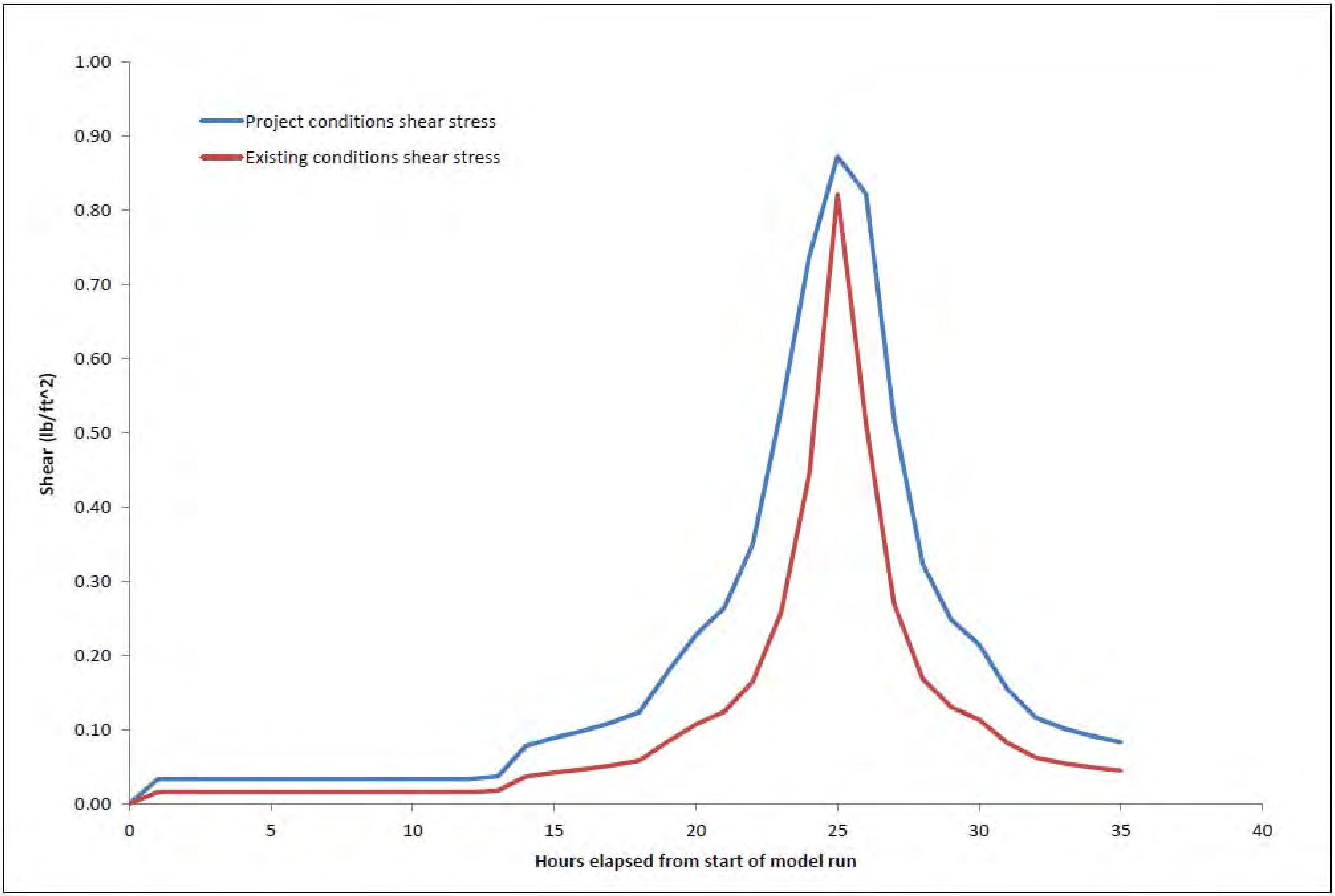

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Figure 15

Q100 Existing and Project Shear Stress Through Time at Station 5400

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APPENDIX F11
Monitoring and Adaptive Management Plan

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Introduction

The purpose of this Hydrodynamics and Water and Sediment Quality Monitoring and Adaptive Management Plan (H&WSQ-MAMP) is to provide a framework for the Ballona Wetlands Restoration Project (Project) for monitoring, assessing, and managing potential hydrodynamic and water and sediment quality impacts to biological resources and human health from and to the Project after construction. These potential impacts have been identified and discussed in the Sediment Dynamics and Budget Report (ESA 2015a), the Water Quality Technical Report (ESA 2015b), and the Environmental Impact Report/Statement (EIRS/S; ESA 2015c). This H&WSQ-MAMP will confirm the effectiveness of project features for potential post-construction impacts to hydrodynamics and water and sediment quality that have been identified in these documents. These potential impacts have been identified as less than significant in the EIR/S, due to planned Project features and regulatory driven actions in the Ballona Creek watershed and tidal prism as well as the mitigation measures. However, due to a number of unknown factors regarding the overall effectiveness of these features, post-construction monitoring and assessment will be needed to confirm that impacts remain less than significant. In the case where impacts are indicated based on comparisons to Project or regulatory thresholds, adaptive management measures will be needed. This framework provides a summary of the potential post-construction impacts, the Project features that are being taken to make them less than significant, and the monitoring program that will be the basis for continued assessment of these features. Adaptive management measures are also presented that would be taken if impacts are identified based on multiple lines of evidence. This framework meets the requirements of the CEQA process and provides the basis to develop a more detailed final MAMP.

Summary of Potential Impacts, Planned Mitigation Measures, and Effectiveness Monitoring

Potential hydrodynamic impacts may originate from the Project due to increased deposition or erosion caused by the reconnection of Ballona Creek to the floodplain. Water and sediment quality impacts may originate from the Project due to re-exposure of historical dredge sediments or marsh material from site grading that contain legacy constituents above thresholds. Legacy or recent constituents in sediment within the wetland channels can also be mobilized from channel scouring due to channel reconfiguration. Impacts to sediment and water quality within the Project may result from constituent loading from stormwater runoff from the watershed and surrounding urbanized areas adjacent the Project.

These and other potential impacts are summarized in Table 1 and categorized by “impacts from the Project” and “impacts to the Project.” Table 1 also summarizes the planned Project features to address potential impacts from the Project. The watershed and project measures to address the impacts to the Project are also summarized. Watershed measures are the responsibility of the Permittees and listed parties to the applicable total maximum daily loads (TMDL) enforced through the municipal separate storm sewer system (MS4) stormwater permit. In the final column of Table 1, the planned monitoring to confirm the effectiveness of these features is summarized.

Monitoring and Adaptive Management Framework

The framework for the H&SWQ-MAMP is based on the impacts identified from and to the Project, and the planned Project and watershed measures listed in Table 1. The framework is also based on the monitoring elements listed in Table 1 to confirm Project features are effective. Building on these elements, the Monitoring and Adaptive Management Framework has been developed and is presented in Figure 1.

The MAMP framework is based on answering the following key questions for impacts from and to the Project:

Monitoring Questions (impacts from the Project):

- Has the Project increased deposition in Ballona Creek to a point that could cause flooding?
- Has the Project increased deposition in the entrance to Marina del Rey to a point that could impact navigation?
- Is the site experiencing erosion that could threaten levee stability?
- Has increased scouring of Ballona Creek resulted in migration of sediment containing legacy and emerging constituents above thresholds that can impact biological resources or human health within the estuary?
- Have exposure and/or migration of legacy constituents above thresholds in marsh sediments resulted in potential impact to biological resources?

Monitoring Questions (Impacts to the Project):

- Have dry weather flows and stormwater from the watershed and adjacent lands resulted in accumulation of constituents in sediments within Ballona Creek and the connected wetland channels at concentrations that result in a significant impact to biological resources or human health?
- Has sea level rise increased managed water levels in South and Southeast Area B to levels that will flood Culver Blvd., Jefferson Blvd, and/or the Gas Company?

Current Monitoring

To address these key questions, Project monitoring will be coordinated with sediment monitoring in Marina del Rey. Los Angeles County and USACE conduct conditions surveys of the Marina del Rey harbor entrance as well as sediment sampling. Cooperation with regional monitoring programs is also important, as these programs provide developed standard protocols, baseline data, and the ability to compare to other estuaries in Southern California. The regional program includes the Bight program, which has a coastal wetland assessment component. Currently under development is a framework for a regional assessment of wetland conditions. This assessment framework can be used in combination with the framework presented in this MAMP to provide a multiple-line of evidence approach to assessing the health of the wetlands and informing management actions. Further development and implementation of these regional programs are dependent on funding priorities. Collaboration with these regional programs is fundamental to the development of the final MAMP, which will include reference to these programs and the methods, protocols, and baseline data developed under these programs.

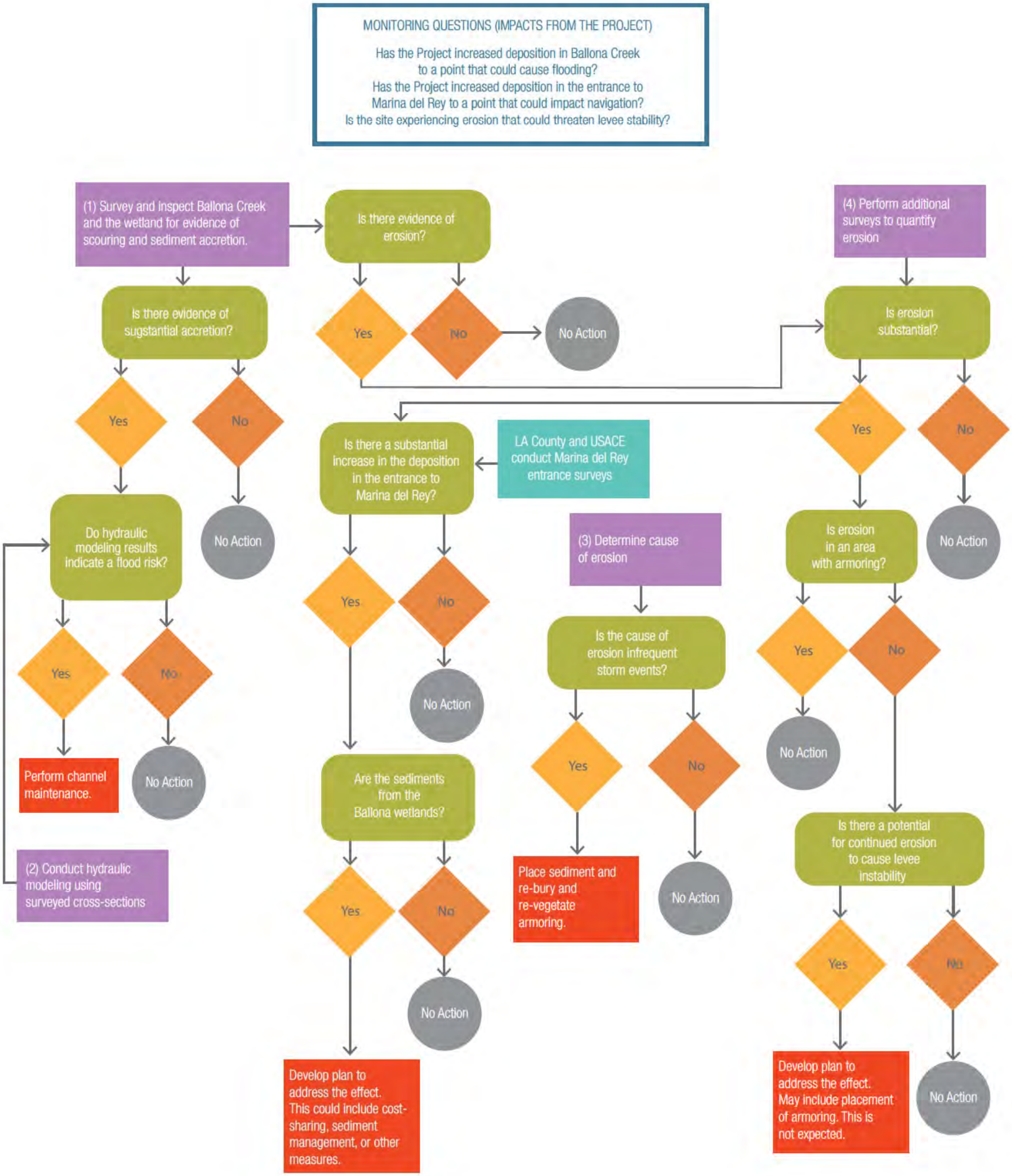
Table 1: Summary of Potential Impacts, Mitigation Measures, and Effectiveness Monitoring

Potential Impacts	Planned Project Features or Watershed Management Measures	Planned Post-Construction Monitoring to Assess Effectiveness of Mitigation Measures
"From the Project"		
Channel Deposition – Deposition in the channel or entrance to Marina del Rey could cause flooding or increase the amount of dredging for navigation	**New Levees** – The new Project levees are designed to accommodate some level of channel deposition and maintain flood protection. An assessment of maintenance limits was performed for the EIR/S in the Modeling Addendum (ESA 2015c). Under Alternative 1, the maintenance limit was modeled as a reduced equilibrium tidal channel hydraulic geometry cross-section. These reduced dimensions are conservative and are not expected to be reached due to limited sediment supply. The dimensions represent a minimum channel size limit, because even if adequate sediment supply was available, tidal flows would maintain this equilibrium cross-section. Modeling results showed that freeboard from the water surface to the levee would be maintained with these reduced dimensions, and the need for maintenance is therefore not expected. In the other alternatives, the existing Ballona Creek levee remains in either West Area B (Alternative 2) or the whole site (Alternative 3), so the flood protection is not as great as in Alternative 1. The maintenance limit that was modeled was 4 feet of deposition in the channel, and results showed positive freeboard under this scenario.	**Channel Cross-Section Monitoring** – Based on annual channel surveys, any locations with substantial channel deposition would be identified and channel cross-sections would be surveyed. The survey results would be compared to the maintenance limits established for the Project. If channel surveys show that channel dimensions are reduced below the established maintenance limit in any location along the channel, the potential effect of the deposition on flood levels would be assessed. This assessment would include updating the hydraulic model with the surveyed channel dimensions to test whether the deposition would negatively affect flood performance. This assessment would be overseen by a qualified licensed professional civil engineer. If flood performance was found to be impacted, channel maintenance would be performed. If no impact was found, surveys would continue to be performed with an adjusted focus on areas of deposition. **Marina del Rey Entrance Monitoring** – LA County and USACE perform regular monitoring of elevations in the Marina del Rey harbor entrance. If significant erosion is observed in the Reserve, surveys would be performed to quantify the amount of erosion. Monitoring data from the harbor entrance would be assessed in coordination with LA County and USACE to determine if a corresponding significant increase in deposition in the harbor entrance occurred. If such an assessment indicates that erosion from the wetlands could have potentially caused a significant increase in deposition, additional sampling of sediment deposits in the harbor entrance channel would be performed to assess sediment properties and compare them against sediment properties in the Reserve area of erosion. If the project partners determine that erosion due to the Project caused a significant increase in deposition in the entrance channel, then the partners would coordinate and agree to a plan to accommodate the increase in sediment deposition. This could include cost-sharing proportional to the increase in deposition, sediment management measures to re-use/replace deposited sediment within the Reserve, or other measures.
Channel Erosion – Erosion or migration of the channel could threaten levee stability	**Project Erosion Protection** – The Project would provide erosion protection by realigning the flood risk management levees to the perimeter of Area A around the restored wetlands and restoring a wide vegetated floodplain that gradually slopes from wetland to upland habitats along the new perimeter levees. These broad slopes are expected to reduce storm flow depths and velocities near the new levees, thereby reducing the potential for levee erosion. Flow in the restored Ballona Creek channel would be guided by the sloping floodplain and upland peninsulas. Some gradual channel migration and periodic localized bank erosion and sedimentation would be expected to occur as is typical for natural river and estuary systems. The restoration is designed so that (1) this level of change would be acceptable for the habitat restoration and flood risk management and (2) the channel would not require regular maintenance. Where higher flows do occur and scour potential is increased, levees and channel banks would be protected by rock armoring as described further in the Preliminary Design Report (ESA 2015d). The erosion protection features are intended to guide Ballona Creek flows back into the existing channel and to reduce the potential for the channel to meander too far north or south.	**Erosion Monitoring** – Levees and channel banks would be inspected for erosion. Any locations of significant erosion would by assessed for potential effects. Inspection and assessment should be performed by a qualified licensed professional civil engineer. In any locations where erosion exposes buried armor protection, it would be assessed whether the erosion was due to an infrequent event or more regular flows. If erosion is determined to be due to an infrequent event, sediment would be placed to re-bury and re-vegetate the armoring, and monitoring focused on this area would be continued. If erosion along unprotected levees, such as the perimeter of Area A and the southeast side of West Area B, is observed, it would be assessed to determine if the erosion is negatively affecting the levee integrity. If negative effects were determined, a plan would be developed, which could include actions such as placement of armoring or buried armoring. Note that this is not expected. If any locations of significant channel bank erosion are observed in sections of the channel bank without armoring, the areas would be assessed for potential continued erosion that could negatively affect habitat or adjacent levees/infrastructure. If negative effects were determined, a plan would be developed, which could include actions such as placement of armoring or buried armoring. This is not anticipated.
Erosion of marsh sediments with legacy constituents – Legacy constituents at concentrations above thresholds could become exposed and/or migrate through stormwater runoff or new channel scouring.	**Pre-Construction Sediment Sampling** – A pre-construction sampling analysis plan would identify sediments with high levels of constituents and designate those sediments for burial or use in less effected habitats. As part of the final permit and design process, pre-construction sampling and analysis of sediment for legacy constituents that will be exposed or used as foundation material for the wetlands and upland habitat will be performed. This pre-construction sampling will provide additional representative characterization to address any potential impacts from identified legacy constituents above threshold levels that pose a significant impact to biological resources and human health. The testing and analysis will also meet dredge material characterization requirements for marine placement. The results of this sampling and analysis will be used to develop the sediment management specifications for the Project.	**Monitoring of Marsh Sediment Quality** – Potential impact will be monitored in coordination with Permittees' TMDL monitoring of Ballona Channel. The TMDL monitoring of the channel will be supplemented by sampling of sediment in new wetland channels subject to erosion and accumulation of migrated sediment and analyzed for legacy constituents (metals, PCBs, DDT, PAHs) and compared to TMDL sediment criteria. If the results indicate concentrations of these legacy constituents exceed the criteria, toxicity and benthic surveys will be conducted and results compared to Sediment Quality Objectives (SQOs). Further testing to identify the source of these constituents will be performed to confirm these results and the source of the constituents. Management action will be taken based on results of the SQO analysis, confirmation sampling, and source identification studies.

Table 1: Summary of Potential Impacts, Mitigation Measures, and Effectiveness Monitoring (continued)

Potential Impacts	Planned Project Features or Watershed Management Measures	Planned Post-Construction Monitoring to Assess Effectiveness of Mitigation Measures
Erosion of Ballona Creek sediments with legacy constituents – Legacy constituents in sediments such as copper, zinc, and PCB may pose impacts to fish tissue and human health.	**TMDL/NPDES Permit Monitoring and Watershed Pollutant Reductions** – The TMDL sets a plan and schedule for addressing the existing impacted sediment in the channel. Permittees are required to conduct testing and analysis of creek sediment within the tidal prism that includes chemical, toxicity, and benthic assessment for comparisons to the SQOs, to determine if sediments are impaired. If a sample is determined to be impaired, then further action is required. These actions may include further monitoring, reductions of pollutant loading from the watershed, and/or removal of the impacted sediment. Permittees are also required to conduct tissue sampling and compare to TMDL targets. These actions are to be taken and targets met prior to the estimated construction of the Project. The presence of legacy constituents at concentrations that can impact biological resources and human health will, therefore, be addressed prior to construction. **Covering of Impacted Sediments from Project** – Additionally, portions of Ballona Creek with sediments that contain legacy and emerging constituents will be covered as part of the creek re-alignment. These buried impacted sediments will not be subject to exposure and impact to the biological community or human health.	**Monitoring of Channel Sediment Quality** – Monitoring of sediments within the Channel will be conducted by the Permittees in accordance with the required TMDL monitoring program. Monitoring of sediments at the Marina del Rey harbor entrance will be conducted by LA County and the USACE as part of the Marina del Rey harbor entrance navigation maintenance and dredging program. This monitoring will assess the sediment quality compared to the SQOs and other applicable criteria for dredging. If samples are identified as impaired, further reductions in pollutant loading from the watershed or other actions will be taken. If results indicate new emerging constituents such as synthetic pyrethroids, which have not been fully addressed through the TMDL, are resulting in impacts, further action will be required under the MS4 Permit (if these emerging issues are from MS4 discharges). Sediment sampling under this MAMP will be coordinated with the Permittees' monitoring, ongoing Regional Wetland Monitoring programs, and LA County and USACE's monitoring in the Marina del Rey entrance. MAMP monitoring will occur outside of the main channel in the connecting channels of the Project. Monitoring will be conducted if results of the main channel monitoring indicated sediments remain impacted and may be subject to additional scouring and possible migration of emerging constituents. If the results of sediment sampling in wetland channels (not main channel) indicate concentrations of these constituents exceed the TMDL sediment thresholds, toxicity and benthic surveys will be conducted and results compared to Sediment Quality Objectives (SQOs). Further testing to identify the source of these constituents will be performed and management action taken based on results of the SQO analysis. **Monitoring of Fish Tissue under TMDL**- Fish tissue sampling and testing as required by the TMDL will assess impacts to human health until targets are reached.
"To the Project"		
Deposition of sediments with high constituents in the marsh – Constituents that are hydrophobic such as many metals, pesticides, and PAH will adsorb to sediment that is carried by stormwater to the wetland and settle out, potentially impacting the existing and restored wetland biological resources.	**TMDL/NPDES Permit Monitoring and Watershed Pollutant Reductions** – The amended Toxic Pollutant TMDL (R13-010 December 5, 2013) sets a plan and schedule for reducing the current waste load allocations. Permittees have developed Enhanced Watershed Management Plans to meet TMDL load reductions by 2021; before the construction of the Project is finished. The permittees are required to monitoring for pesticides and if reductions are not obtained, the Regional Board will require further action. **Tidal Channel Design** – The Project has been designed to allow for natural flushing and circulation within wetland channels to improve water quality. **Stormwater Treatment Best Management Practices (BMPs) –** The Project plans to implement BMPs to collect and treat stormwater from outfalls that discharge directly to the wetlands. A retention treatment BMP is planned for the largest stormwater outfall from an urbanized area of Playa del Rey that was shown to impact sediments in the wetland channel of Area B. Bioswales are planned along Culvert Boulevard to remove sediment and constituents from runoff from this roadway that runs through Area B.	**Monitoring of Watershed Storm Flows and Dry Weather Flows** – The Permittees under the TMDL will continue to monitor water quality from the watershed above the tidal prism and sediment quality and fish tissue within the tidal prism of Ballona Creek to track progress toward and confirm attainment of load reductions and TMDL targets. **Monitoring of Wetland Channel Sediment Quality** – Long-term monitoring of existing and new wetland channels, which are subject to stormwater discharge, will be performed in accordance with approach outlined in this MAMP. The TMDL monitoring of the channel will be supplemented by sampling of sediment in existing and new wetland channels, which are subject to accumulation of migrated sediment from watershed and adjacent property, analyzed for legacy constituents (metals, PCBs, DDT, PAHs), and compared to TMDL sediment criteria. If the results indicate concentrations of these legacy constituents exceed the criteria, toxicity and benthic surveys will be conducted and results compared to Sediment Quality Objectives (SQOs). Further testing will be performed to confirm these results and determine the source of the constituents (Is the source from the watershed, site or adjacent properties?). Management action will be taken based on results of the SQO analysis, confirmation sampling and source identification studies. If stormwater is determined to be the source, additional BMPs may be implemented.
Sea level rise causing increased flood risk south of Culver Blvd	**Culvert Flap Gates- The Project has been designed to allow for the addition of flap gates to the culvert leading into South and Southeast Area B to manage water levels south of Culver Blvd.**	**Water Level Monitoring- The Project would conduct annual water level monitoring in South and/or Southeast Area B. Based on monitoring results, flap gates would be added to the culverts over time to limit the amount of watering entering the areas south of Culver Blvd as sea level rises. Initial modeling indicates that one flap gate will be added to the culverts every 25 years. Water level monitoring will determine when water levels need to be reduced by adding a flap gate.**

Figure 1: Accretion and Erosion Monitoring and Adaptive Management Flow Chart



Additional water and sediment quality monitoring is conducted through the amended Toxic Pollutant TMDL (R13-010 December 5, 2013), which requires the Permittees to conduct water quality monitoring in the non-tidal segment, including analysis of settable solids in storm flows for cadmium, copper, lead, silver, zinc, chlordane, dieldrin, total DDT, total PCBs, total PAHs, and total organic carbon. Sediment quality evaluations will be conducted every 5 years and include a full chemical suite, two toxicity tests, and four benthic indices, as specific in the SQO. Sediment chemistry and sediment toxicity samples will be collected annually (in addition to the SQO samples) to evaluate trends in general sediment quality constituents (e.g. TOC, grain size) and listed constituents (i.e. cadmium, copper, lead, silver, zinc, chlordane, total DDT, total PAHs, and total PCBs. The Permittees will also monitor chlordane, total DDTs, and PCBs in fish and mussel tissue within the estuary on an annual basis per the TMDL. The results of this Permittee monitoring will be coordinated with Project Monitoring to answer the key Monitoring questions as presented in Figure 1.

Additionally, as part of the Marina del Rey entrance dredging program, LA County and USACE conducts sediment sampling prior to dredging.

Accretion and Erosion Framework Steps

As presented in Figure 1, the MAMP framework provides steps that are to be taken in coordination with other monitoring efforts. The steps of the framework are highlighted in purple, which differ from the current monitoring elements, in teal. Each step includes decision points that determine if the next step is taken or if no further action is needed. The decision points are shown in Figure 1 as questions in green with yes or no responses.

Step 1: Erosion and Accretion Monitoring. The framework begins with Project monitoring of Ballona Creek and the wetland channels for evidence of scouring and sediment accretion. These site inspections and surveys are to be conducted on an annual basis.

Step 2: Hydraulic Modeling. If the surveys conducted in Step 1 show that Ballona Creek has experienced enough accretion to reach the maintenance limits of the channel, hydraulic modeling will be conducted to determine any potential impacts to flooding. This assessment would include updating the hydraulic model with the surveyed channel dimensions to test whether the deposition negatively affects flood performance. This assessment would be overseen by a qualified licensed professional civil engineer.

Management Actions. If hydraulic modeling shows the accretion in the channel could cause flooding, channel maintenance would be performed.

Step 3: Quantify Erosion. In areas where the inspection in Step 1 shows substantial erosion, the erosion would be quantified through additional surveys.

Step 4: Assess Cause of Erosion. In areas where the inspection in Step 1 shows substantial erosion (as determined by Step 3) the cause of the erosion would be evaluated. A licensed civil engineer would assess whether erosion is due to an infrequent event and whether placement of sediment to re-bury and re-vegetate the armoring is likely to be sustainable. This assessment may include continuing focused monitoring.

Management Actions. If the erosion is determine to be due to infrequent storm events, sediment may be placed to re-bury the armoring and re-vegetation could occur. If the erosion is occurring in an area without armoring, armoring could be placed to protect levee stability. This is not expected.

Step 5. Sediment Sampling. If surveys conducted by LA County and USACE show an increase in the deposition in Marina del Rey during the same period that substantial erosion from the marsh has been observed, sediment sampling will be conducted to determine sediment properties in the marsh. These properties will be compared to data from LA County and USACE in the marina entrance to determine if the increased sediment is a result of the Project.

Management Actions. If sediment sampling shows the increase in deposition or lowered sediment quality in the marina entrance is due to the Project, then the partners will coordinate and agree to a plan to accommodate the increase in sediment deposition. This could include cost-sharing proportional to the increase in deposition, sediment management measures to re-use/replace deposited sediment within BWER, or other measures.

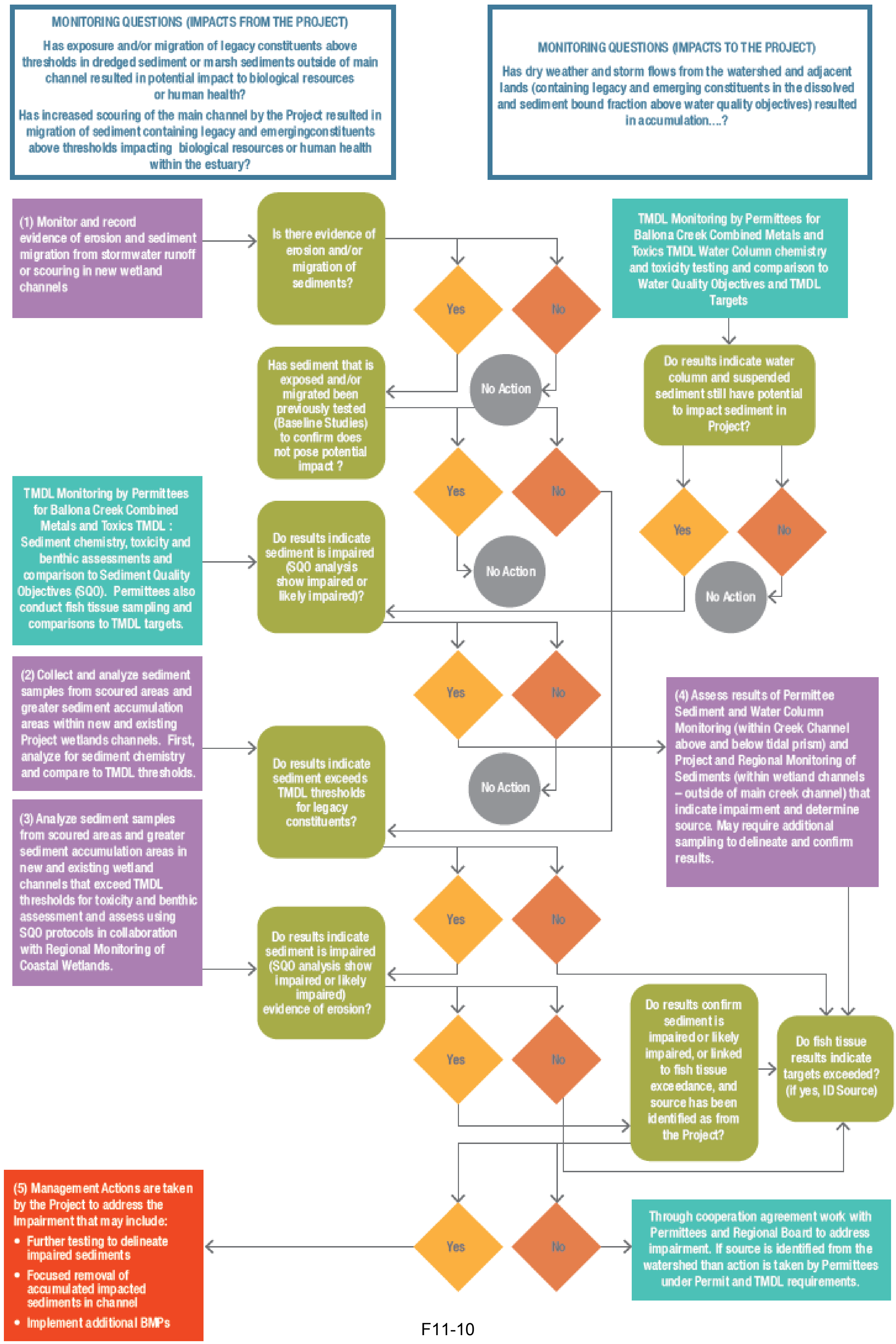
Water and Sediment Quality Framework Steps

Step 1: Erosion and Accretion Monitoring. The framework begins with Project monitoring of the wetland channels for evidence of scouring and sediment accretion (Figure 2). These site inspections are to be conducted on an annual basis. Evidence of scouring or accumulation of sediments in new channels will be identified and recorded. The observed or likely source of the sediment that has accumulated will be assessed and recorded. Potential observations of scouring and erosion and likely potential sources are listed in the table below:

Example Potential Observations	Potential Likely Sources
Accumulation of sediments in existing or new wetland channels near observed stormwater runoff outfall or erosion in upland area	-Stormwater runoff from adjacent land that may or may not be managed through Project BMPs -Stormwater from upland area that has channelized and eroded existing soils
Accumulation of sediments in wetland channels in areas that are predicted for higher sediment accretion from the watershed with no evidence of local channel scouring	-Watershed storm flows
Accumulation of sediments in wetland channels in areas that are predicted for higher sediment accretion from the watershed, but also show evidence of local channel scouring	-Watershed storm flows -Localized scouring of wetland channels
Scouring of Ballona Creek observed and accumulation of sediments in adjacent and downstream wetland channels	-Ballona Creek sediments
Accumulated sediment in new channels with multiple observations of Ballona Creek and wetland channel scouring and likely loading from the watershed	-Watershed storm flows -Localized scouring of wetland channels -Ballona Creek sediment

These observational data are to be used in combination with previous baseline and pre-construction testing of sediments to determine if additional action is needed. If previous testing indicated no potential impact from sediments in areas that have been exposed, or in accumulated sediments from a known site source, then no further action is needed. If exposure or accumulated sediment is from an on-site source that has not been characterized, then further Project monitoring is needed. This additional Project monitoring is to be coordinated with the results of the Permittees TMDL monitoring of

Figure 2: Water and Sediment Quality Monitoring and Adaptive Management Flow Chart



Ballona Creek water column above the tidal prism and sediments within the tidal prism. If the TMDL monitoring identifies through SQO assessment that the sediments within the tidal prism are impaired or likely impaired, than these results will inform further Project monitoring as outlined in the framework in Figure 2.

Step 2: Sediment Testing. If the erosion and accretion monitoring and review of existing sediment quality data indicate further monitoring is required, than the second step would include the sampling and analysis of targeted sediment within wetlands channels. This sampling and analysis should be coordinated with regional monitoring programs and the Permittee TMDL monitoring. For this step the analysis will be limited to chemical analysis of legacy and identified new constituents such as synthetic pyrethroid pesticides. The concentrations of these constituents will be compared to the TMDL sediment quality targets based on the effects range low (ER-Ls) or other applicable thresholds for the emerging pollutants.

Step 3: Toxicity and Bioassessment Testing. If the ER-L targets or thresholds are exceeded, further analysis of the sediment will be conducted to include toxicity and benthic bioassessment to assess the sediments using SQO methods.

Step 4. Determine Source. If the sediment is identified through the SQO process to be impaired or likely impaired, than the next step would be conducted. This step includes an assessment of all the data from the various monitoring programs and identification of the likely or known sources of the constituents that are predominant in resulting in the impaired condition. This may require additional monitoring and testing. For example, to determine the sources of sediment impairment in accumulated sediment in new wetland channels, evaluation of the chemistry data may indicate that the presence of synthetic pyrethroid pesticides above the L_{50} based threshold. Further testing of the sediments could indicate that the sediment results in a toxic response to marine arthropods. Toxicity identification evaluations (TIE) testing could then indicate that the toxicity is due to these pesticides. Since these pesticides have only recently been introduced and heavily use (last 10 years), the analysis could conclude that the source of sediment was not the dredge material from Marina del Rey placed in Area A, or historical marsh sediments in areas that have not been subject to recent watershed or adjacent urbanized land storm flows. The analysis would show that the sediment is likely from the watershed where these pesticides are used.

In addition to impairment of biological resources, impact to human health needs to also be monitored. Monitoring for fish tissue is part of the Permittee TMDL monitoring. In addition to conducting the sediment quality analysis under Step 4, results of any fish tissue testing and comparison to targets should be used to identify further actions as shown on Figure 2. If the fish tissue data indicated an exceedance of targets to protect human health, than the data shall be assessed to determine if there are linkages between the fish tissue results and observed exceedances of sediment or water quality from the watershed or with eroded or accumulated sediment in the Estuary. The collection and assessment of the monitoring data from all four steps is used to answer the key Monitoring questions highlighted above and listed in Figure 2 at the top of the page.

Management Actions. Management actions will be taken if the results of steps 1 through 4 confirm sediment is impaired or likely impaired, or linked to fish tissue exceedance, and the source has been identified as from the Project. Management actions that may be taken by the Project to address the impairment include:

- **Further testing to delineate impaired sediments** – further delineation of the sediment that contains constituents that are resulting in impairment may be needed to limit the extent and depth of sediment to be managed.
- **Focused removal of impacted sediments in channel –** following delineation of the sediments that contain concentrations above the thresholds and result in SQO identified impaired or likely impaired conditions, management actions may require focused removal of sediment. Sediment removal would be balanced with impacts to sensitive species and habitat within the wetlands channels. No sediment removal outside the channels is recommended due to the potential impact to habitat.
- **Implementation of Additional BMPs –** additional BMPs to treat stormwater from adjacent lands that discharge to the wetlands may be needed to remove constituents that continue to accumulate in sediments within the wetland channels.

Management actions will also be taken if the results indicate that the sources of impaired or likely impaired sediments or fish tissue exceedance are from constituents present in storm and/or dry flows from the watershed. For these management actions, the Project will work with Permittees and the Los Angeles Regional Water Quality Control Board through cooperation agreements to address the impairment. If the source of the impairment is identified directly due dry weather or storm flows from the Ballona watershed, and from constituents under an existing TMDL, than action will be taken by Permittees under Permit and TMDL requirements.

Summary

This framework outlines the monitoring and assessment elements needed to determine if Project features and watershed actions are effective in addressing potential impacts to biological resources or human health. This framework also uses monitoring to assess sources, if impacts are determined through comparison to established thresholds and compliance targets. As Project features address potential accretion, erosion, and water and sediment quality impacts, the monitoring outlined in the framework is to assess the effectiveness of these features. In addition, this framework addresses the potential unknowns that include the potential erosion and accretion of sediments, the exposure and migration of sediment that has not been previously characterized and contains constituents above the thresholds, and the accumulation of emerging pollutant from the watershed that are not addressed in the current TMDL, such as synthetic pyrethroid pesticides. This monitoring and adaptive management framework therefore provides an additional Project feature to mitigate for the uncertainties that are not fully addressed by the Project or through the existing monitoring for the watershed and marina.