G3 Updated Sea Level Rise Impact Analyses

Los Cerritos Wetlands Restoration and Oil Consolidation Project

Beach Oil Minerals Partners

Updated Sea Level Rise Impact Analyses

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EXECUTIVE SUMMARY

The Los Cerritos Wetlands Restoration and Oil Consolidation Project (proposed project/project site) would implement a comprehensive wetland restoration and oil consolidation project that will restore a privately owned oil field in the City of Long Beach through the creation of a mitigation bank on a portion of an existing oil field, consolidation of oil production facilities onto two nearby parcels, and phased removal of existing oil wells. The project is proposed by Beach Oil Minerals Partners (BOMP). This hydraulic study report was prepared to assess sea level rise impacts of the proposed project to adjacent properties and proposed wetlands.

AdH two-dimensional numerical models were created as a part of the project to simulate hydraulic conditions under the existing and proposed project conditions. The potential habitat changes were assessed for six sea level rise (SLR) conditions from 1 foot to 5 feet with 1-foot increments and a 5.5-foot rise. The modeling results indicate that SLR would change both the tidal range and tidal inundation frequencies in the proposed salt marsh. The salt marsh habitats would evolve as a result of these changes. The habitat elevation breaks for each habitat category would shift upward. The intertidal habitat acreage would initially increase from 57.1 acres under the no SLR condition to 63.4 acres with a 2-foot SLR due to increased tidal range, and then will decrease to 41.6 acres with a 5.5-foot SLR. The decrease is due to much of the area becoming subtidal habitat with further SLR. The vegetated marsh area would generally decrease as some marsh habitats would convert to mudflat or subtidal due to the increased tidal inundation frequency. Overall, salt marsh would evolve from a diverse range of habitats to be more of subtidal and mudflat after sea level rises.

The SLR impacts for flood risks were assessed for the following three SLR and fluvial storm scenarios:

1. The lower bound of SLR projection of 0.5 feet in year 2060
2. The upper bound of SLR projection of 2.6 feet in year 2060, and
3. The upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm

The numerical modeling results indicate that the proposed project would not change tide and storm water levels in the vicinity of the proposed project site under all three scenarios modeled. Comparison of water surface elevations between Scenarios 2 and 3 indicates the additional water surface elevation increase due to stormwater is 0.2 feet. Therefore, the fluvial storm impact to the hydraulic system is relatively small compared to SLR. Water would be contained within the proposed Phase 1 study area on the Synergy site and would not flood adjacent areas (Studebaker Road, 2nd Street, or Pacific Coast Highway) under scenario 3 (the worst case). Therefore, there would not be any impacts to the Phase 2 area of the Synergy site, the Los Cerritos Wetlands Authority (LCWA) site at the northeast corner of the Studebaker Road and 2nd Street, the Pumpkin Patch site, or the City's 33 acres under the projected SLR conditions in year 2060 together with a 50-year fluvial storm.

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Appendix A: Existing Synergy Site Topography
Appendix B: RMA2 Model Calibration Results

1.0 INTRODUCTION

The proposed project would implement a comprehensive wetland restoration and oil consolidation project that will restore a privately owned oil field in the City of Long Beach. This will occur through the creation of a mitigation bank on a portion of an existing oil field, consolidation of oil production facilities onto two nearby parcels, and phased removal of existing oil wells. Beach Oil Minerals Partners (BOMP) plans to consolidate 50% of the oil wells by year 2040 and 100% by year 2060. Therefore, the Phase 2 restoration is projected to start in year 2060, which coincides with the planning year for the City's Southeast Area Development Improvement Plan (SEADIP). Therefore, sea level rise (SLR) in year 2060 was choosen to assess the flood risk impacts due to SLR. The general project location is shown in Figure 1-1, and Figure 1-2 shows the project vicinity map. The paragraphs below provide a general description of four sites of the proposed project, which are shown in Figure 1-3.

Synergy Oil Field site: The Synergy Oil Field consists of an approximately 150-acre property located at 6433 E. 2nd Street. The site is bound by Pacific Coast Highway to the west, 2nd Street to the south, Studebaker Road to the east and the Los Cerritos Channel to the north.

Pumpkin Patch site: The Pumpkin Patch site comprises an approximately 7-acre property located at 6701 E. Pacific Coast Highway. The site is located adjacent to the southern boundary of a single-story commercial-retail development called the Marketplace. The site is bound by Pacific Coast Highway to the west, the San Gabriel River to the south, the commercial-retail uses at the Marketplace to the north, and undeveloped land associated with City-owned property to the east. The proposed project will occur on approximately 5 acres in the southwest portion of the site, with the remaining 2 acres in the northeast portion to be avoided. Adjoining the Pumpkin Patch site to the north is a 0.80-acre undeveloped parcel that is currently within the City's right-of-way. The proposed project would implement street improvements to this offsite parcel in order to provide access into the Pumpkin Patch site.

Los Cerritos Wetlands Authority (LCWA) site: The LCWA site consists of an approximately 4-acre parcel located at the northeast corner of the 2nd Street and Studebaker Road intersection. The site is bound by Westminster Avenue to the south and Studebaker Road to the west, and is adjacent to buildings associated with industrial uses to the north and east.

City Property site: The City Property site is an approximately 33-acre site located at 2nd Street and Shopkeeper Road. The site is bound by Shopkeeper Road to the west, 2nd Street to the north, undeveloped land to the east, and the San Gabriel River to the south.

This hydraulic study report was prepared to assess the SLR impacts of the proposed Phase 1 Wetland Mitigation Bank project to four adjacent project sites including: Phase 2 Synergy site, LCWA, Pumpkin Patch, and the City's 33 acres (also known as Marketplace Marsh), as shown in Figure 1-3.

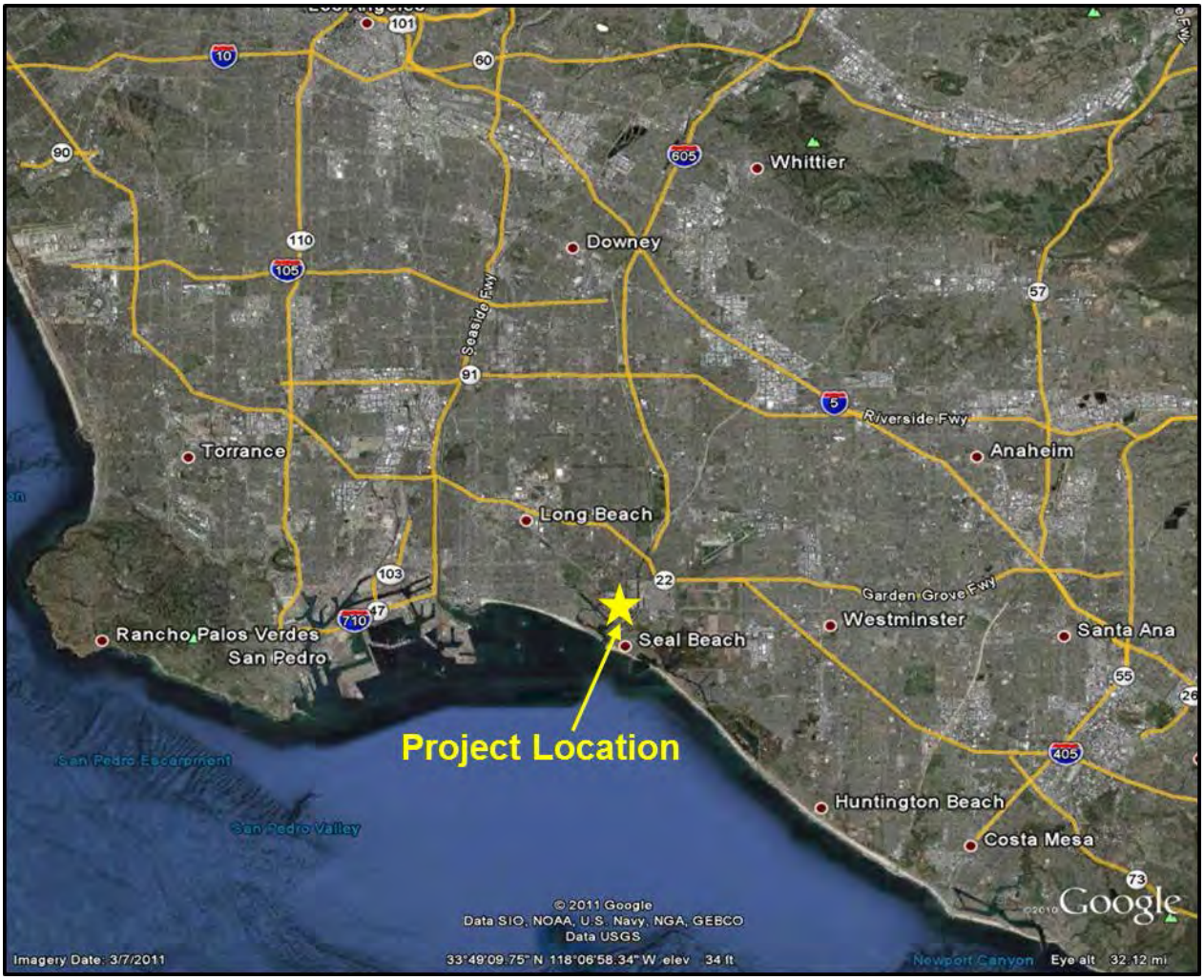


Figure 1-1: Project Location Map

Figure 1-2: Project Vicinity Map

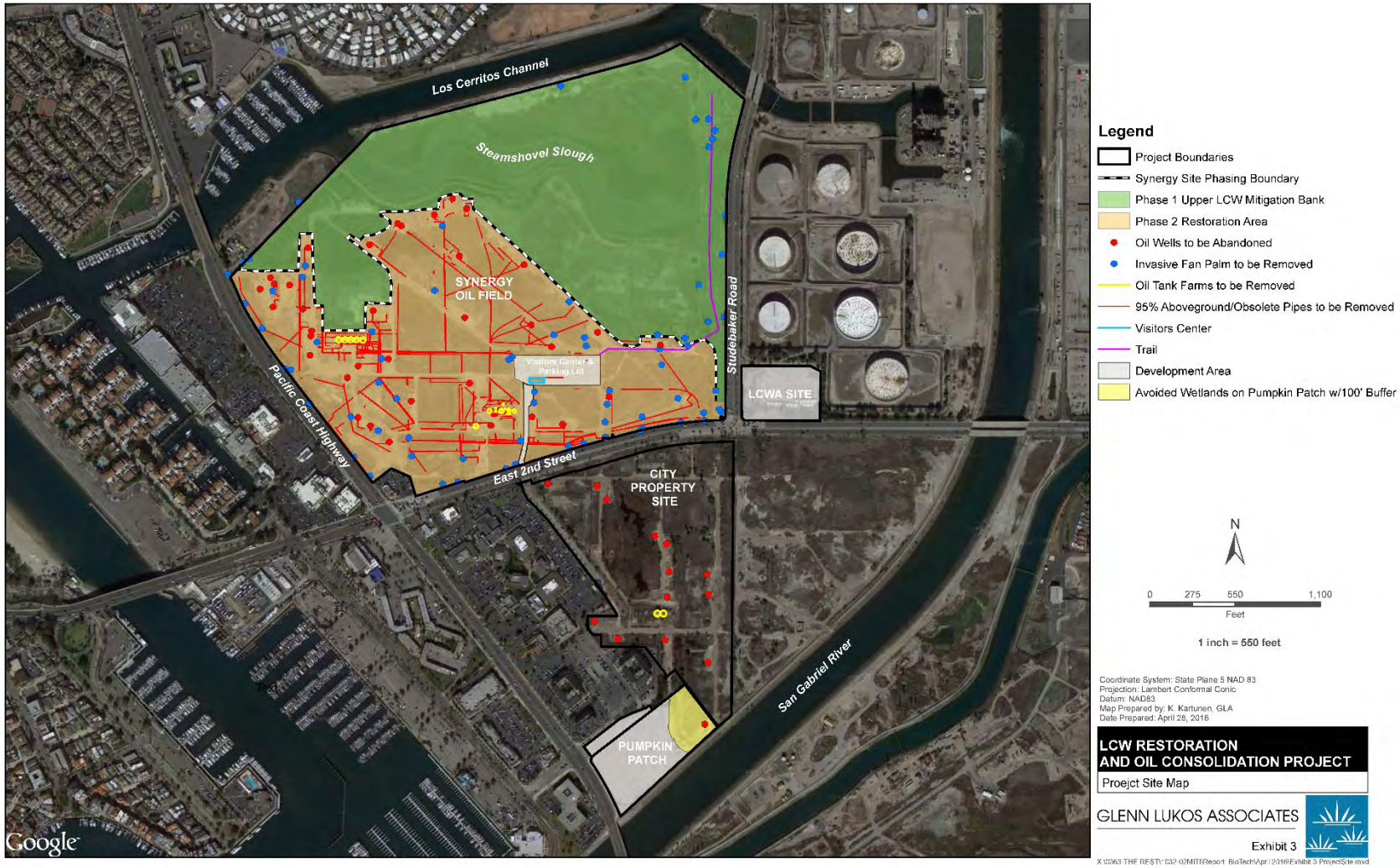


Figure 1-3: Synergy SLR Study Area

1.1 Project Background

In a prior study for Synergy, Moffatt & Nichol (M&N), together with Glenn Lukos Associates (GLA), developed a wetland restoration plan for the Phase 1 Wetlands Mitigation Bank area on the Synergy site shown in Figure 1-3. M&N performed Adaptive Hydraulics (AdH) hydraulic modeling analyses for the proposed project condition evaluating tides and stormflow for future SLR scenarios. Similar hydraulic modeling analyses were performed for the no-project existing condition in a separate study (referred to as the SEADIP Study) by M&N in 2015 for the City of Long Beach. The SEADIP study used the RMA2 model. Both the RMA2 and AdH models are two-dimensional (2-D) hydrodynamic models developed by the U.S. Army Corps of Engineers (USACE). The AdH model is a successor of the RMA2 model. Both models perform well for high tidal and flood water level conditions. In M&N's experience, the AdH model performs better than the RMA2 model for low tide elevations with tidal muting. Also, the RMA2 has an upper limit on the total number of modeling grids, while the AdH model does not. Therefore, the AdH model was used in the hydraulic analyses for the proposed Synergy mitigation bank project. The no-project existing condition was also modeled with the AdH model in oder to better assess the potential project impacts.

1.2 Scope of Work

The scope of work for this study includes:

1) Perform AdH numerical modeling and prepare tidal inundation frequencies and habitat maps under the proposed Phase 1 project condition for the following seven SLR conditions: 0, 1, 2, 3, 4, 5, and 5.5 feet. The purpose of these modeling runs is to provide tide inundation elevation bounds for habitat design and to assess impacts of SLR to the proposed project.
2) Perform AdH modeling runs under the no-project existing and proposed project conditions for the following three SLR and storm flow conditions to assess potential impacts of the proposed Phase 1 project to local roadways and adjacent development and to determine the interim berm elevation:
    a. The lower bound of SLR projection of 0.5 feet in year 2060
    b. The upper bound of SLR projection of 2.6 feet in year 2060, and
    c. The upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm as provided by the County of Los Angeles.
3) Perform one AdH modeling run under the no-project existing condition for the average tidal condition to assess potential impacts of the proposed Phase 1 project to Steamshovel Slough.
4) Peform one AdH modeling run under the proposed project condition for the extreme tide condition to assess scour potential in Steamshovel Slough and proposed project area. The peak flood/ebb tidal velocities under both the average and extreme tidal conditions are to be reviewed and results presented.
5) Update the Sea Level Rise Impacts Analyses report to include additional modeling results and incorprate comments provided by the City on the draft report.

2.0 WETLAND RESTORATION ALTERNATIVE

2.1 No-Project Existing Condition

Under the no-project existing condition, no change would happen to the project site. The existing topography and bathymetry were used to build the existing condition hydrodynamic model to simulate the baseline project conditions. The modeling results of the baseline project conditions are compared with the results of the proposed project condition to assess potential impacts of the proposed project.

2.2 Proposed Wetlands Restoration

The proposed project would implement a comprehensive wetland restoration and oil consolidation project that will restore wetlands on a portion of a privately owned oil field in the City of Long Beach. This will occur through the creation of a mitigation bank, consolidation of oil production facilities onto two nearby parcels, and phased removal of existing oil wells. The proposed project would be implemented on the four properties (shown in Figure 1-3) described below, all of which are located in the southeast portion of the City. A summary of the project activities proposed at each of the sites is provided below.

Synergy Oil Field site: The proposed project would divide the Synergy Oil Field into two phases. Phase 1 would establish the Upper Los Cerritos Wetlands Mitigation Bank and public access trail on the northerly 77.3 acres of the Synergy Oil Field (formerly known as the Bixby Oil Field). Figure 2-1 shows the Phase 1 conceptual grading plan. A combination of interim sheetpile wall (redline) and berm (green fill) is proposed at the project phase boundary to prevent potential flooding of the Phase 2 property area before being restored. Phase 2 would occur on the southerly 72.84 acres of the Synergy Oil Field. Within the Phase 2 area, the project would implement public access improvements, including a parking lot and conversion of an existing building for use as a visitor's center on approximately 3 acres of existing disturbed or developed areas. The removal of oil facilities such as above-ground pipelines and tanks would occur throughout the Phase 2 area, along with the removal and abandonment of 39 oil wells over time. A revegetation plan for the Phase 2 area would be implemented upon removal of the oil facilities.

Pumpkin Patch site: The proposed project would construct an approximately 5,200-square-foot, two-story office building 35 feet in height, an approximately 9,750 square feet of storage/ warehouse facility 22 feet in height, and a 47-space parking area on approximately 5 acres of the southwest portion of the site. Additionally, a portion of the oil production activities currently being conducted at the Synergy Oil Field will be developed on the Pumpkin Patch site. The project proposes the development of three oil well cellars that will house up to a maximum of 50 wells (oil production and water injection), and construction of two tanks: a 3,000 barrel "wet oil" tank (30 feet in diameter and 24 feet high), and a 2,000-barrel "skim oil" tank (24 feet in diameter and 24 feet high). A drill rig, approximately 160 feet in height, will be used on-site to initially drill the wells. A workover rig, approximately 120 feet in height, will be brought onsite to re-drill wells as necessary. A 22-foot wall will be constructed on the perimeter of the site. The remaining approximately 2 acres of the site in the northeast would be avoided. One oil well located within the avoided 2-acre area would be removed and abandoned in the same manner as the wells on the Synergy Oil Field. Immediately north of the Pumpkin Patch site is a 0.80-acre undeveloped

parcel that is currently within the City's right-of-way. The proposed project would implement street improvements to this offsite parcel in order to provide access into the Pumpkin Patch site.

Los Cerritos Wetlands Authority (LCWA) site: The project proposes to develop up to a maximum of 70 wells (oil production and water injection) in three well cellars to be constructed on approximately 4 acres of the LCWA site referred to as the Offer to Dedicate (OTD) parcel. In addition to the wells, the project proposes the construction of two oil tanks (a 28,000 barrel oil tank 70 feet in diameter and 48 feet high and a 5,000-barrel injection water tank 35 feet high and 32 feet in diameter) and three natural-gas-powered turbines that will be used to generate power for the oil production operations on both the LCWA and Pumpkin Patch sites. A drill rig, approximately 160 feet in height, will be used on-site to initially drill the wells. A workover rig, approximately 120 feet in height, will be brought on site to re-drill wells as necessary. A 15- to 20-foot-high ground flare will also be built on-site. To convey oil from the Pumpkin Patch site to the LCWA site, an underground pipeline will be jacked and bored beneath the two sites.

City Property site: The proposed project would remove oil facilities such as above-ground pipelines and tanks throughout the City-owned property located at 2nd Street and Shopkeeper Road (Marketplace Marsh). Over time, the proposed project would remove and abandon 13 oil wells currently being operated by Synergy on the approximately 33-acre City-owned property. A revegetation plan for the City-owned property would be implemented upon removal of the oil facilities.

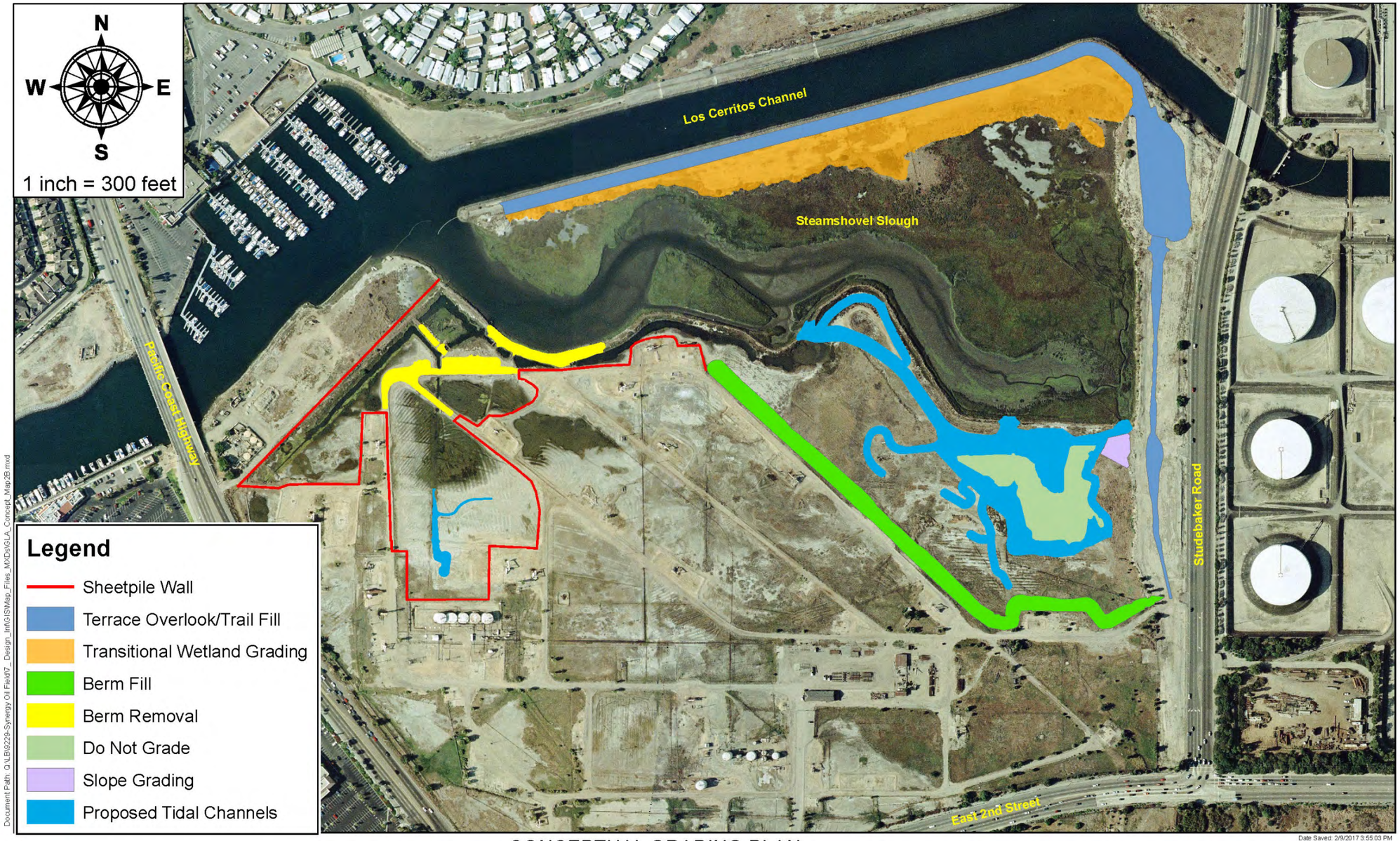


Figure 2-1: Phase 1 Conceptual Grading Plan

3.0 ADAPTIVE HYDRAULICS MODEL DEVELOPMENT

Numerical modeling of tidal and flood hydraulics was performed for the proposed project condition to evaluate wetland hydraulics under dry weather conditions and flood hydraulics during a 50-year storm. The numerical modeling for the no-project existing condition was performed as a part of the SEADIP Study (M&N 2015). This section describes the AdH model development.

3.1 Model Selection and Description

The hydraulic complexity in the project area requires a 2-D model, and the project requires simulations of hydrodynamics for the hydraulic system. In M&N's experience, the AdH model performs better than the RMA2 model used in the SEADIP Study for low tide elevations with tidal muting. Also, the RMA2 model has an upper limit on the total number of model grids allowed to setup the model while the AdH model does not have a limit. The limit on the total number of grids would affect the model resolution in the proposed marsh. Therefore, the AdH modeling system was selected to use in this project. The AdH model was developed by the USACE. It is a finite element modeling package that can describe both saturated and unsaturated groundwater, overland flow, three-dimensional (3-D) Navier-Stokes and 3-D shallow water problems, in addition to a 2-D shallow water module. The AdH model uses adaptive numerical meshes that can be employed to improve model accuracy without sacrificing efficiency. It also allows for the rapid convergence of flows to steady-state solutions. The AdH model contains other essential features such as wetting and drying, completely coupled sediment transport, constituents transport (temperature and salinity), and wind effects. The 2-D shallow water formulation was used for this project. A series of modularized libraries make it possible for AdH to include vessel movement and friction descriptions, as well as a host of other crucial features.

3.2 Model Setup

The setup for the hydraulic model included determination of the model area, bathymetry, wetland habitat area, mesh selection, and boundary conditions. For this project, a new AdH model was created for the proposed project condition. The AdH model setup includes all areas of interest and areas that would affect the tidal and flood hydraulics of the project site.

The horizontal coordinate system for the modeling work is North American Datum (NAD) 83, California State Plane Zone 5, and the vertical datum is NGVD 1929 (NGVD29), which is equivalent to Mean Sea Level (MSL) at that time. As sea level has risen since 1929, NGVD29 is lower than existing MSL by approximately 0.18 feet. The reason that the vertical datum is NGVD29 is that the existing topographic survey of the site is referenced to NGVD29. Both horizontal and vertical units are in feet.

3.2.1 Model Area

The numerical model area for the proposed project condition, shown in Figure 3-1, covers the nearshore ocean, all of Alamitos Bay (including Marine Stadium and the lower end of the Los Cerritos Channel), and the project area below the +10 foot NGVD29 contour line. The ocean boundary is approximately 2.0 miles from the shoreline; this distance was deemed to be sufficient to minimize boundary effects within the area of interest.

Figure 3-1: Numerical Modeling Area

None of the peripheral sites (Pumpkin Patch site, LCWA site, and City Property site) are connected to sources of seawater. Also, the elevation of the Pumpkin Patch site and the LCWA site is above the high tidal elevation even with the projected upper end of 2.6 ft SLR in year 2060; hence, they are not included in the hydraulic model. The northern San Gabriel River Levee has a crest elevation ranging from 13.6 to 15 ft NGVD29 in the reach and would not be overtopped even

with a 2.6-foot SLR. In addition, the elevation of the Pumpkin Patch site is approximately +14.0 NGVD29, and it is higher than the San Gabriel River Levee in some spots and protected by the levee in others.

3.2.2 Bathymetry

The bathymetry data used in the AdH model is the same as those used in RMA2 models for Los Cerritos Wetlands (M&N 2011) and for the SEADIP Study (M&N 2015). The Alamitos Bay and ocean bathymetry is based on data obtained from the National Oceanic and Atmospheric Administration (NOAA) chart 18749. Certain details of the modeling area were obtained from other sources (LACDPW, the City of Long Beach, and M&N 2007). The existing condition topographic data (included in Appendix A) of the project site was based on a 1996 survey by Dulin and Boynton with the NGVD29 datum and was compared with LIDAR data (NOAA 2013) for accuracy. The LIDAR data were collected between October 2009 and August 2011. Yellow circles in Figure 3-2 are locations where topo data were compared. To avoid potential vegetation impacts to the LIDAR data accuracy, bare earth spots were selected for the comparison. The results indicate the difference between the two data sets is very small, within 0.3 feet. The 1996 topo data is considered acceptable for use in the conceptual design; however, a new topographic survey is recommended for the final design.

Figure 3-2: Topographic Data Comparison

The site has subsided over time. Historic benchmarks monitored by the Long Beach Oil and Gas Department show the elevation decline is attributed to oil production in Seal Beach and Wilmington fields from 1928 to the 1960s. The decline ceased and rebound occurred when water

injection began on THUMS Oil Island Chaffee. Although subsidence has been arrested and the elevation has been stabilized since the 1970s, constant monitoring and control by the Long Beach Oil and Gas Department is ongoing and will continue into the future (City of Long Beach, 2017). The existing condition bathymetry and topography is shown in Figure 3-3.

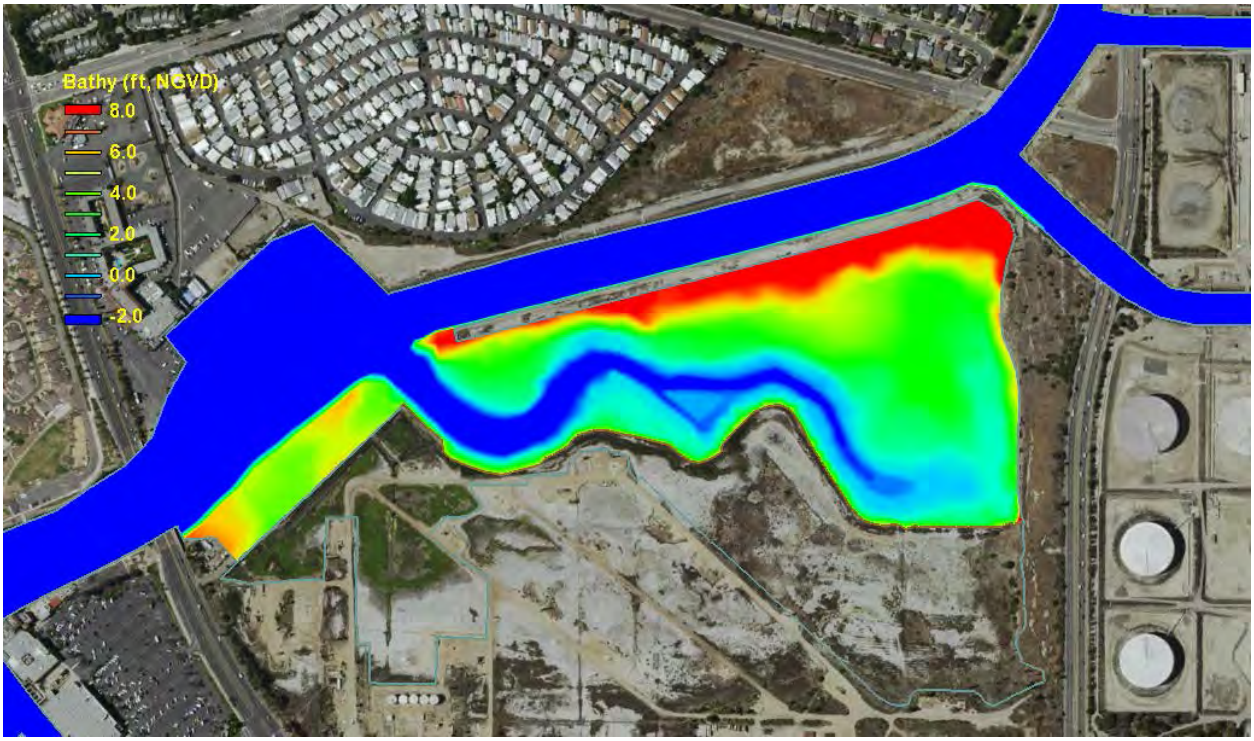


Figure 3-3: Bathymetry/Topography for the Existing Condition

For the proposed project condition, the topographic data for the Phase 1 project area is based on the proposed grading plan described in Section 2.2. The bathymetry of the proposed project condition is shown in Figure 3-4.

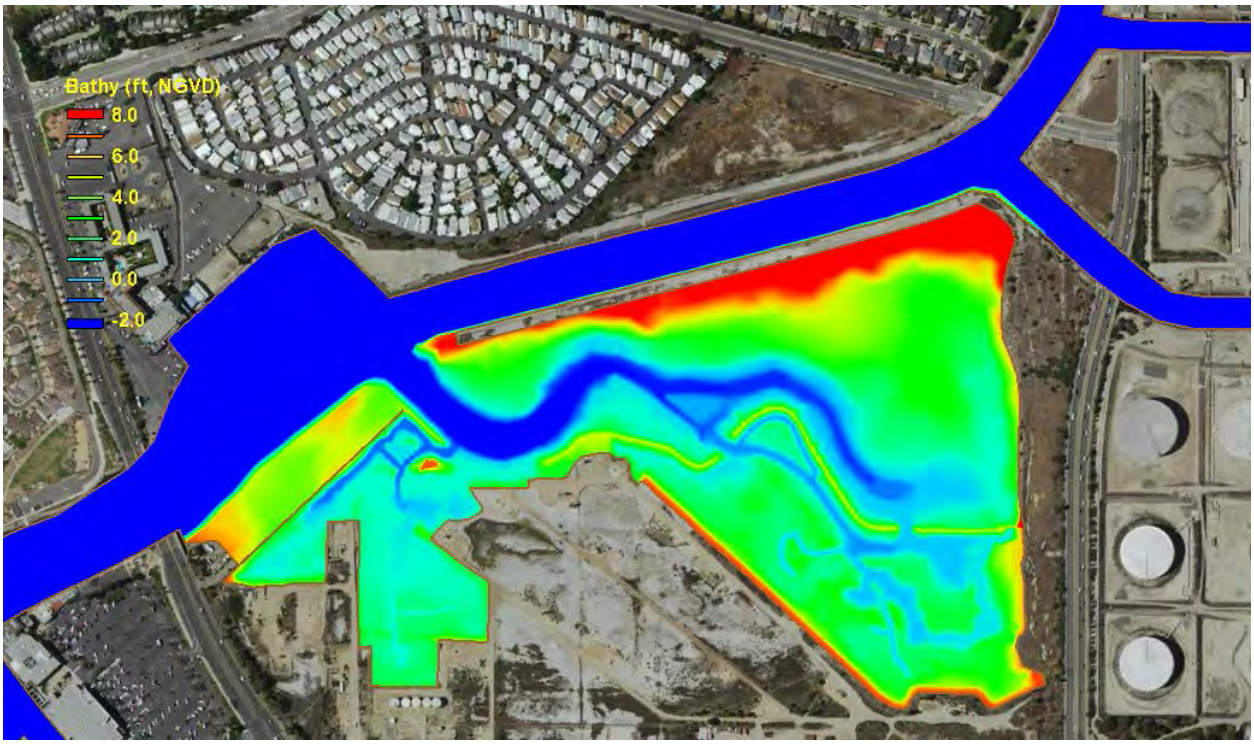


Figure 3-4: Bathymetry/Topography for the Proposed Project Condition

3.2.3 Finite Element Mesh

The AdH modeling system requires that the estuarial system be represented by a network of nodal points and elements, points defined by coordinates in the horizontal plane and by water depth, and areas made up by connecting these adjacent points, respectively. Nodes can be connected to form 2-D elements, having from three to four nodes. The resulting nodal/element network is commonly called a finite element mesh and provides a computerized representation of the estuarial geometry and bathymetry.

The two important aspects to consider when designing a finite element mesh are: (1) determining the level of detail necessary to adequately represent the estuary; and (2) determining the extent or coverage of the mesh. Accordingly, the bathymetric features of the estuary generally dictate the level of detail appropriate for each mesh. These concerns present trade-offs for the modeler to consider. Too much detail can cause the model to run slowly. Too little detail renders the results less useful and the model less stable. For this project, a balance was achieved with a stable and efficient model that yields the level of detail required for determining hydraulic conditions and identifying possible project impacts. The model described in this section is numerically robust and capable of simulating tidal elevations, flows, and constituent transport with reasonable resolution.

There are several factors used to decide the boundary of each mesh. First, it is desirable to extend mesh open boundaries to areas that are sufficiently distant from the proposed areas of change so as to be unaffected by that change. Additionally, mesh boundaries must be located along sections where conditions can reasonably be measured and described to the model. Finally, mesh

boundaries can be extended to an area where conditions have been previously collected to eliminate the need to interpolate between the boundary conditions from other locations.

The finite element meshes for the project area under the existing and proposed project conditions are shown in Figure 3-5 and Figure 3-6, respectively. The finite element mesh for the entire modeling domain is shown in Figure 3-1. The entire modeling area (ocean and inland), approximately 7.15 square miles, is represented as a finite element mesh consisting of 15793 elements and 8494 nodes.

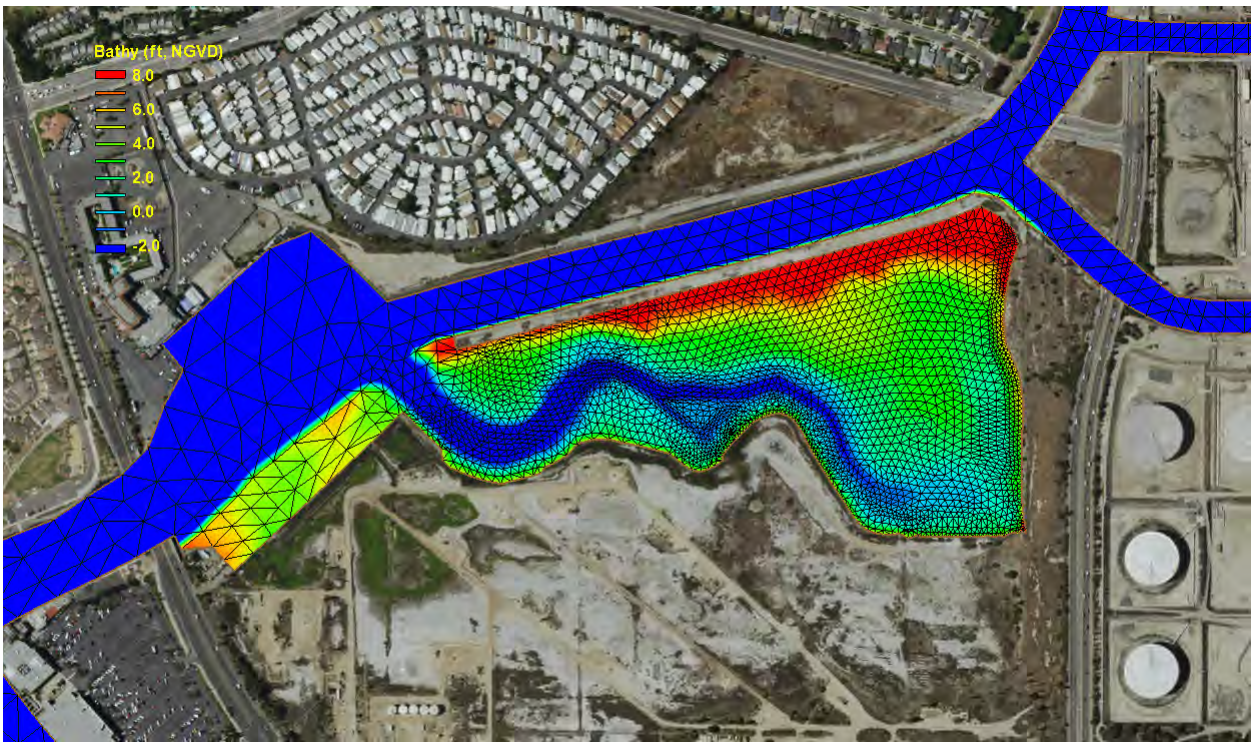


Figure 3-5: AdH Model Mesh for the Existing No-Project Condition

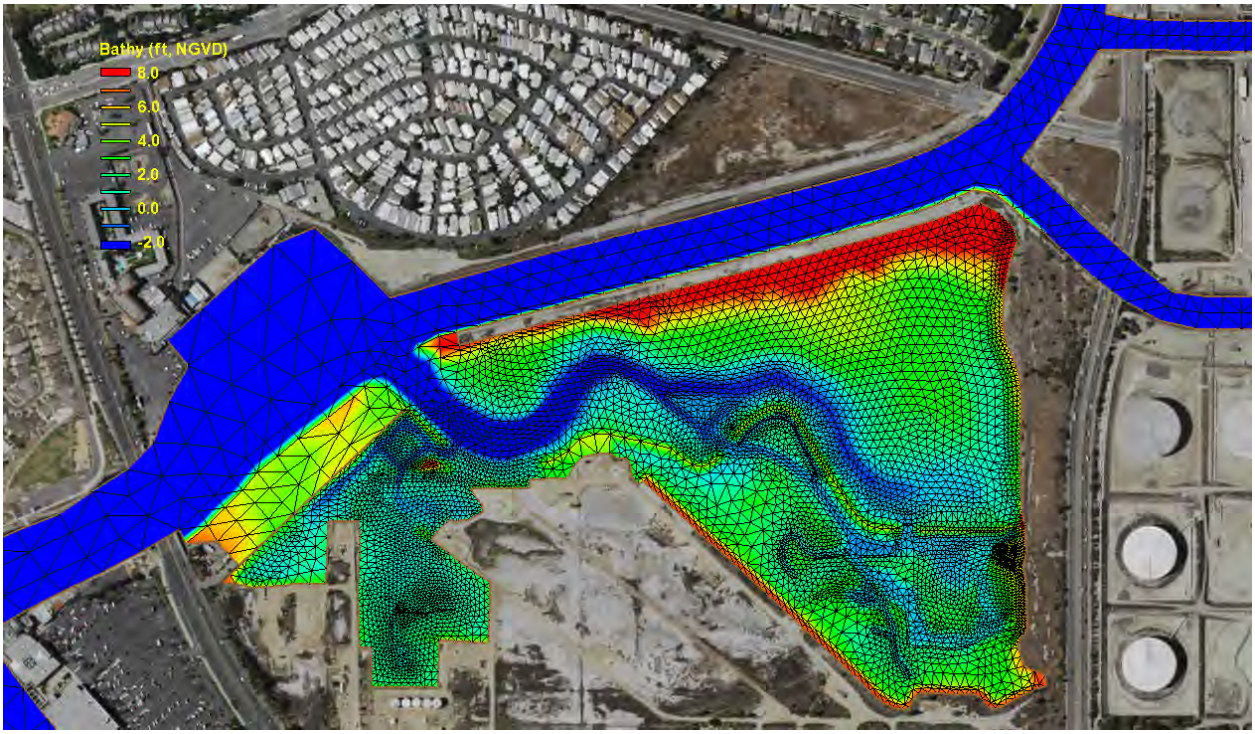


Figure 3-6: AdH Model Mesh for the Proposed Project Condition

3.2.4 Boundary Conditions

3.2.4.1 Tides

There are no official tide stations within Alamitos Bay. As such, the nearest tide station administered by the National Oceanic and Atmospheric Administration (NOAA 2016) at Los Angeles Outer Harbor was assumed to represent the ocean boundary tidal condition, as shown in Table 3-1. The diurnal tide range is approximately 5.49 feet from Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW), and MSL is at +2.83 feet relative to MLLW.

Table 3-1: Recorded Water Levels at Los Angeles Outer Harbor (1983-2001 Tidal Epoch)

Description	Elevation (feet, MLLW)	Elevation (feet, NGVD29)
Extreme High Water (1/10/2005)	7.92	5.29
Mean Higher High Water (MHHW)	5.49	2.86
Mean High Water (MHW)	4.75	2.12
Mean Tidal Level (MTL)	2.85	0.22
Mean Sea Level (MSL)	2.83	0.20
National Geodetic Vertical Datum 1929 (NGVD)	2.63	0.00
Mean Low Water (MLW)	0.94	-1.71
North America Vertical Datum 1988 (NAVD)	0.21	-2.42
Mean Lower Low Water (MLLW)	0.00	-2.63
Extreme Low Water (12/17/33)	-2.73	-5.36

3.2.4.2 Modeling Tidal Series for Habitat Design

The modeling tide series used for habitat design was a representative period from May 31 through June 15, 2006. Modeling long-term hydrologic conditions is typically done using a synthetic (artificially-created) tide series that represents average spring tide conditions over the most recent 19-year tidal epoch, referred to as a Tidal Epoch Analysis (TEA) tide series. The benefit of using a statistical tide is that the long-term condition can be modeled over a shorter time period with less computation time. A TEA tide does not exist for this site, and significant effort (beyond the scope of this study) would be required to prepare a new TEA tide. Therefore, a real tide series available from NOAA (2016) was used that closely matched average spring tide data and served the purpose of a TEA tide.

Replacing a statistical TEA tide with a recorded tide series is not a constraint for modeling if the recorded data possess the same necessary characteristics. To determine whether the recorded tide data possess the needed characteristics of a TEA tide, the modeler evaluated existing tide data from NOAA at Los Angeles Outer Harbor (NOAA 2016). NOAA began publishing spring high and spring low tidal elevations of all tidal cycles in March of 1994. The modeler averaged the spring high and spring low tidal elevations of all tidal cycles from March of 1994 through March 2013 (10 years), then examined the existing data to identify an actual recorded 2-week tidal cycle that matched the average tidal conditions. Tides during the period of May 31 through June 15, 2006 reached nearly the exact same spring high and spring low tidal elevations of NOAA's longer 10-year record average. Also, the average tidal elevation of that May 31 through June 15, 2006 period was compared with the average tidal elevation of the 19-year tidal epoch and was within 0.1 feet. The modeler concluded that tides during the period of May 31 through June 15, 2006 sufficiently matched long-term tides at the site, and possessed the approximate characteristics of a TEA tide. Therefore, use of this record is appropriate for analyzing tidal hydraulics, hydrology and ramifications on habitat designs and analyses. The modeling tide includes both spring and neap tidal ranges, as shown in Figure 3-7.

Although a statistical TEA tide was not prepared for this project, the real tide series used is referred to as the TEA tide in this report for simplification because it essentially serves the purpose of a TEA tide.

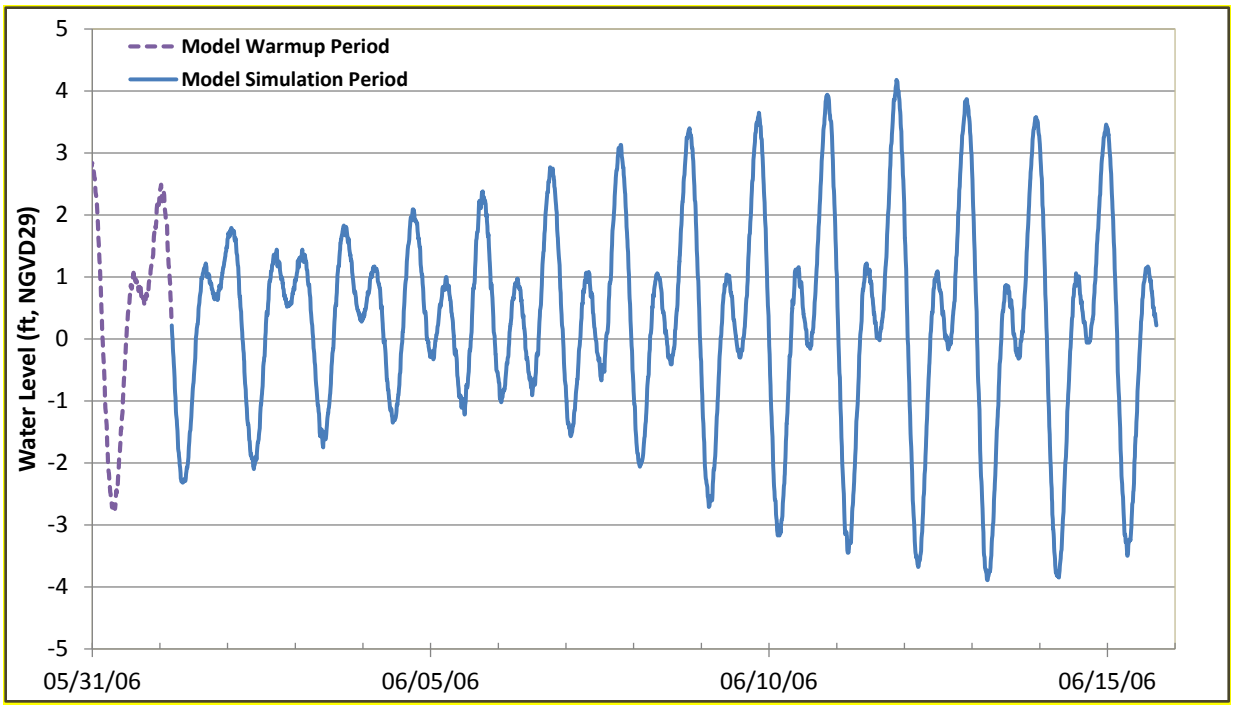


Figure 3-7: Modeling Tidal Series for Habitat Design

3.2.4.3 Extreme High Tidal Series

For assessing potential scour in the proposed project area under the extreme tidal condition, the tidal series including the highest water level observed at the Los Angeles Outer Harbor on January 10, 2005 was selected as the ocean boundary input, shown in Figure 3-8.

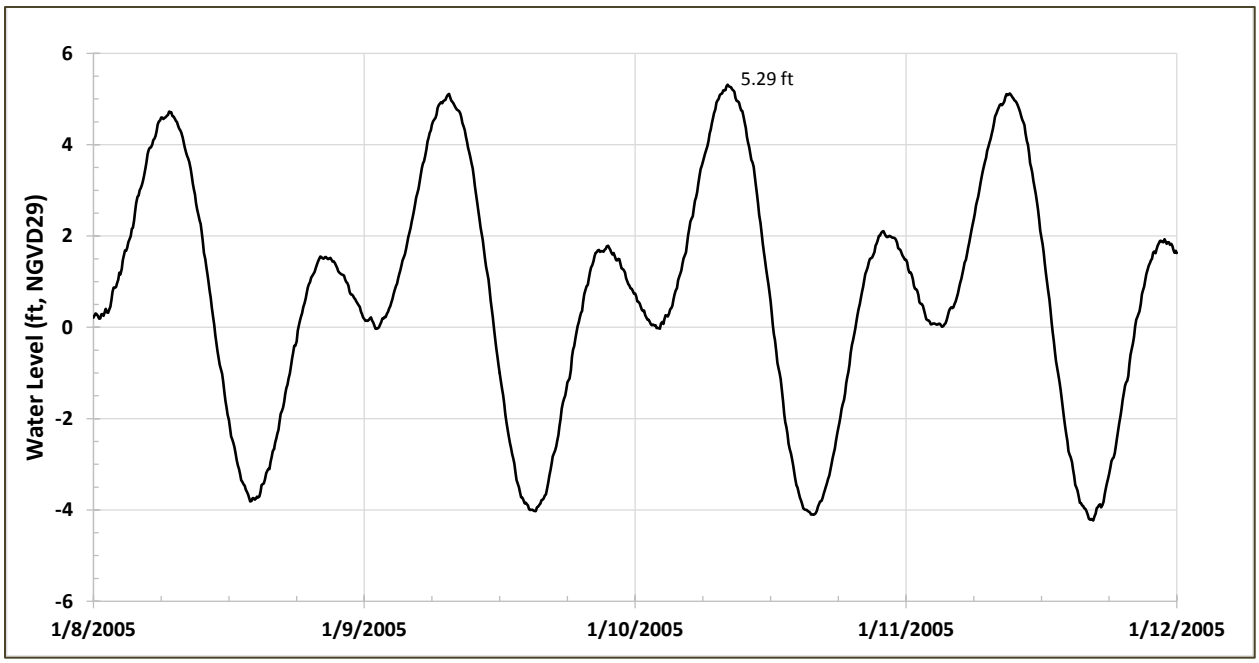


Figure 3-8: Extreme High Tidal Series

3.2.5 100-Year Extreme Ocean Water Level

Extreme ocean water levels for a range of return periods can be estimated by statistical analysis of the measured water level data. NOAA conducted such an analysis for the data collected at Los Angeles Outer Harbor from 1923 through 2006, and the results are presented in Table 3-2. As shown in the table, the 100-year extreme ocean water level estimated for Los Angeles Outer Harbor is +5.18 feet, NGVD29, which is very close to the highest observed tidal elevation of +5.29 feet, NGVD29 that occurred on January 10, 2005.

Table 3-2: Statistical Extreme High Water Levels (Life of the Gage, NOAA 2016)

Event	Elevation (ft MLLW)	Elevation (ft, MSL)	Elevation (ft, NAVD88)	Elevation (ft, NGVD29)
100-Year	7.81	4.99	7.60	5.18
75-Year	7.78	4.95	7.57	5.15
50-Year	7.65	4.82	7.44	5.02
10-Year	7.58	4.76	7.38	4.95
2-Year	7.32	4.49	7.11	4.69
1-Year	6.93	4.10	6.72	4.29

3.2.6 FEMA Base Flood Elevation

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) with ID No. of 06037C1988F and dated September 26, 2008 designates the Steamshovel Slough area as Zone A and the rest of the project areas as Zone X. Zone A consists of areas subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies. Mandatory flood insurance purchase requirements and floodplain management standards apply. Zone X consists of the floodplain areas outside of the 1-percent-chance flood, but subject to inundation by the 0.2-percent-annual-chance flood event. The effective FEMA FIRM in the project area is shown in Figure 3-9. Elevations shown in the FIRM are referrenced to the NAVD88 vertical datum.

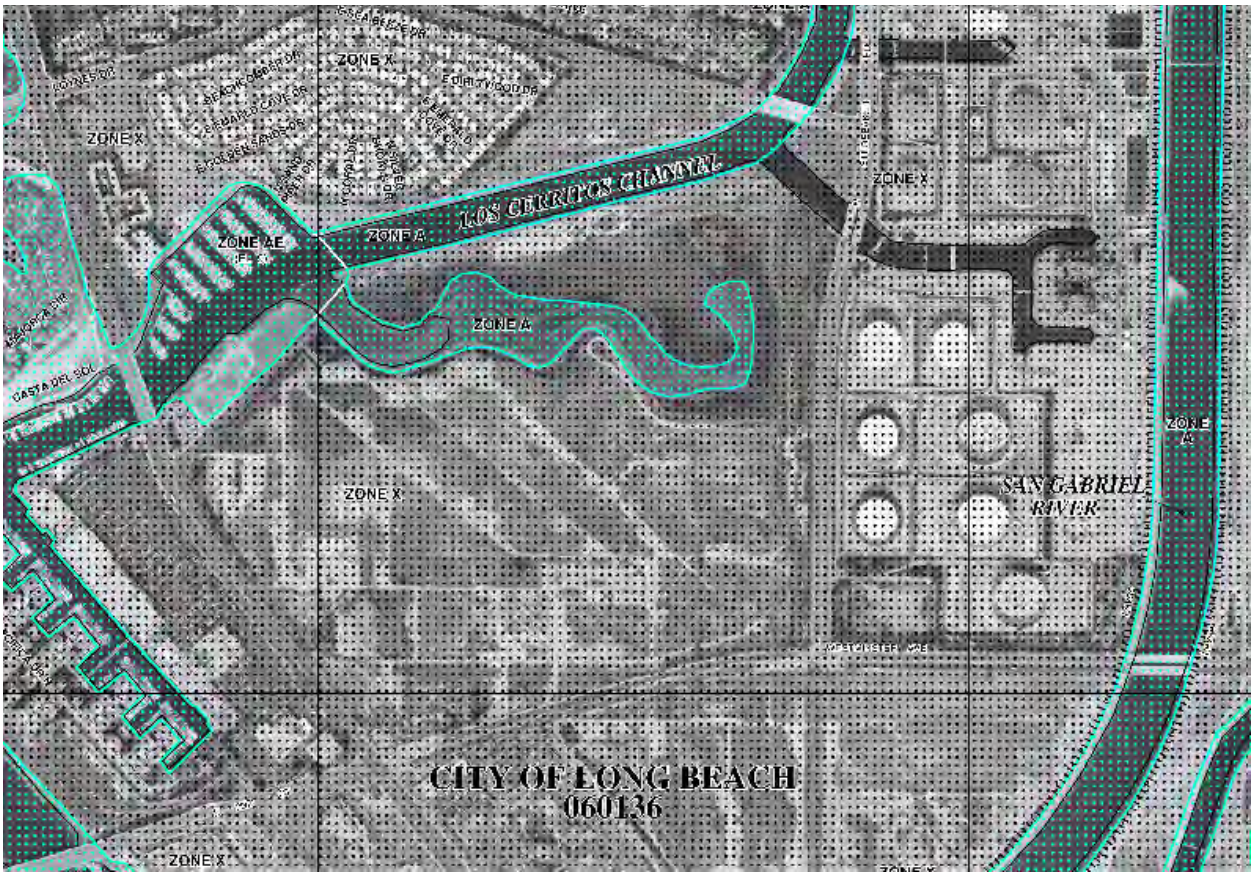


Figure 3-9: Image of Effective FEMA FIRM (Elevation, NAVD88 Datum)

As part of the ongoing Open Pacific Coast Study, FEMA distributed the preliminary FIRM panels, FIS report, Summary of Map Actions (SOMA) and GIS database for Los Angeles County and Incorporated Areas on October 28, 2016. These preliminary FIRMs would supercede the existing FIRM (ID No. of 06037C1988F and dated September 26, 2008) when the study is complete. The preliminary FIRM with ID No. of 06037C1988G and dated October 28, 2016 designates the entire project site as Zone AE with an elevation of 5.58 feet NAVD29 (8.00 feet NAVD88). Zone AE consists of areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. Base Flood Elevations (BFEs) are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply. The effective FEMA FIRM in the project area is shown in Figure 3-10. Elevations shown in the preliminary FIRM are referrenced to the NAVD88 vertical datum.

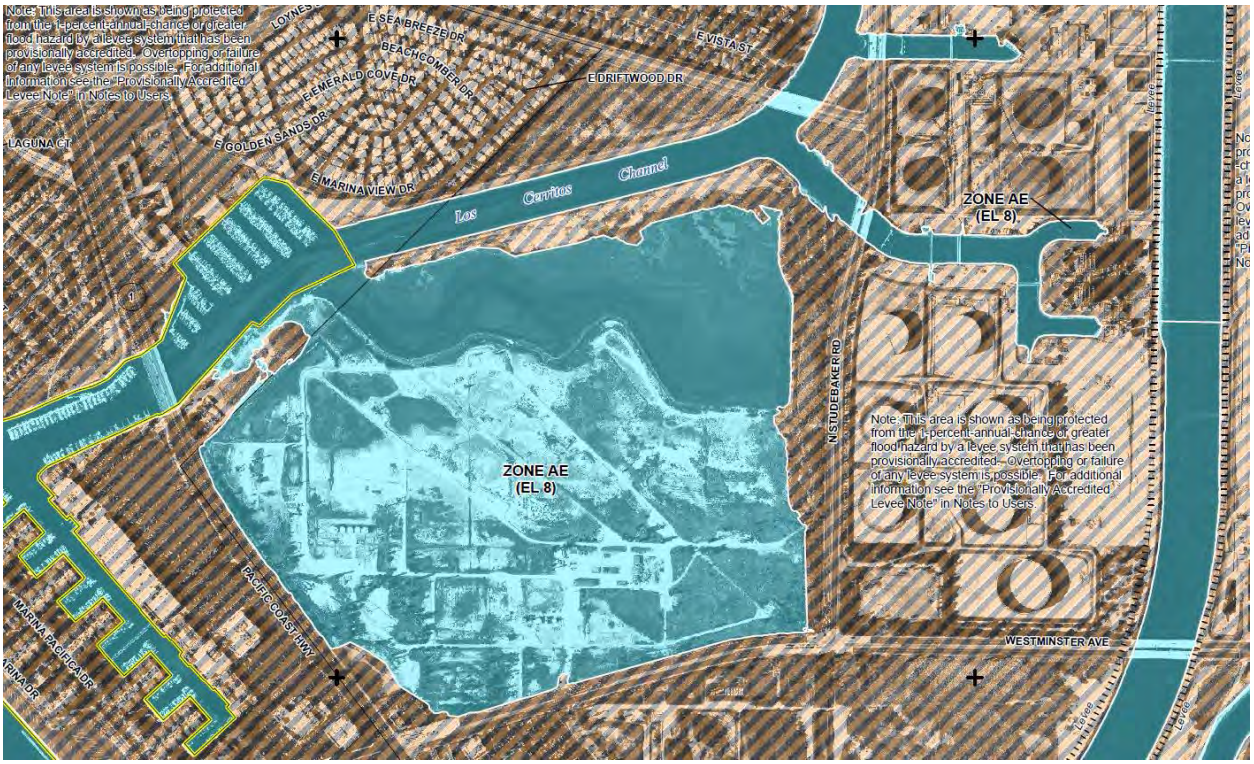


Figure 3-10: Image of Preliminary FEMA FIRM (Elevation, NAVD88 Datum)

3.2.6.1 Sea Level Rise

SLR is projected to occur worldwide in the mid- and long-term future. The SLR projections for the region south of Cape Mendocino based on the 2015 California Coastal Commission (CCC) guidance on SLR are between 0.5 feet to 2.6 feet for the year 2060 when all oil wells in the project site are expected to be consolidated. For the planning study, a lower bound of 0.5 feet and the upper bound of 2.6 feet are selected for modeling for the year 2060 for the purpose of flood risk impact analyses. For AdH model boundary input, the statistical tidal series (plotted in Figure 3-7), is elevated using the SLR projection values to create an elevated tidal series.

3.2.6.2 Storm Flow Boundary

The storm flow tributaries at Los Cerritos Channel and at Colorado Lagoon discharge to Alamitos Bay. The Los Cerritos Channel upstream of the project site is mapped as Zone A with no base flood elevation determined as described in the prior sections. No flood discharge was determined for the Los Cerritos Channel in the FEMA Flood Insurance Study (FIS). The Los Angeles County Department of Public Works (LACDPW) performed a hydrology study for the Los Cerritos Channel watershed in 2011. The 50-year hydrograph of the Los Cerritos Channel provided by the LACDPW (2015) is shown in Figure 3-11. The 50-year hydrograph of the Colorado Lagoon watershed is also provided by the LACDPW and shown in the figure for reference. The peak flow of the Colorado Lagoon watershed is very small and negligible compared to that of the Los Cerritos Channel, hence, it is not included in the model. The LACDPW compared the County's 50-year discharges with FEMA's 100-yr storm discharges for watersheds in the County, and results indicate that the County's 50-yr discharge is often equivalent to or higher than FEMA's

100-yr storm discharge. Therefore, the wet season simulation considered a 50-year stormflow provided by the LACDPW in the Los Cerritos Channel.

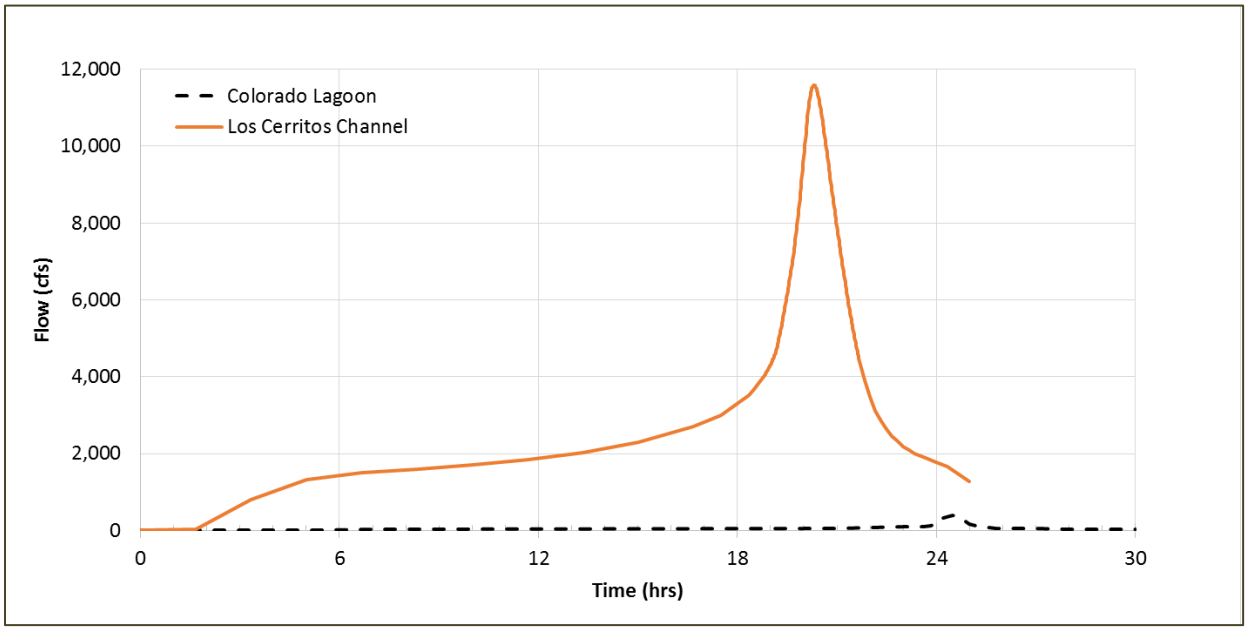


Figure 3-11: 50-Year Hydrograph of Los Cerritos Channel

3.3 Model Calibration

The RMA2 model used in the previous SEADIP Study was calibrated with measured tidal elevations and currents in the Alamitos Bay Circulation Study for the City of Long Beach (M&N 2007). The calibration results indicate that RMA2 model predicted tidal elevations and currents matched well with those measured. The RMA2 model calibration results are included in Appendix B. Similar modeling parameters used in the RMA2 model were assigned for the AdH model. Tidal elevations simulated by the AdH model during the average spring tidal condition are compared with those simulated by the RMA2 model at three locations shown in Figure 3-12. The comparison, shown in Figure 3-13 through Figure 3-15, indicates that both models predicted very similar results. Comparison of the two models' performance was also done for a similar project very recently (San Dieguito Lagoon W-19 Wetlands) and results lined up so closely that it made no sense to go through the calibration process again. Therefore, to conserve effort and time, the approach was simplified to set up the AdH model with the objective of providing more detail where needed in the marsh, and then simply match AdH results to prior RMA2 results in common areas.

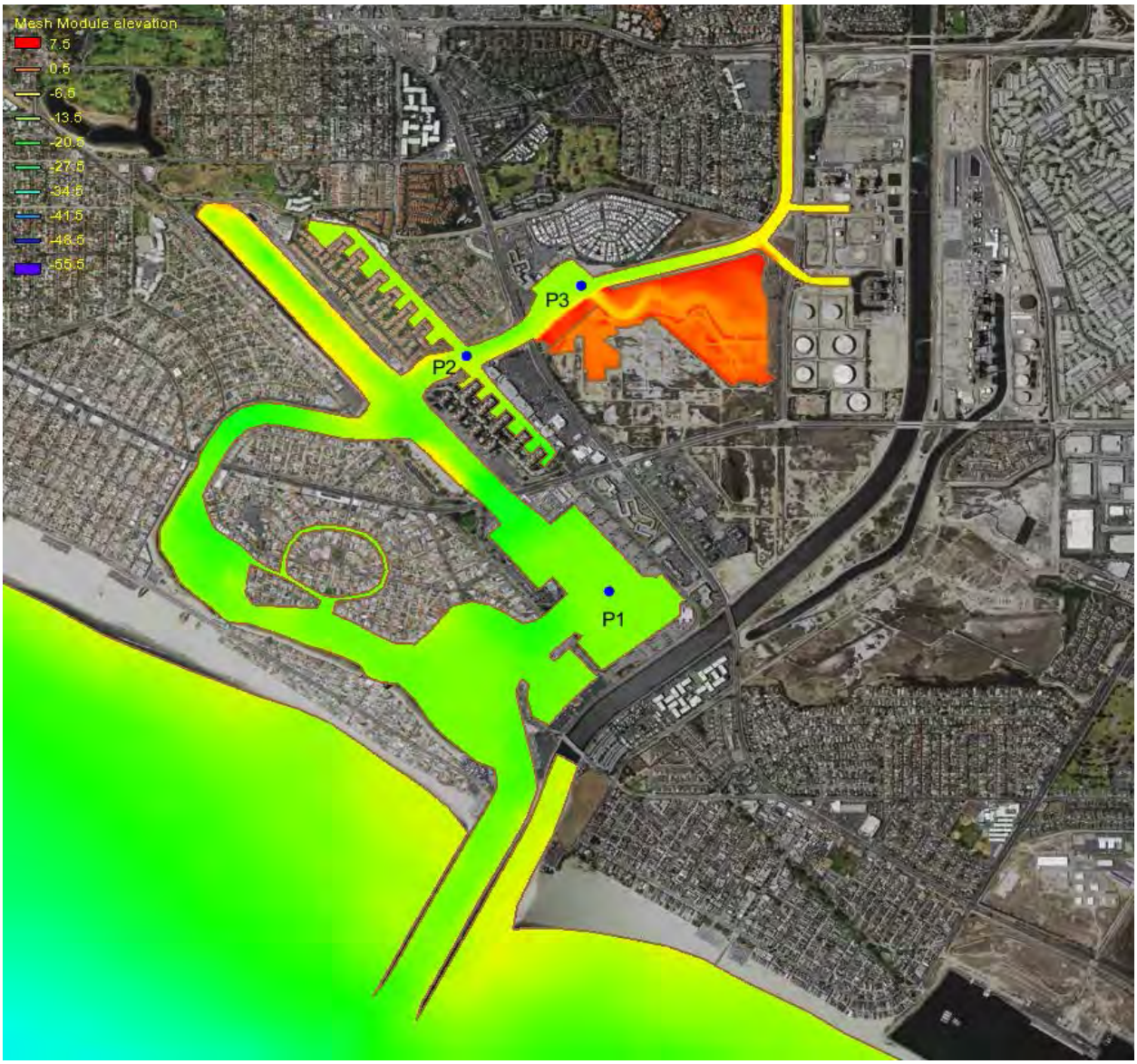


Figure 3-12: Gage Locations for AdH and RMA2 Model Comparison

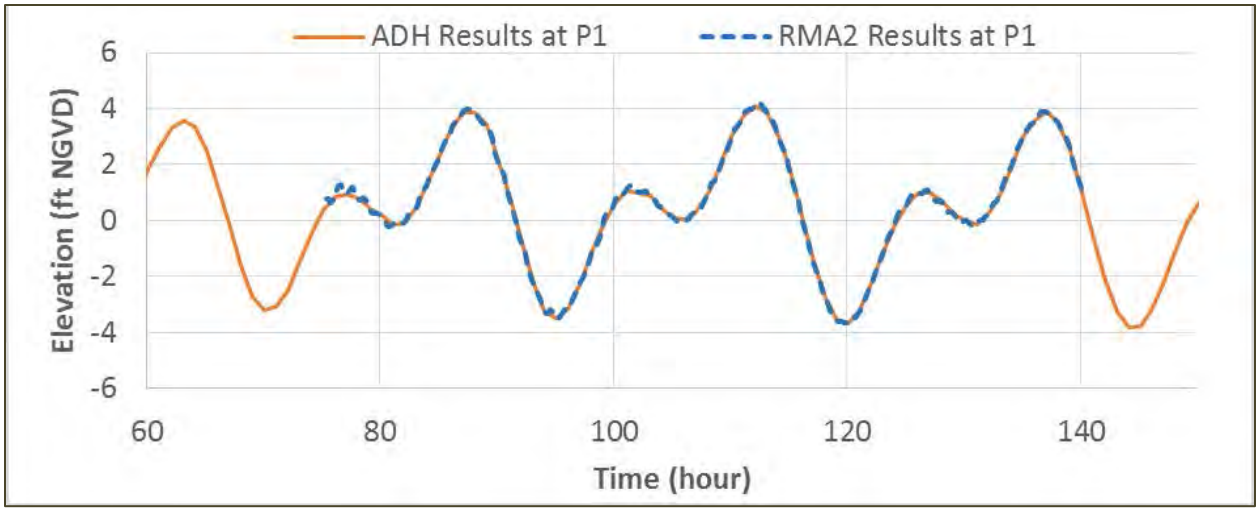


Figure 3-13: Comparison of AdH and RMA2 Models at P1

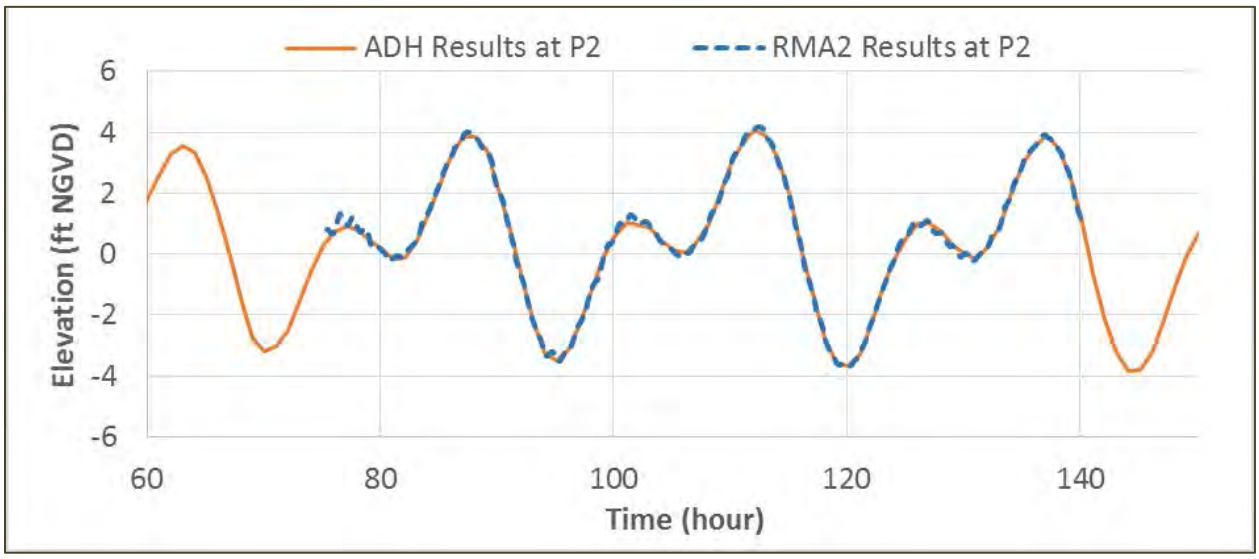


Figure 3-14: Comparison of AdH and RMA2 Models at P2

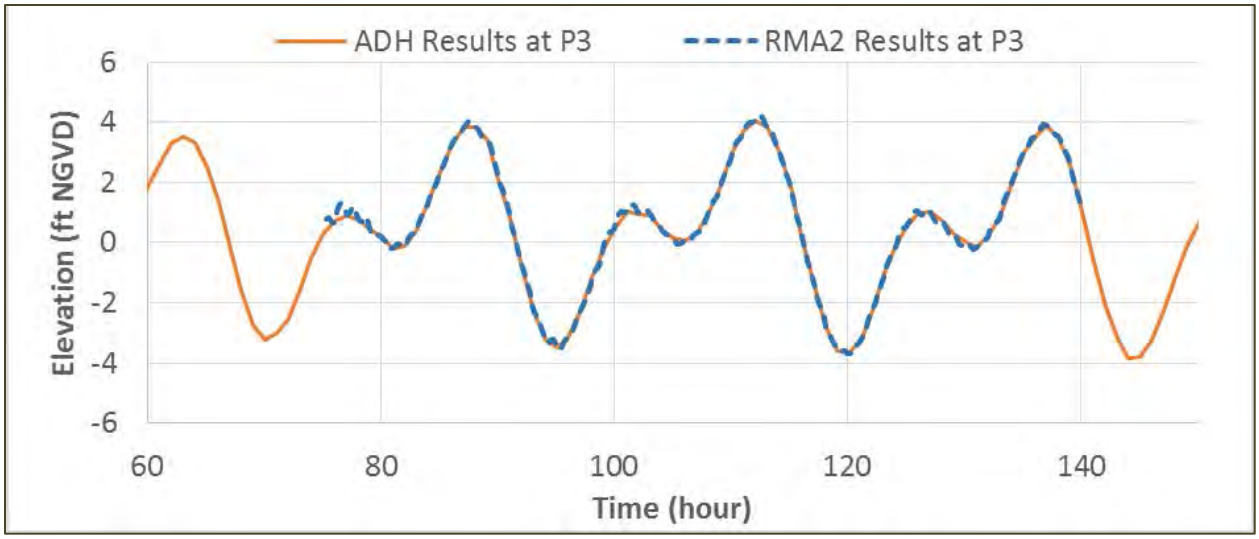


Figure 3-15: Comparison of AdH and RMA2 Models at P3

4.0 HYDRAULIC MODELING RESULTS

A series of AdH modeling runs were performed to provide:

- comparison of the AdH and RMA2 models,
- tidal elevations and inundation frequencies for wetland grading to achieve the desired habitats,
- water surface elevations under SLR and riverine storm conditions in year 2060 to assess potential flood impacts to adjacent roadway and properties and for interim berm design, and
- tidal inundation frequency under various SLR conditions to assess potential SLR impacts to wetlands.

Table 4-1 summarizes the modeling runs performed for this study.

Table 4-1: Summary of AdH Numerical Hydrodynamic Simulations

Alternative	Tide Condition	Flood Flow	SLR (ft)	Purpose
Existing	TEA (Average)	None	None	Baseline condition
	Measured Highest	None	None	Baseline condition for erosion assessment
	Spring tide	None	+ 0.5	Baseline condition for flood impact assessment
	Spring tide	None	+ 2.6	Baseline condition for flood impact assessment
	Spring tide	50-year	+ 2.6	Baseline condition for flood impact assessment
Phase 1	TEA	None	None	Habitat design Erosion impact assessment
	Measured Highest	None	None	Erosion impact assessment
	Spring tide	None	+ 0.5	Flood impact assessment
	Spring tide	None	+ 2.6	Flood impact assessment
	Spring tide	50-year	+ 2.6	Flood impact assessment
	TEA	None	+ 1	Habitat impact assessment
	TEA	None	+ 2	Habitat impact assessment
	TEA	None	+ 3	Habitat impact assessment
	TEA	None	+ 4	Habitat impact assessment
	TEA	None	+ 5	Habitat impact assessment
	TEA	None	+ 5.5	Habitat impact assessment

4.1 Tidal Inundation Frequency and Habitat Maps

4.1.1 Post-Construction Without SLR Condition

The AdH model run was performed by applying the TEA tide series at the model ocean boundary for the dry weather condition. The purpose of the model run is to: 1) predict tidal elevations and flow velocities over time and space within the modeling area; 2) calculate the tidal inundation

frequency in the wetlands to determine probable habitat distribution, and 3) determine any potential impacts to the Steamshovel Slough, which will be discussed in the following sections.

Results are analyzed for two hydraulically different areas separately: 1) the Steamshovel Slough area and 2) the new proposed marsh area to the west, referred as the West Marsh area in this report. The black line in the figure is an internal boundary between the two areas. The two red dots in Figure 4-1 are gage locations where hydraulic results are extracted from the model to represent the Steamshovel Slough area and the West Marsh area, respectively. The two gage locations are carefully selected to represent the average condition of Steamshovel Slough and West Marsh area. Due to tidal muting and lag, the low tide elevation at the gage locations does not track with the ocean low tide, which is evident from the fact that the slough never completely runs dry, although the elevation at the gage location in the Steamshovel Slough is shallower than the ocean spring low tide. There is a very small area downstream from the gage in Steamshovel Slough at the confluence with Los Cerritos Channel of less than 1 acre where the bathymetry is lower than the selected gage location. At this location subtidal acreage may be slightly over estimated, but the difference is very small and more detailed analyses is not necessary.

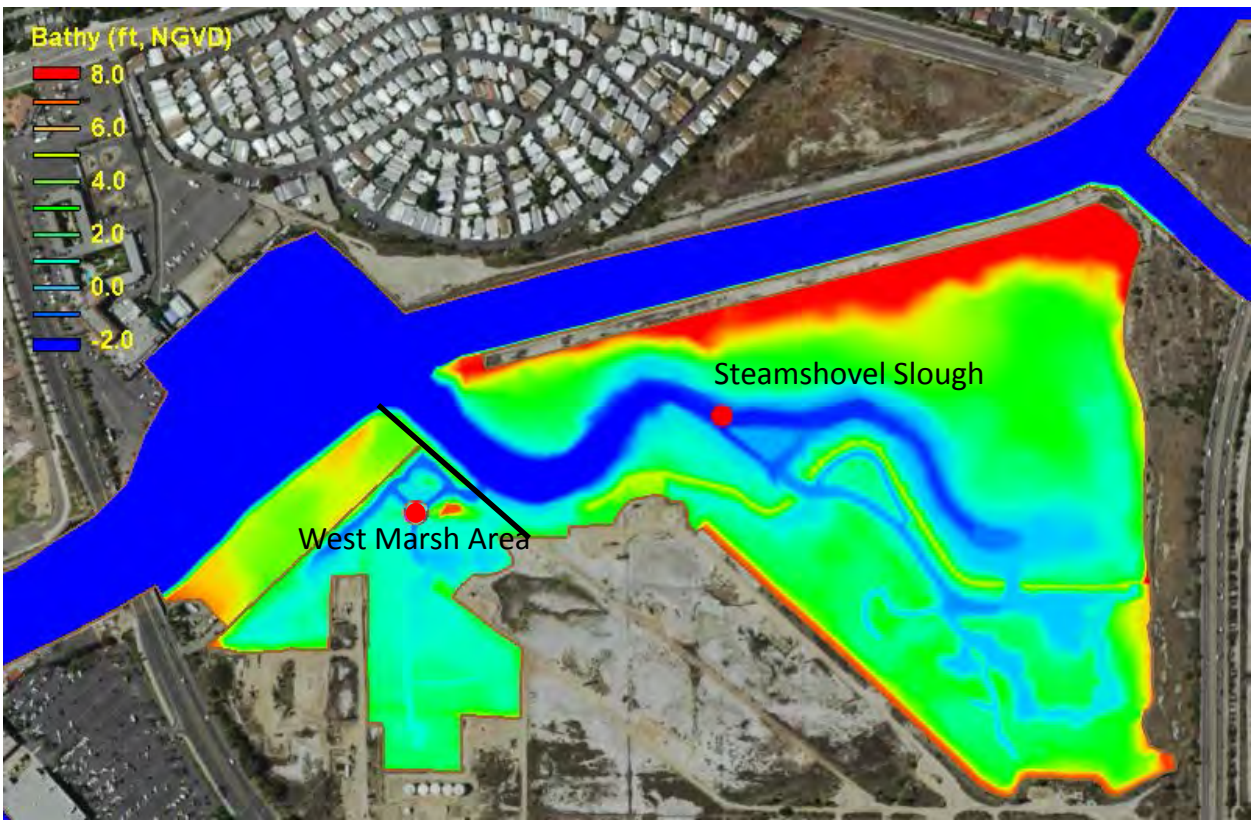


Figure 4-1: Gage Locations for Inundation Frequency Analysis

The model simulated TEA tidal series are shown in Figure 4-2. The results indicate the high tide in the proposed project area will reach the ocean high tide. However, the low tide will be truncated due to shallow bathymetry in the slough and the West Marsh areas. The tidal range in both Steamshovel Slough and West Marsh is smaller than that in the ocean. Therefore, marsh tides are muted from the ocean under existing conditions. This is due to friction over the marsh bottom, and flow retarding effects of the shallow and narrow channels through the site.

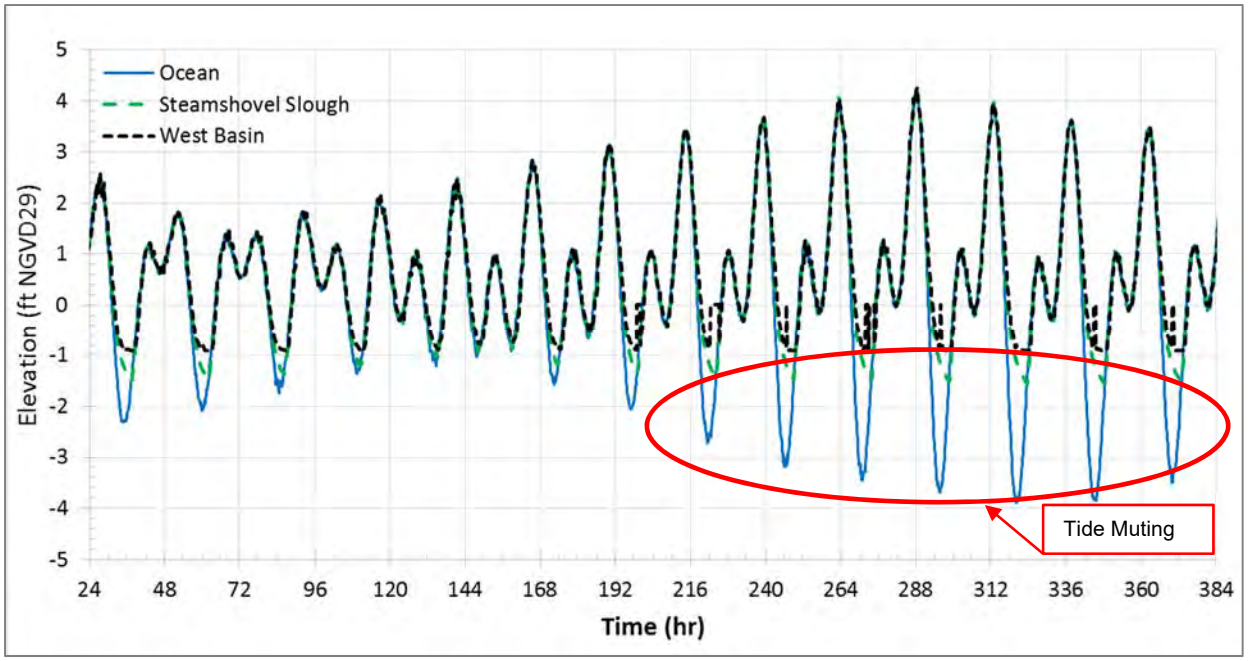


Figure 4-2: Predicted TEA Tidal Series Under the Phase 1 Project Condition

Tidal inundation frequency analyses were performed with tidal hydraulic results from the AdH model. Inundation frequency is the percentage of time that the tidal elevation exceeds a certain marsh elevation. It is an important factor for habitat design and distribution because the plants become established at particular inundation frequencies. Table 4-2 presents predicted inundation frequency and acreage for each habitat type and its corresponding habitat elevation range at the proposed wetland under the post-construction without SLR condition. For example, the inundation frequency for the low-marsh would range from 20% to 40% and its corresponding habitat elevation ranges from +0.79 feet to +1.58 feet in Steamshovel Slough, and from 0.83 feet to 1.56 feet for the West Marsh area under the no SLR condition. The model-predicted upper bound elevation for the high-marsh is +4.3 feet; however, the vegetation survey indicates that the high-marsh extends to elevation +5.1 feet since plants are able to colonize higher elevations than the tide reaches as roots are able to tap moisture down below the ground surface. Therefore, the upper bound elevation for the high marsh was raised by 0.8 feet to +5.1 feet. Similar adjustment is also made for the upper bound of the high-marsh under SLR conditions. Transition zone is defined to be a 2-foot elevation range zone starting from the upper end of the high-marsh to 2 feet above that value.

Table 4-2: Habitat Elevation Breaks in the Proposed Wetland Without SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	3.1	100		Lower limit of bathymetry	-1.55	Lower limit of bathymetry	-0.90
Mudflat (Unvegetated)	14.4	100	40	-1.55	0.79	-0.9	0.83
Low-marsh (Cordgrass)	11.1	40	20	0.79	1.58	0.83	1.56
Mid-marsh (Pickleweed)	24.8	20	4	1.58	3.37	1.56	3.38
High-marsh (Pickleweed)	6.8	4	0	3.37	5.10*	3.38	5.10*
Transitional	6.9	0		5.10*	7.10	5.10*	7.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

The relation between inundation frequency and habitat zonation was based on Josselyn and Welchel (1999) for marsh habitats in San Dieguito Lagoon for the SONGS mitigation program. The habitat breaks from monitoring performed by ESA in San Dieguito Lagoon matched well with those predicted using the AdH model by M&N with the zonation and inundation frequency developed by Josselyn and Welchel (1999). In addition, the tidal inundation frequencies for tidal habitats is also supported by work done for San Elijo Lagoon that used data from Joy Zedler as interpreted by Chris Nordby (M&N 2012). Figure 4-3 shows the tidal inundation frequency curves in the proposed project area. The inundation frequency of the ocean tide is also included as a reference. The comparison indicates the tidal range in the marsh is compressed compared to that in the ocean due to the low tide muting and truncation. Figure 4-4 shows the habitat map under the proposed Phase 1 project condition under the no SLR condition.

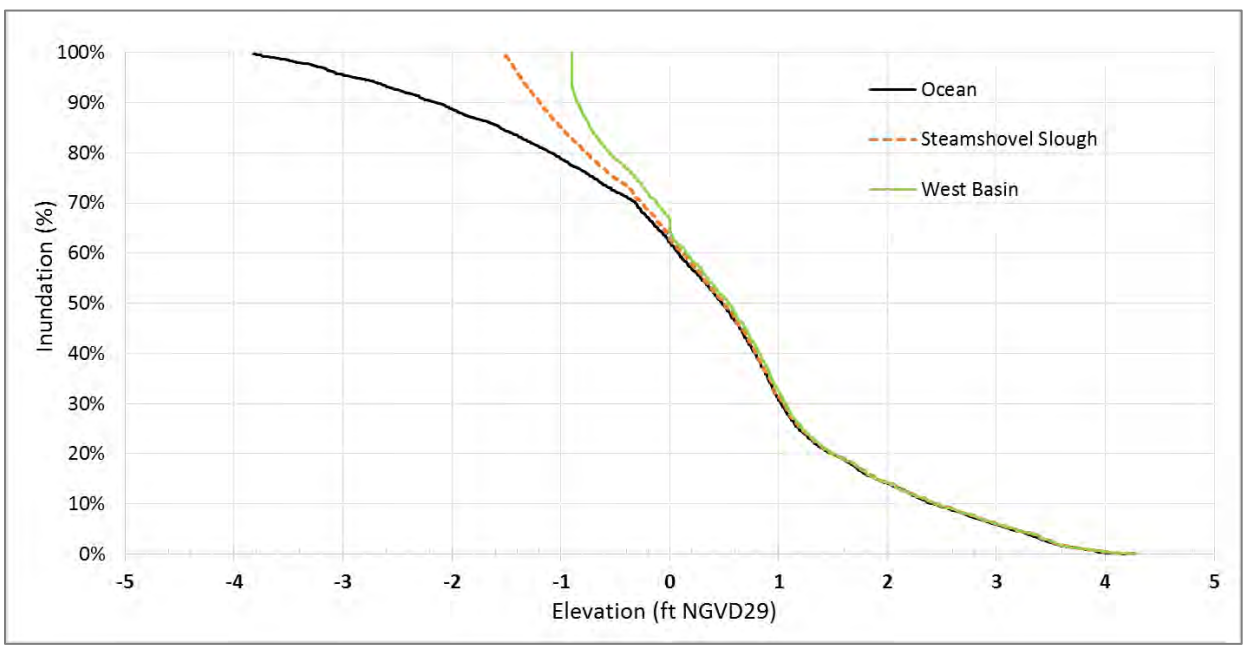
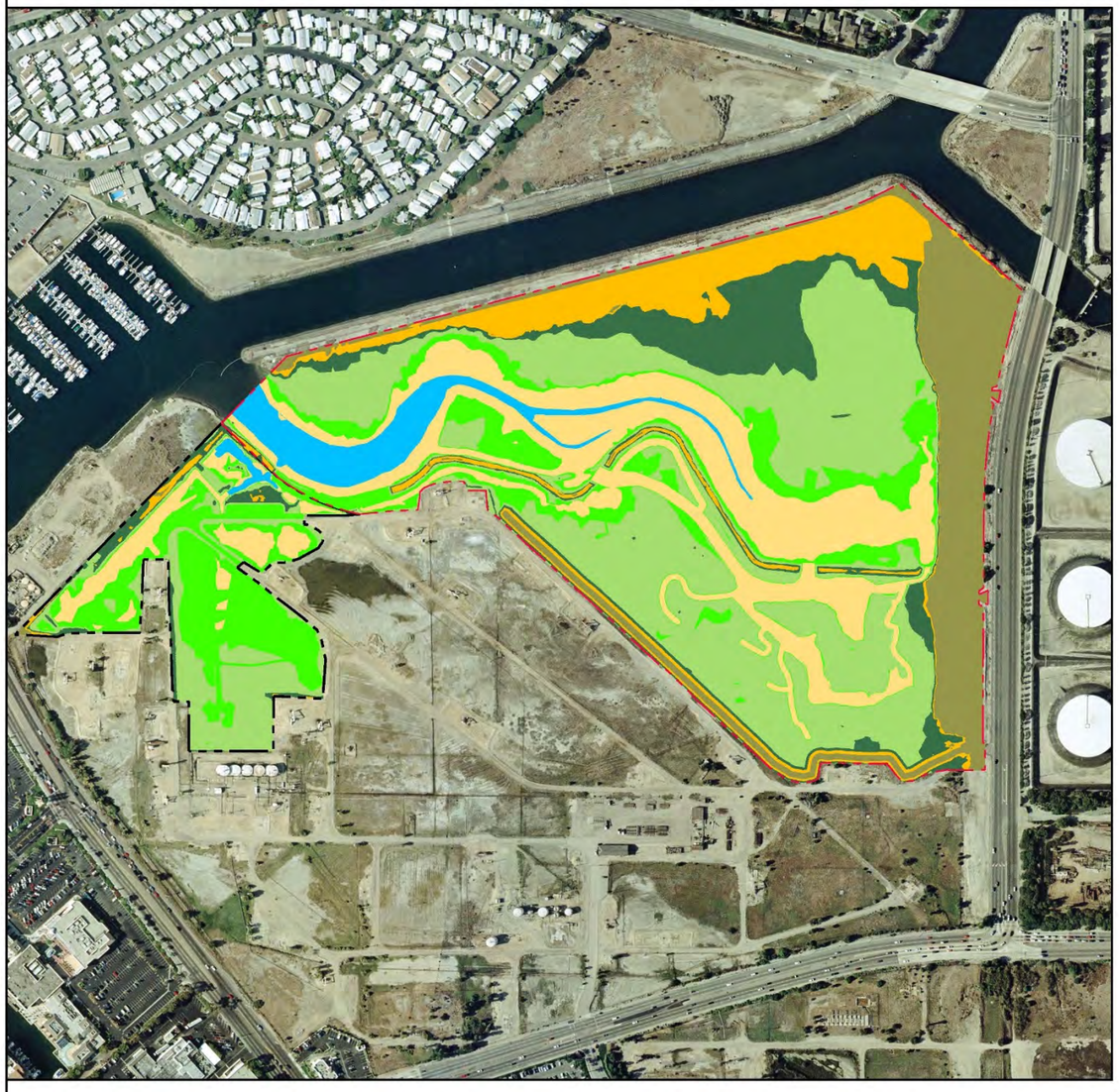


Figure 4-3: Tidal Inundation Frequency for the Phase 1 Project Condition Without SLR



400' 0' 400' 800'

SCALE: 1"=400'

SLOUGH BOUNDARY

SLOUGH ELEV RANGE (FEET)	HABITAT	Area (ac.)
−5.0 – −1.6	SUBTIDAL	2.9
−1.6 – 0.8	MUDFLAT	12.5
0.8 – 1.6	LOW MARSH	6.1
1.6 – 3.4	MID MARSH	21.4
3.4 – 5.1	HIGH MARSH	6.0
5.1 – 7.1	TRANSITIONAL	6.7
7.1 – 16.0 +	UPLAND	8.9

WEST MARSH BOUNDARY

INTERIOR ELEV RANGE (FEET)	HABITAT	Area (ac.)
−1.5 – −0.9	SUBTIDAL	0.2
−0.9 – 0.8	MUDFLAT	1.9
0.8 – 1.6	LOW MARSH	5.0
1.6 – 3.4	MID MARSH	3.4
3.4 – 5.1	HIGH MARSH	0.8
5.1 – 7.1	TRANSITIONAL	0.2
7.1 – 16.0 +	UPLAND	0.0

Note: All Elevations Are Referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

Los Cerritos Wetlands Phase 1 Restoration
With No SLR

Glenn Lukos Associates
moffatt & nichol

Figure 4-4: Habitat Map for the Proposed Phase 1 Project Condition Without SLR

4.1.2 Post-Construction with SLR Conditions

To properly factor SLR into the wetland design and to assess the potential impacts of projected SLR to habitat distributions, six SLR conditions were modeled including: 1, 2, 3, 4, 5, and 5,5 feet of SLR for the proposed Phase 1 project condition. The TEA series shown Figure 3-7 was linearly shifted up by the amount of the corresponding SLR and the resulting series was applied at the AdH model ocean boundary. No riverine storm flow is included for the SLR habitat impact assessment.

Table 4-3 through Table 4-8 present predicted habitat acreage, habitat elevation breaks and inundation frequency for each habitat type and its corresponding habitat elevation range at the proposed wetland under the six different SLR conditions. For example, the inundation frequency for the low-marsh would range from 20% to 40% and its corresponding habitat elevation for the Steamshovel Slough ranges from +1.8 feet to +2.58 feet under the 1-foot SLR condition.

Table 4-3: Habitat Elevation Breaks in Proposed Wetland with 1-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	3.4	100		Lower limit of bathymetry	-1.40	Lower limit of bathymetry	-0.90
Mudflat (Unvegetated)	28.6	100	40	-1.40	1.80	-0.90	1.78
Low-marsh (Cordgrass)	13.3	40	20	1.80	2.58	1.78	2.58
Mid-marsh (Pickleweed)	13.1	20	4	2.58	4.39	2.58	4.38
High-marsh (Pickleweed)	7.7	4	0	4.39	6.10*	4.38	6.10*
Transitional	1.9	0		6.10*	8.10	6.10*	8.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Table 4-4: Habitat Elevation Breaks in Proposed Wetland with 2-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	3.8	100		Lower limit of bathymetry	-1.20	Lower limit of bathymetry	-0.88
Mudflat (Unvegetated)	43.5	100	40	-1.20	2.80	-0.88	2.80
Low-marsh (Cordgrass)	7.2	40	20	2.80	3.57	2.80	3.57
Mid-marsh (Pickleweed)	10.5	20	4	3.57	5.38	3.57	5.38
High-marsh (Pickleweed)	2.2	4	0	5.38	7.10*	5.38	7.10*
Transitional	2.3	0		7.10*	9.10	7.10*	9.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Table 4-5: Habitat Elevation Breaks in Proposed Wetland with 3-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	4.8	100		Lower limit of bathymetry	-0.73	Lower limit of bathymetry	-0.67
Mudflat (Unvegetated)	50.6	100	40	-0.73	3.80	-0.67	3.80
Low-marsh (Cordgrass)	3.5	40	20	3.80	4.57	3.80	4.56
Mid-marsh (Pickleweed)	7.5	20	4	4.57	6.39	4.56	6.38
High-marsh (Pickleweed)	1.7	4	0	6.39	8.10*	6.38	8.10*
Transitional	1.9	0		8.10*	10.10	8.10*	10.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Table 4-6: Habitat Elevation Breaks in Proposed Wetland with 4-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	12.0	100		Lower limit of bathymetry	0.10	Lower limit of bathymetry	0.10
Mudflat (Unvegetated)	47.4	100	40	0.10	4.80	0.10	4.80
Low-marsh (Cordgrass)	6.0	40	20	4.80	5.57	4.80	5.57
Mid-marsh (Pickleweed)	2.1	20	4	5.57	7.37	5.57	7.38
High-marsh (Pickleweed)	2.0	4	0	7.37	9.10*	7.38	9.10*
Transitional	1.3	0		9.10*	11.10	9.10*	11.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Table 4-7: Habitat Elevation Breaks in Proposed Wetland with 5-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	21.3	100		Lower limit of bathymetry	1.05	Lower limit of bathymetry	1.10
Mudflat (Unvegetated)	44.1	100	40	1.05	5.80	1.10	5.80
Low-marsh (Cordgrass)	1.0	40	20	5.80	6.56	5.80	6.56
Mid-marsh (Pickleweed)	1.8	20	4	6.56	8.38	6.56	8.38
High-marsh (Pickleweed)	1.5	4	0	8.38	10.10*	8.38	10.10*
Transitional	2.1	0		10.10*	12.10	10.10*	12.10
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Table 4-8: Habitat Elevation Breaks in Proposed Wetland with 5.5-Foot SLR

Habitat Type	Acreage	% Inundation Frequency		Ele. at Steamshovel Slough (ft, NGVD)		Ele. at West Marsh Area (ft, NGVD)	
		Max	Min	Low	High	Low	High
Subtidal	28.5	100		Lower limit of bathymetry	1.55	Lower limit of bathymetry	1.57
Mudflat (Unvegetated)	37.7	100	40	1.55	6.30	1.57	6.30
Low-marsh (Cordgrass)	0.9	40	20	6.30	7.06	6.30	7.06
Mid-marsh (Pickleweed)	1.8	20	4	7.06	8.87	7.06	8.87
High-marsh (Pickleweed)	1.2	4	0	8.87	10.60*	8.87	10.60*
Transitional	2.3	0		10.60*	12.60	10.60*	12.60
Note*Elevation adjusted based on vegetation survey indicating plants can colonize 0.8' higher than the high tide							

Figure 4-5 through Figure 4-10 show the tidal inundation frequency curve at Steamshovel Slough and West Marsh areas under various SLR conditions as compared to that in the ocean. The acreage of mudflat in West Marsh area does not increase appreciably with a SLR less than 3 feet, and the increase is within the rounding off accuracy of 0.1 acres. Table 4-9 compares high and low tidal elevations and tidal range in the marsh under the proposed project condition to those in the ocean. The tidal range in both Steamshovel Slough and West Marsh increases with SLR until the SLR reaches 4 feet. After that the tidal range becomes constant and almost the same as that in the ocean. Under the current time horizon and with relatively low SLR conditions, the low tide is truncated due to the shallow bathymetry. Therefore, the vertical range of the intertidal vegetation colonization is expected to increase with SLR.

Table 4-9: Comparison of Tidal Range and Elevations in Feet NGVD

Sea Level Condition	Steamshovel Slough			West Marsh Area			Ocean		
	High Tide	Low Tide	Range	High Tide	Low Tide	Range	High Tide	Low Tide	Range
No SLR	4.27	-1.55	5.8	4.28	-0.90	5.2	4.18	-3.89	8.3
+1 SLR	5.30	-1.40	6.7	5.30	-0.90	6.2	5.18	-2.89	8.3
+2 SLR	6.27	-1.18	7.5	6.28	-0.81	7.1	6.18	-1.89	8.3
+3 SLR	7.28	-0.73	8.0	7.27	-0.67	7.9	7.18	-0.89	8.3
+4 SLR	8.28	0.08	8.2	8.28	0.11	8.2	8.18	0.11	8.3
+5 SLR	9.28	1.05	8.2	9.28	1.09	8.2	9.18	1.11	8.3
+5.5 SLR	9.77	1.55	8.2	9.77	1.57	8.2	9.68	1.61	8.3

Possible habitat maps of Phase 1 wetland restoration under six SLR conditions are presented in Figure 4-11 through Figure 4-16. As the sea level gradually rises, both the tide and the tidal range in the marsh areas increase; consequentially, the tidal inundation frequency adjusts and the habitat elevation breaks shift upward. Table 4-10 compares habitat acreage for each habitat category between different sea level conditions, results indicate:

- The subtital area continuously increases with SLR from 3.1 acres under no SLR condition all the way to 28.5 acres with a 5.5-foot SLR.
- The mudflat acreage first gradually increases from 14.4 acres under the no SLR condition to 50.6 acres with a 3-foot SLR, and then gradually decreases to 37.7 acres with a 5.5-foot SLR when some mudflat is converted into subtidal with a continuous increase in SLR.

- The intertidal habitat acreage increases from 57.1 acres to 63.4 acres with a 2-foot SLR, decreases to 57.5 acres with a 4-foot SLR, and then increases again with a 5-foot SLR, then decreases again to 41.6 acres with a 5.5-foot SLR. The acreage changes are results of combined effects of varying bathymetry and SLR.

Overall, wetlands will be skewed toward being subtidal and mudflat areas rather than vegetated marsh as sea level rises.

Table 4-10: Comparison of Habitat Acreage Between Different SLR Conditions

Habitat	No SLR	1' SLR	2' SLR	3' SLR	4' SLR	5' SLR	5.5' SLR
Subtidal	3.1	3.4	3.8	4.8	12	21.3	28.5
Mudflat	14.4	28.6	43.5	50.6	47.4	44.1	37.7
Low-marsh	11.1	13.3	7.2	3.5	6	1	0.9
Mid-marsh	24.8	13.1	10.5	7.5	2.1	1.8	1.8
High-marsh	6.8	7.7	2.2	1.7	2	1.5	1.2
Transitional	6.9	1.9	2.3	1.9	1.3	2.1	2.3
Intertidal Sub-total	57.1	62.7	63.4	63.3	57.5	68.2	41.6

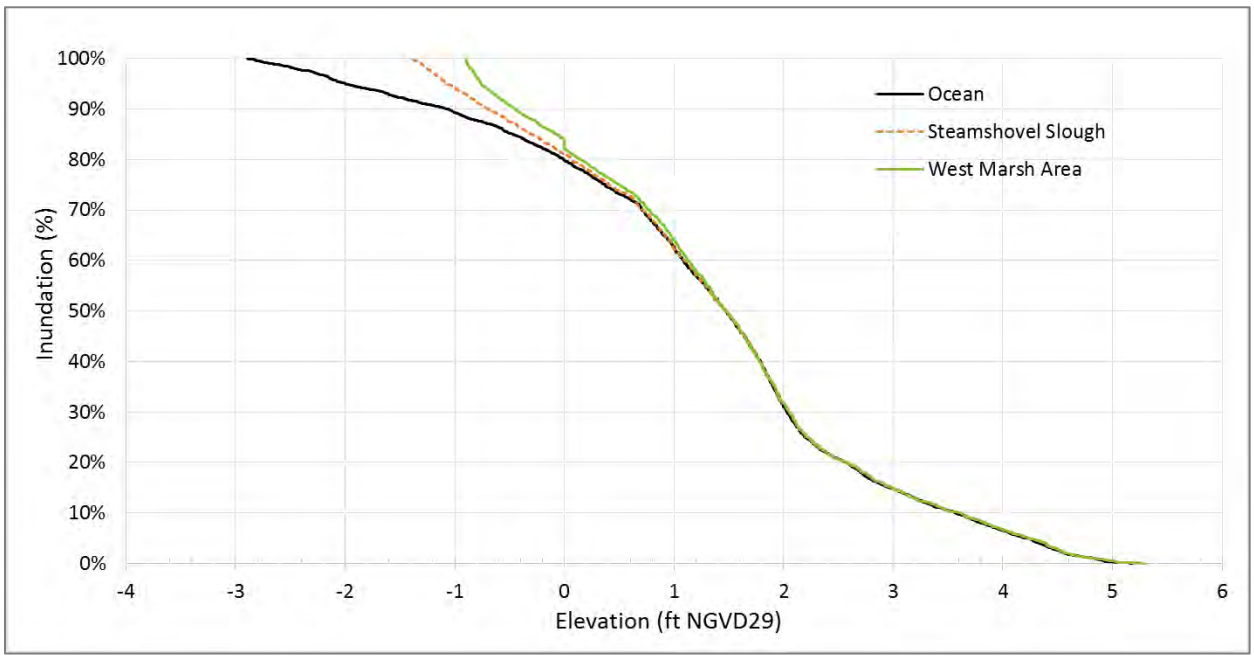


Figure 4-5: Tidal Inundation Frequency for Phase 1 Project Condition with 1-Foot SLR

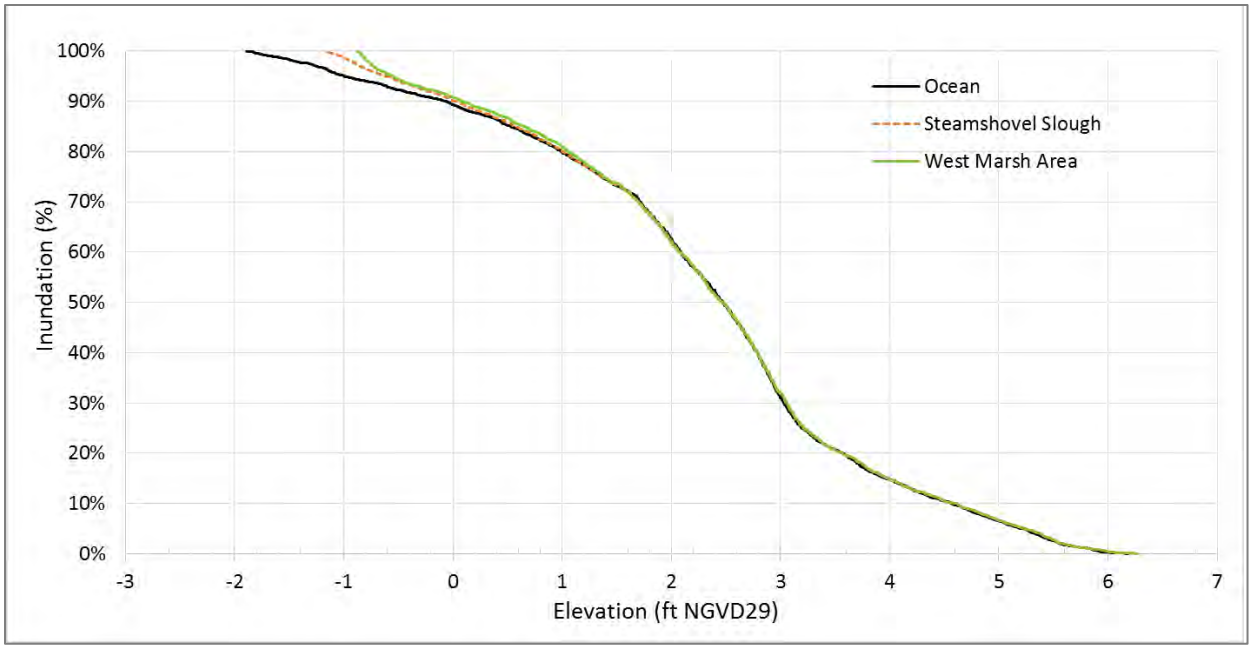


Figure 4-6: Tidal Inundation Frequency for Phase 1 Project Condition with 2-Foot SLR

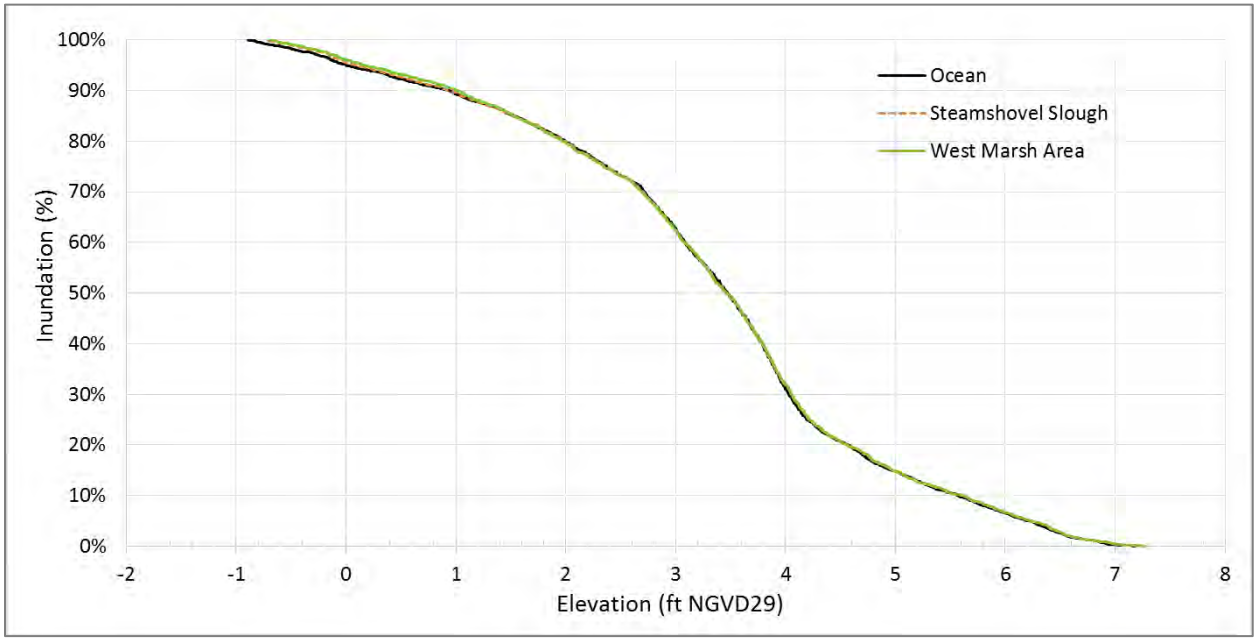


Figure 4-7: Tidal Inundation Frequency for Phase 1 Project Condition with 3-Foot SLR

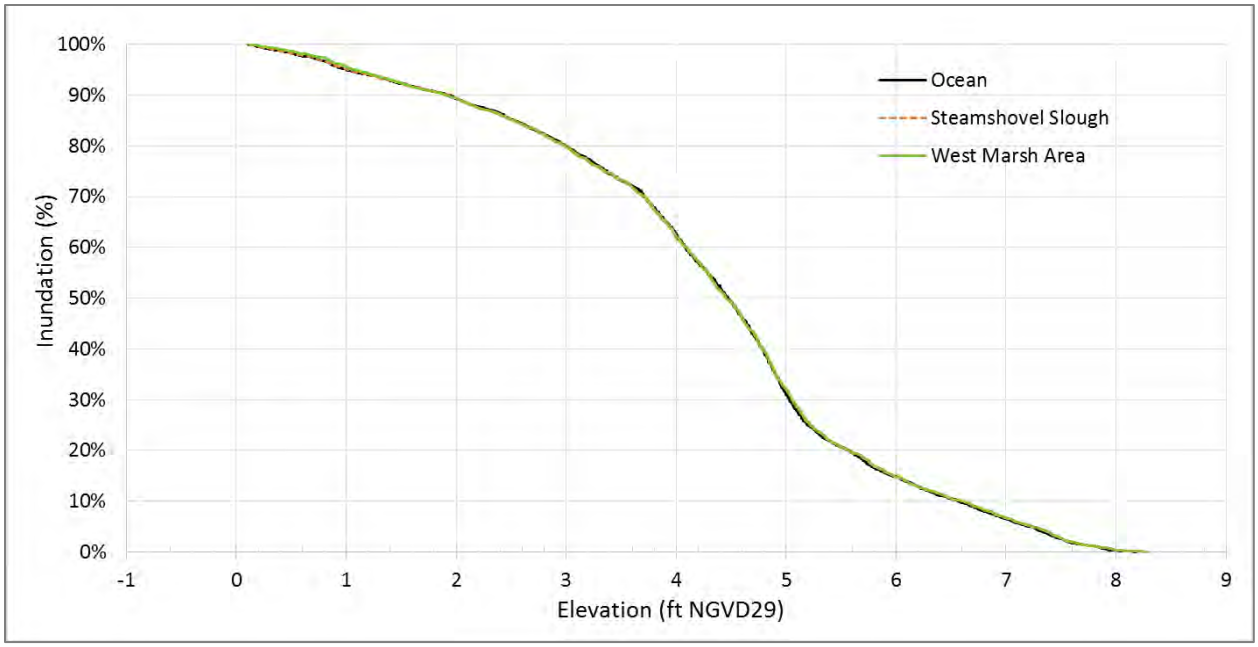


Figure 4-8: Tidal Inundation Frequency for Phase 1 Project Condition with 4-Foot SLR

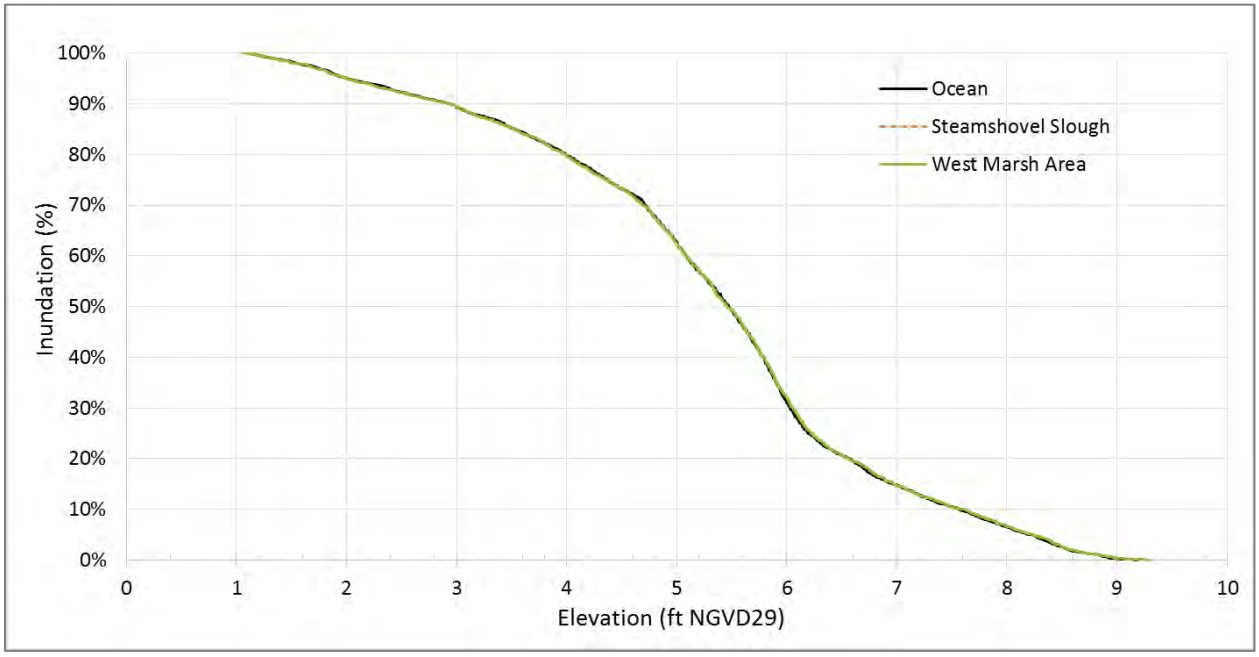


Figure 4-9: Tidal Inundation Frequency for Phase 1 Project Condition with 5-Foot SLR

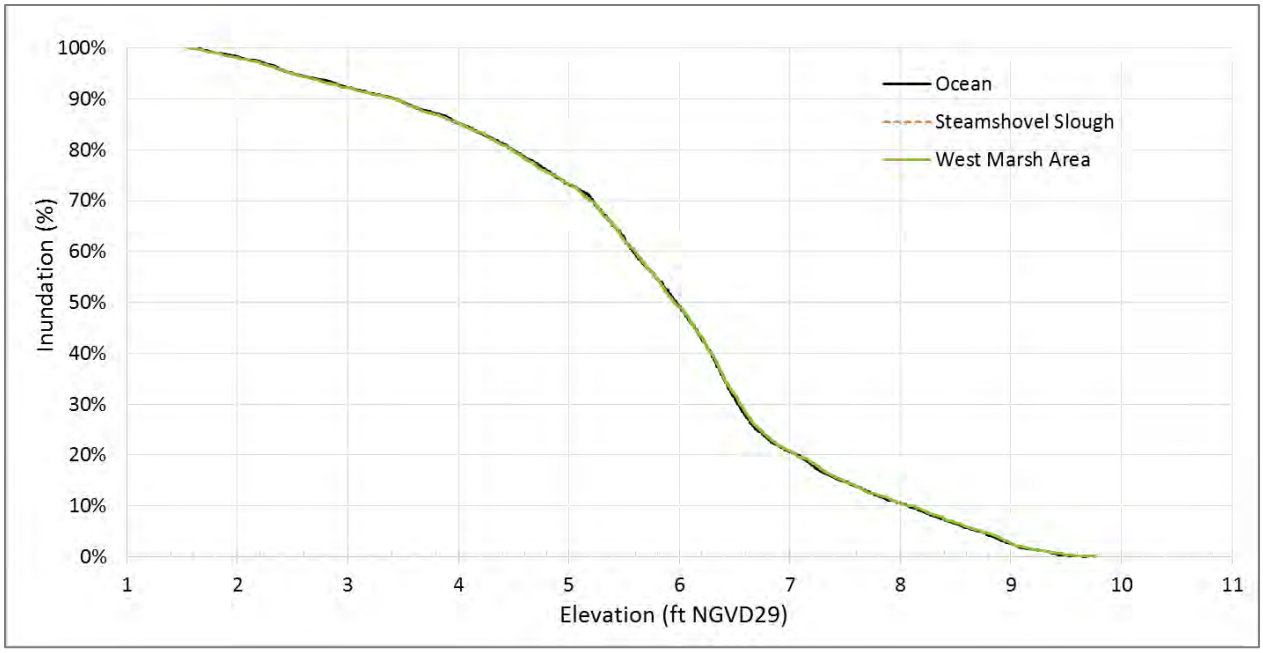


Figure 4-10: Inundation Frequency for Phase 1 Project Condition with 5.5-Foot SLR

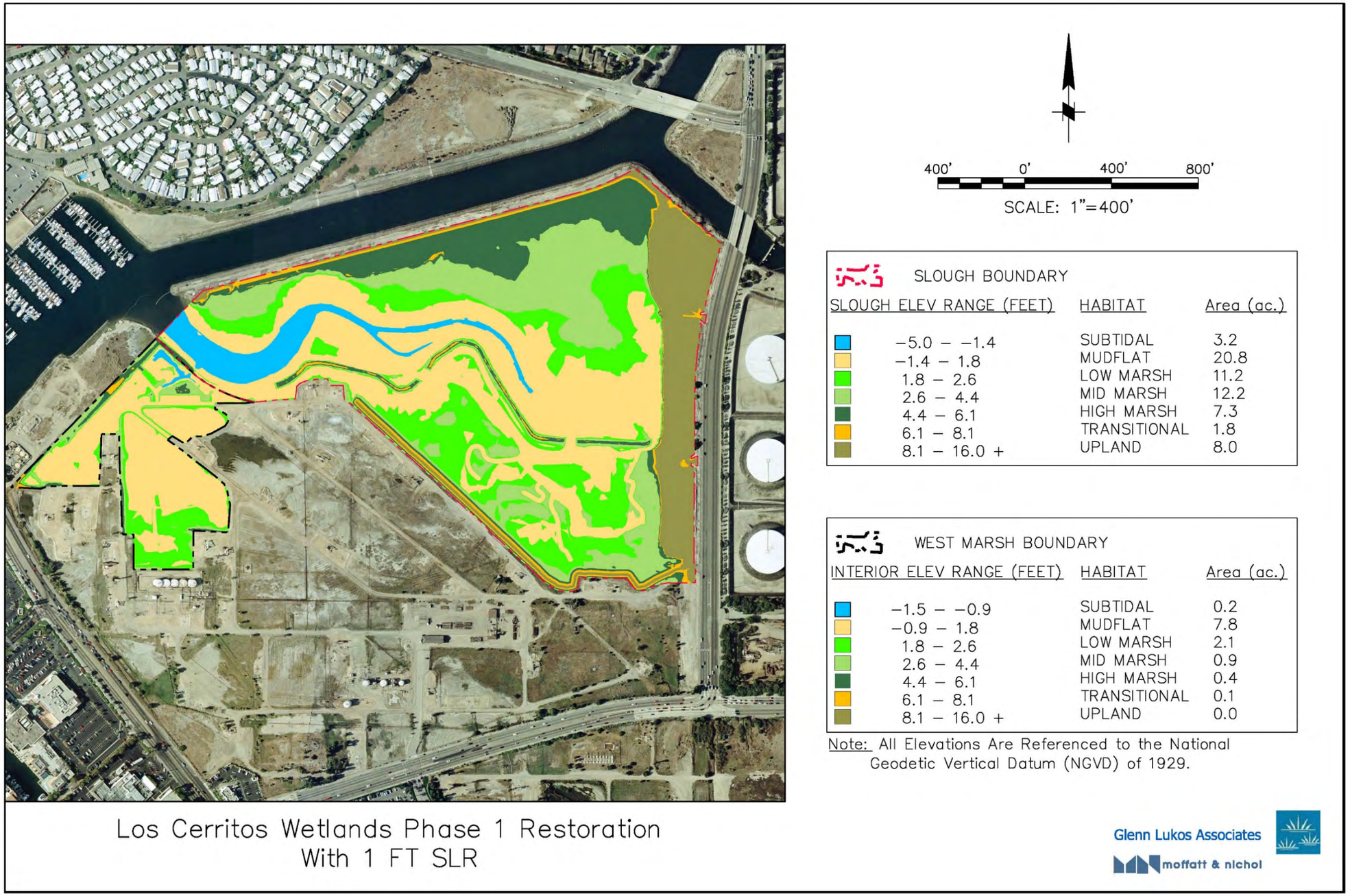


Figure 4-11: Habitat Map for Proposed Phase 1 Project Condition with 1-Foot SLR

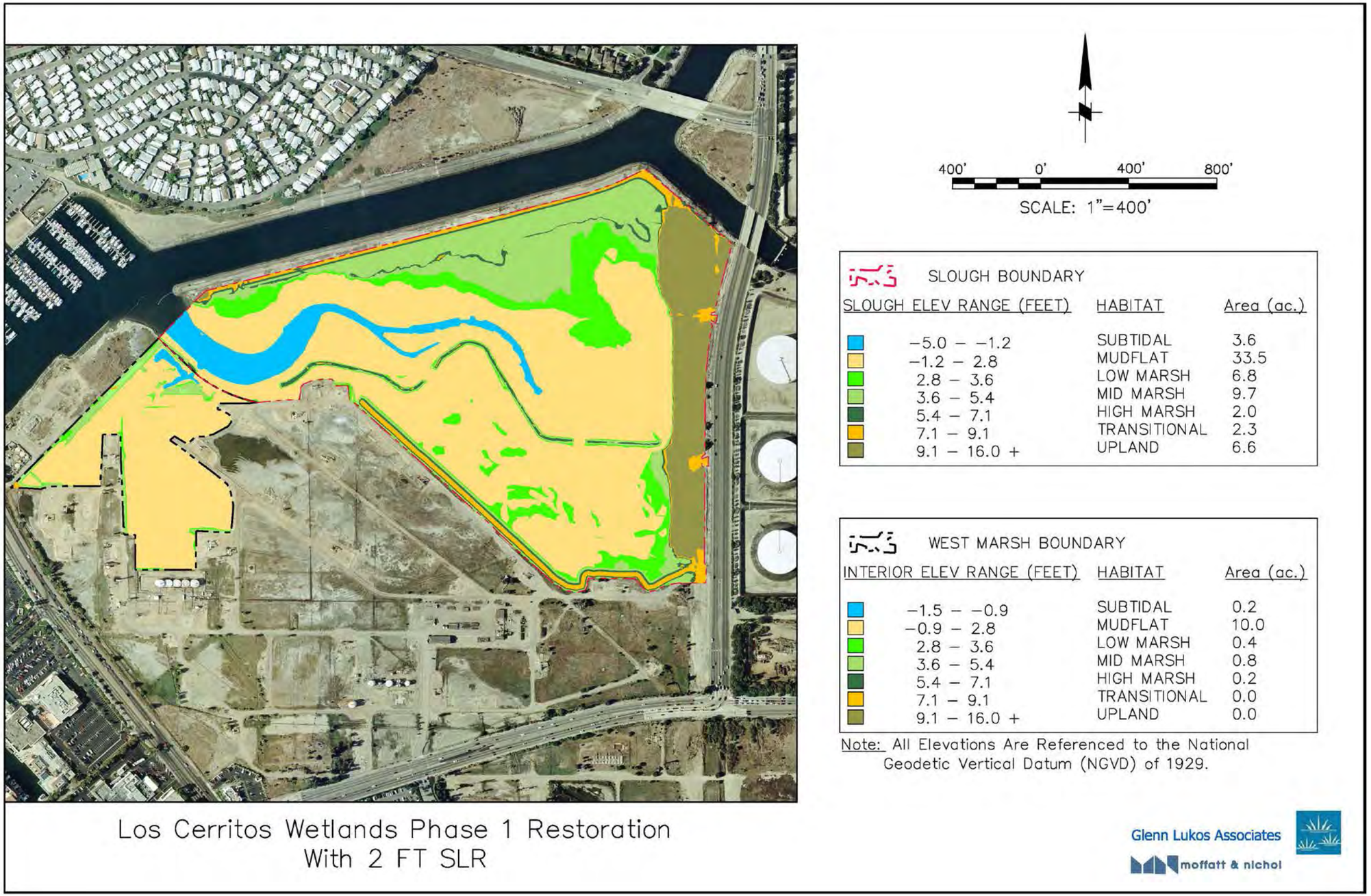
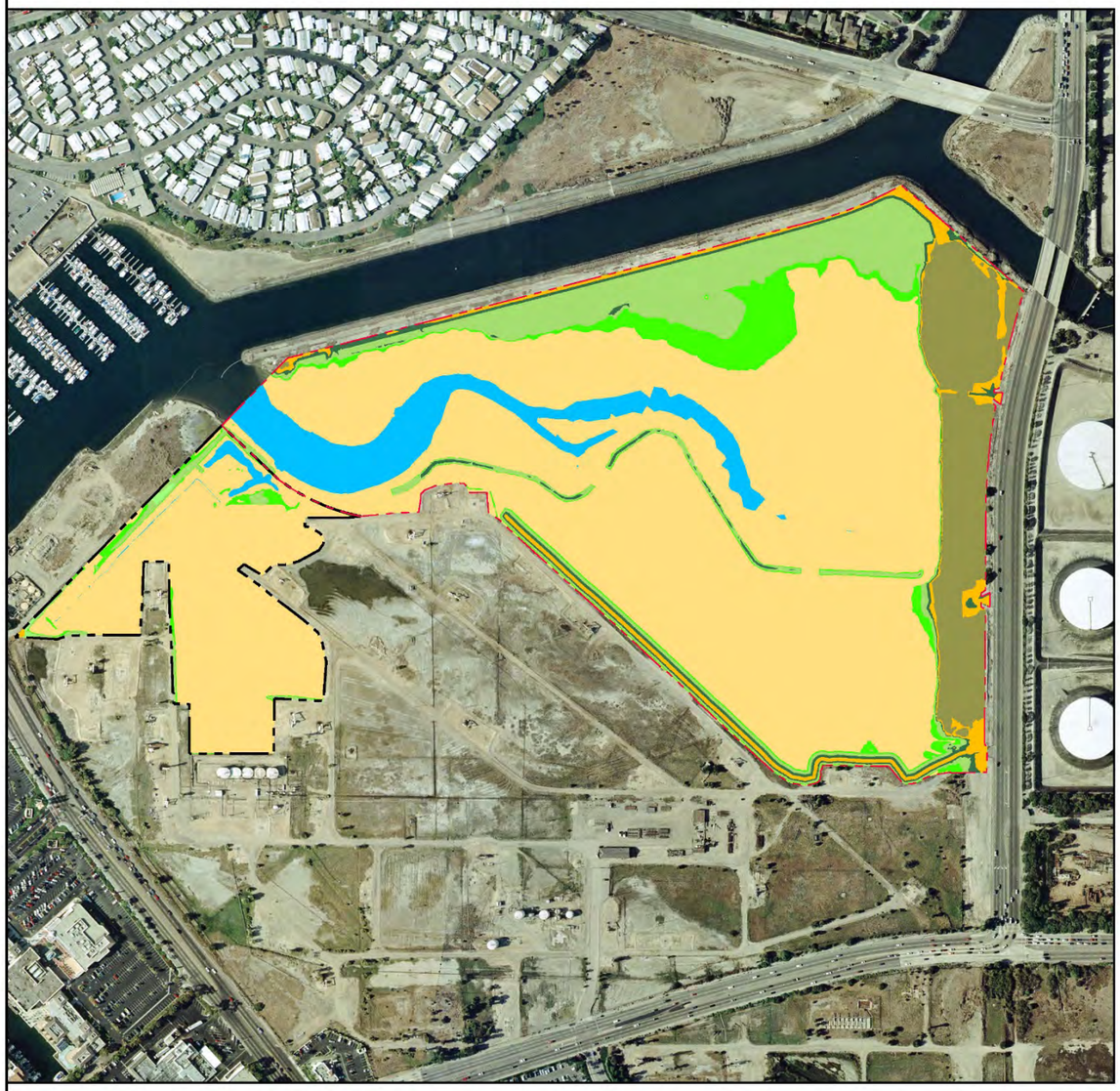


Figure 4-12: Habitat Map for Proposed Phase 1 Project Condition with 2-Foot SLR



400' 0' 400' 800'

SCALE: 1"=400'

SLOUGH BOUNDARY

SLOUGH ELEV RANGE (FEET)	HABITAT	Area (ac.)
−5.0 – −0.7	SUBTIDAL	4.6
−0.7 – 3.8	MUDFLAT	40.2
3.8 – 4.6	LOW MARSH	3.1
4.6 – 6.4	MID MARSH	7.1
6.4 – 8.1	HIGH MARSH	1.6
8.1 – 10.1	TRANSITIONAL	1.9
10.1 – 16.0 +	UPLAND	6.1

WEST MARSH BOUNDARY

INTERIOR ELEV RANGE (FEET)	HABITAT	Area (ac.)
−1.5 – −0.7	SUBTIDAL	0.2
−0.7 – 3.8	MUDFLAT	10.4
3.8 – 4.6	LOW MARSH	0.4
4.6 – 6.4	MID MARSH	0.4
6.4 – 8.1	HIGH MARSH	0.1
8.1 – 10.1	TRANSITIONAL	0.0
10.1 – 16.0 +	UPLAND	0.0

Note: All Elevations Are Referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

Los Cerritos Wetlands Phase 1 Restoration
With 3 FT SLR

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Figure 4-13: Habitat Map for Proposed Phase 1 Project Condition with 3-Foot SLR

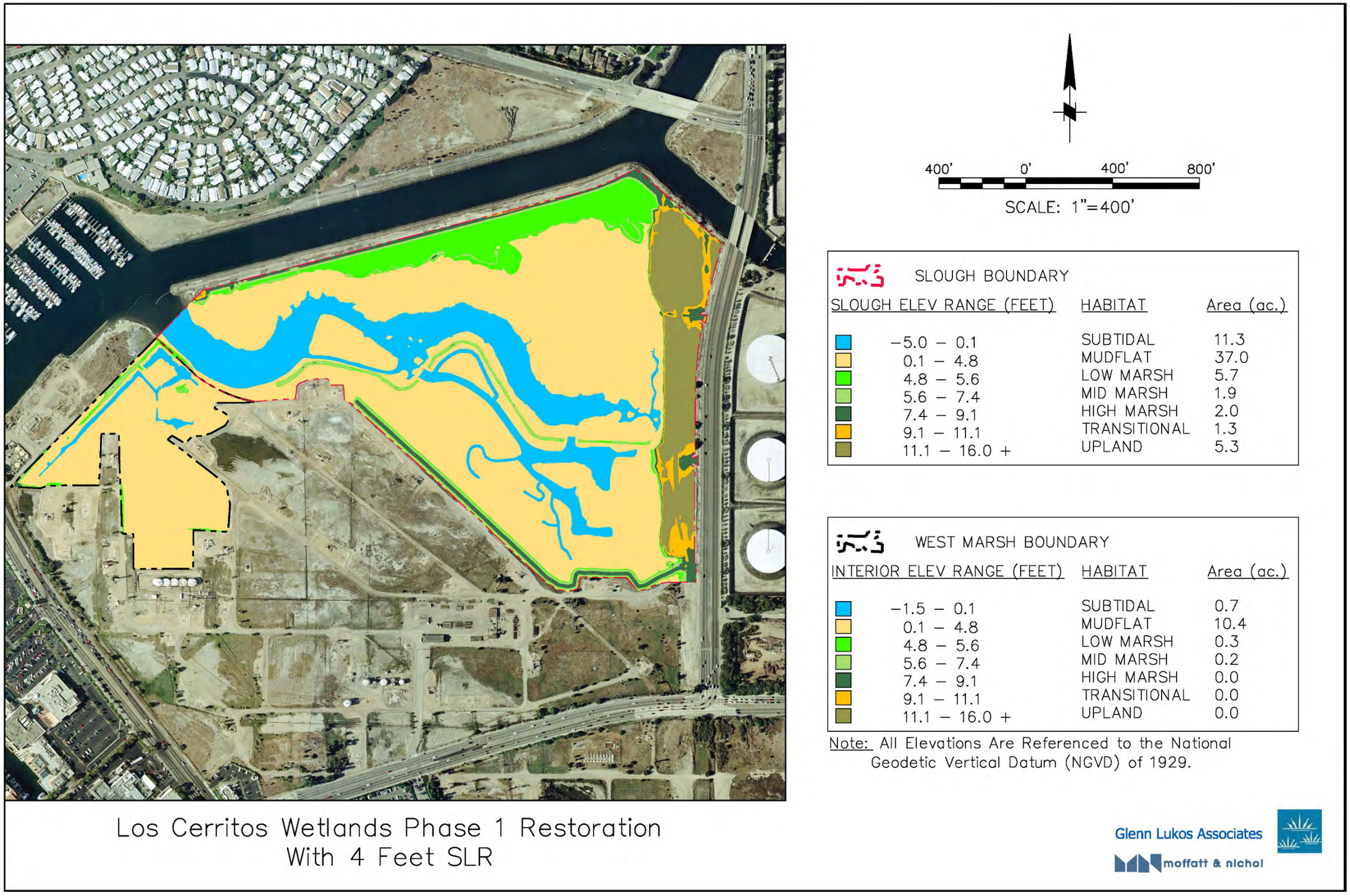
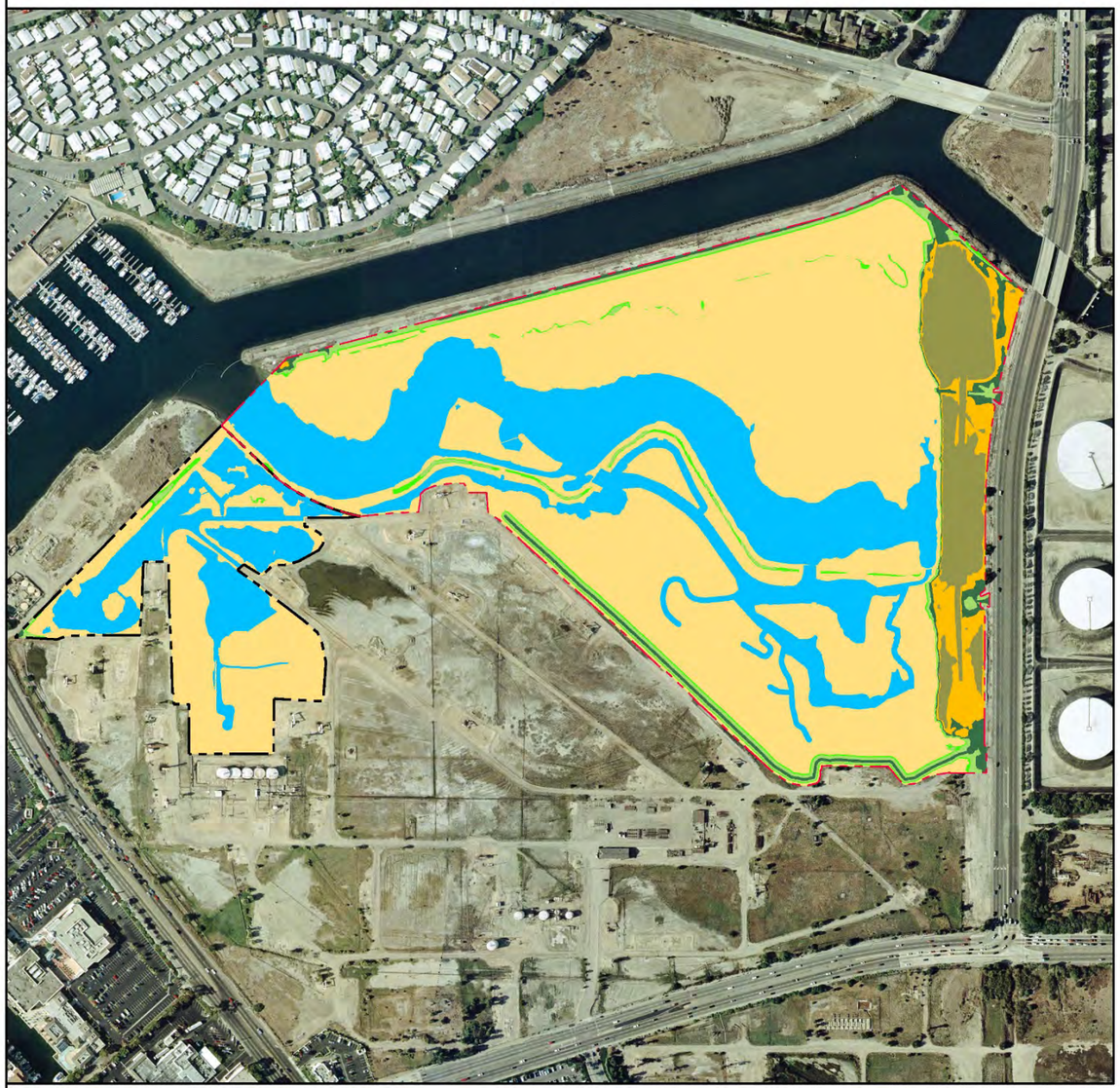


Figure 4-14: Habitat Map for Proposed Phase 1 Project Condition with 4-Foot SLR



400' 0' 400' 800'

SCALE: 1"=400'

SLOUGH PROJECT BOUNDARY

SLOUGH ELEV RANGE (FEET)	HABITAT	Area (ac.)
−5.0 – 1.0	SUBTIDAL	16.6
1.0 – 5.8	MUDFLAT	37.5
5.8 – 6.6	LOW MARSH	0.9
6.6 – 8.4	MID MARSH	1.7
8.4 – 10.1	HIGH MARSH	1.5
10.1 – 12.1	TRANSITIONAL	2.1
12.1 – 16.0 +	UPLAND	4.0

WEST MARSH BOUNDARY

INTERIOR ELEV RANGE (FEET)	HABITAT	Area (ac.)
−1.5 – 1.1	SUBTIDAL	4.7
1.1 – 5.8	MUDFLAT	6.6
5.8 – 6.6	LOW MARSH	0.1
6.6 – 8.4	MID MARSH	0.1
8.4 – 10.1	HIGH MARSH	0.0
10.1 – 12.1	TRANSITIONAL	0.0
12.1 – 16.0 +	UPLAND	0.0

Note: All Elevations Are Referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

Los Cerritos Wetlands Phase 1 Restoration
With 5 FT SLR

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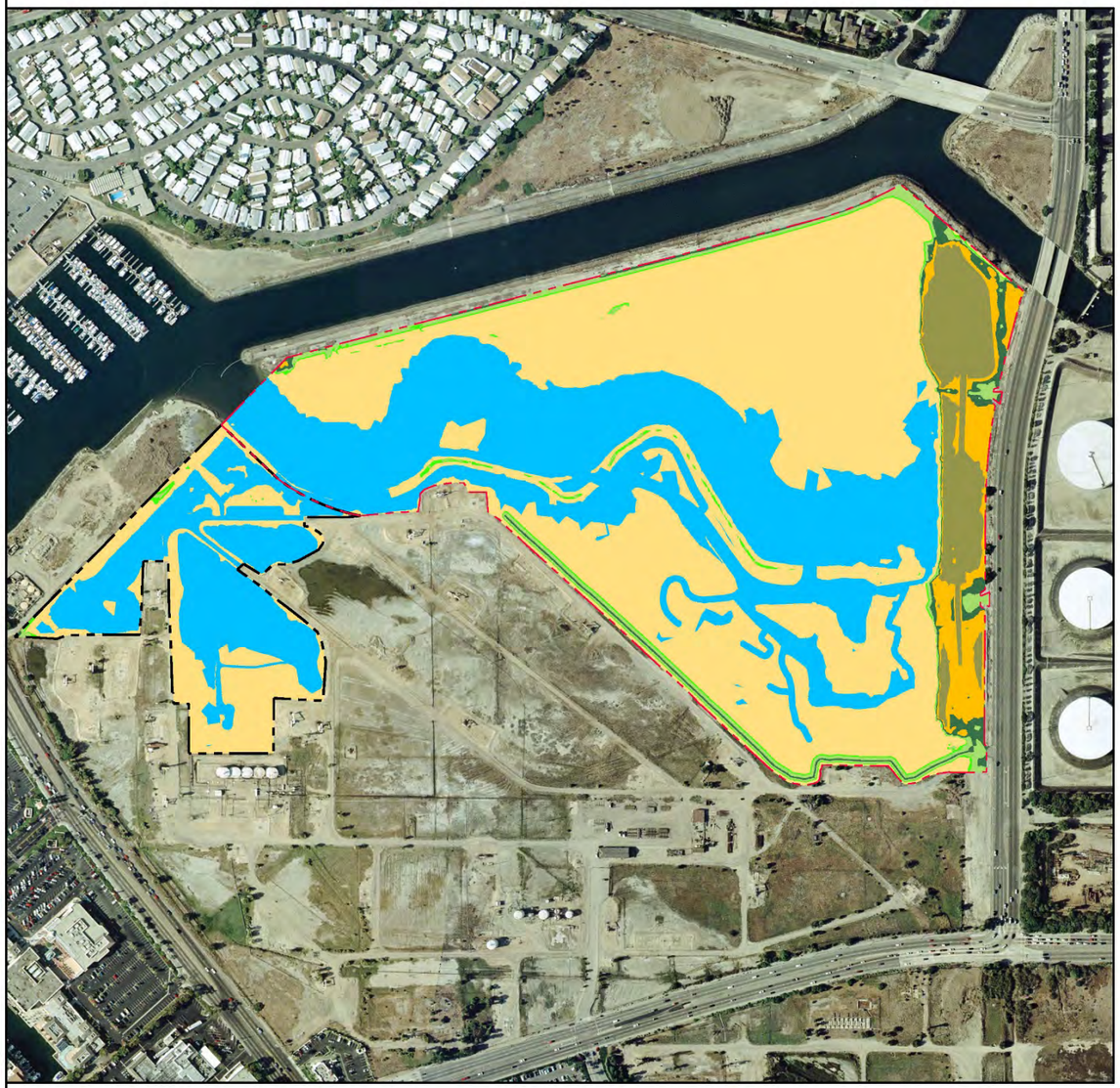
Figure 4-15: Habitat Map for Proposed Phase 1 Project Condition with 5-Foot SLR



400' 0' 400' 800'

SCALE: 1"=400'

SLOUGH BOUNDARY

SLOUGH ELEV RANGE (FEET)	HABITAT	Area (ac.)
−5.0 – 1.6	SUBTIDAL	21.5
1.6 – 6.3	MUDFLAT	33.3
6.3 – 7.1	LOW MARSH	0.8
7.1 – 8.9	MID MARSH	1.8
8.9 – 10.6	HIGH MARSH	1.2
10.6 – 12.6	TRANSITIONAL	2.3
12.6 – 16.0 +	UPLAND	3.6

WEST MARSH BOUNDARY

INTERIOR ELEV RANGE (FEET)	HABITAT	Area (ac.)
−1.5 – 1.6	SUBTIDAL	7.0
1.6 – 6.3	MUDFLAT	4.4
6.3 – 7.1	LOW MARSH	0.1
7.1 – 8.9	MID MARSH	0.0
8.9 – 10.6	HIGH MARSH	0.0
10.6 – 12.6	TRANSITIONAL	0.0
12.6 – 16.0 +	UPLAND	0.0

Note: All Elevations Are Referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

Los Cerritos Wetlands Phase 1 Restoration
With 5.5 FT SLR

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Figure 4-16: Habitat Map for Proposed Phase 1 Project Condition with 5.5-Foot SLR

4.2 Impacts of the Proposed Project to Adjacent Properties

To assess potential flood risk impacts of the proposed project to adjacent roadways and developrment in the current time horizon and in year 2060, AdH modeling simulations were performed for the following four scenarios:

a. The current no SLR condition,
b. The lower bound of SLR projection of 0.5 feet in year 2060,
c. The upper bound of SLR projection of 2.6 feet in year 2060, and
d. The upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm in Los Cerritos Channel.

The average spring high tide series was applied at the model ocean boundary for the no SLR condition. The average spring high tide series was shifted up linearly by the amount of SLR for the SLR conditions modeling. The modeling results at Steamshovel Slough, shown in Figure 4-1, are listed in Table 4-11. The comparison indicates that the water levels between with and without project conditions are essentially the same for all four scenarios, and the difference is well within the model round off error. This comparison indicates that the proposed project would not have any measurable impact to the tide and stormwater levels in the Alamitos Bay hydraulics system.

Table 4-11: Water Surface Elevations at the Synergy Site (feet NGVD29)

SLR Scenarios	Existing No Project	Proposed Project
No SLR	4.28	4.27
With a 0.5 ft SLR (Lower Bound)	4.78	4.76
With a 2.6 ft SLR (Upper Bound)	6.89	6.87
With a 2.6 ft SLR + 50-yr Storm	7.09	7.10

Based on the above modeling results, the interim berm separating the two project phases will be designed with a crest elevation of +9.0 feet NGVD29 . As discussed in Section 3.2, the measured highest and 1% high tidal elevation are +5.29 and +5.18 feet, respectively. The FEMA 1% base flood elevation is +5.58 feet. The FEMA 1% base flood elevation controls the flood protection requirement in this case, and the interim berm would have more than 3-feet of freeboard. With a 2.6 feet of SLR in year 2060, the projected 1% base flood elevation due to coastal flooding will be at +8.18 feet (5.58+2.6 feet), which will still be lower than the proposed berm elevation of +9.0 feet. Without the proposed project and the interim berm, an +8.18 foot water level would overtop both the Pacific Coast Highway (PCH) and 2nd Street; hence, the proposed project with the proposed interim berm would improve the flood protection in the area. Since FEMA does not consider SLR in floodplain mapping studies and assessing flood risk under the 1% annual chance coastal flood with SLR is beyond FEMA requirement, no inundation map is prepared for this scenario.

The modeling was performed with an average spring high tide since it would be overly conservative for the design of an interim berm to assume the extreme fluvial storm occurs coincident with the extreme high tide condition with an upper end of the SLR projection (very low probability). Based on the above modeling results, inundation maps were prepared for the existing and proposed project conditions for the following three scenarios:

a. The lower bound of SLR projection of 0.5 feet in year 2060
b. The upper bound of SLR projection of 2.6 feet in year 2060, and
c. The upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm from Los Cerritos Channel.

Figure 4-17 through Figure 4-22 show inundation maps in the proposed project area for both no-project existing conditions and proposed project conditions under the three scenarios described above.

In summary, the proposed project would not affect adjacent roadways and properties including the Phase 2 Synergy site, LCWA site, Pumpkin Patch site, and City's 33 acres site under the projected 2.6 feet of SLR together with a 50-year storm in year 2060. For the no-project existing condition, both storm and tidal waters coming from Steamshovel Slough will be contained within the Synergy site without overtopping surrounding streets (Pacific Coast Highway, Shopkeeper Road, 2nd Street, and Studebaker Road). However, the west bound lanes of 2nd Street just east of PCH may be inundated under the scenarios of 2.6 feet of SLR and 2.6 feet of SLR combined with the 50-year stormflow. These findings are consistent with results of the City SEADIP study. For the proposed project condition, both storm and tide water would be contained within the Phase 1 property boundary, as the proposed berm along the Phase 1 boundary will have an elevation of +9.0 ft NGVD29, which is approximately 2 feet above the water level under the upper bound of the SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm condition. Therefore, the proposed Phase 1 project with the interim berm would improve the flood protection of the Phase 2 area, PCH and 2nd Street.

Future conditions beyond year 2060 would be assessed at that time to determine if additional SLR adaptation measures may be needed to protect sensitive areas on-site and surrounding areas. Such measures may include internal and/or perimeter dikes and high ground to control inundation and habitat distributions. With regard to relocation of the Visitor's Center in the Phase 2 area, it is understood that the proposed project would elevate the building at the time it is relocated to accommodate the upper end of the sea level rise scenario in the year 2100, which is to approximately +5.5 feet. This would preempt the need for future sea level rise adaptations to the building.

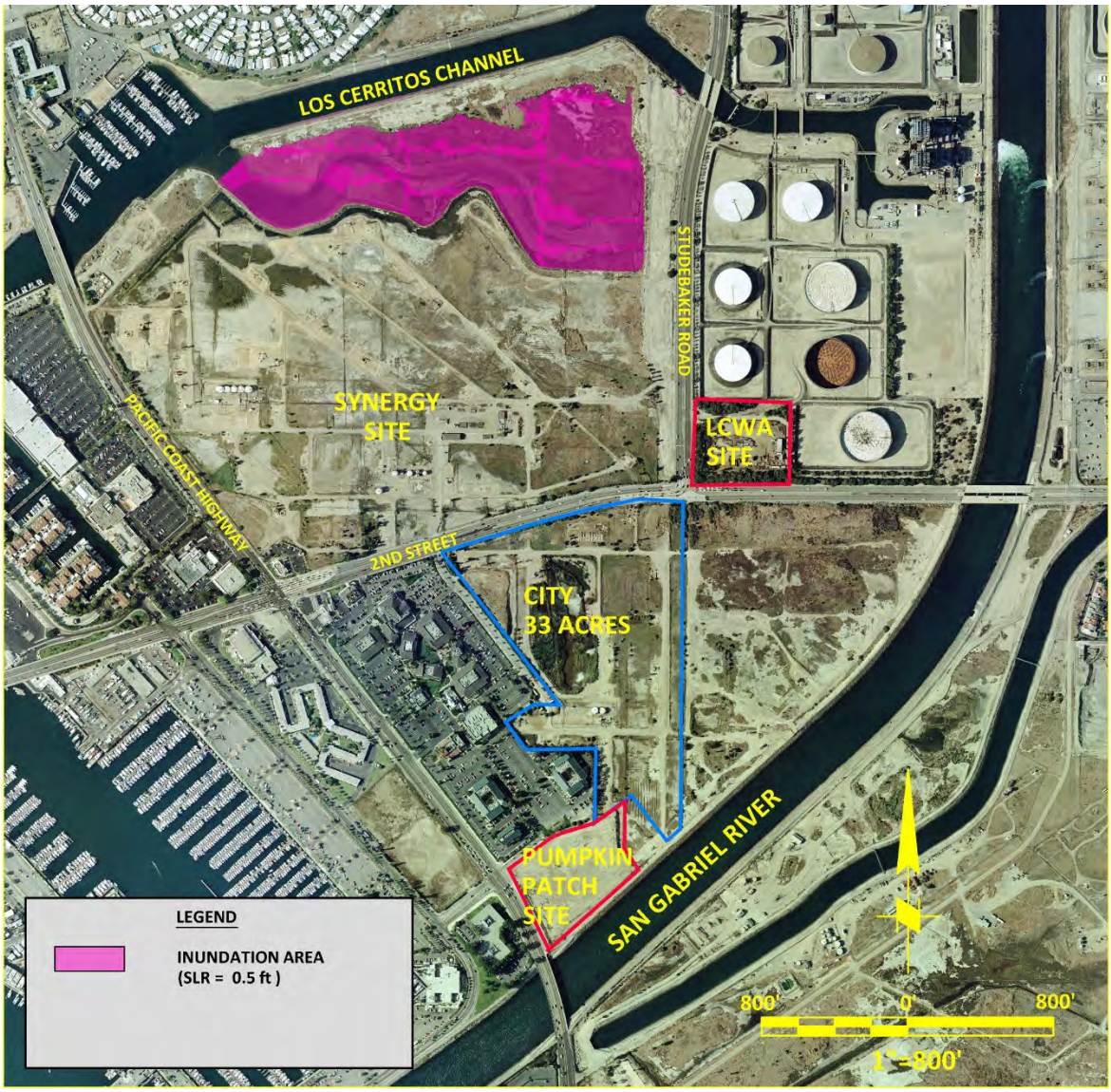


Figure 4-17: Possibly Inundated Area with 0.5 Feet SLR, No-Project Existing Conditions

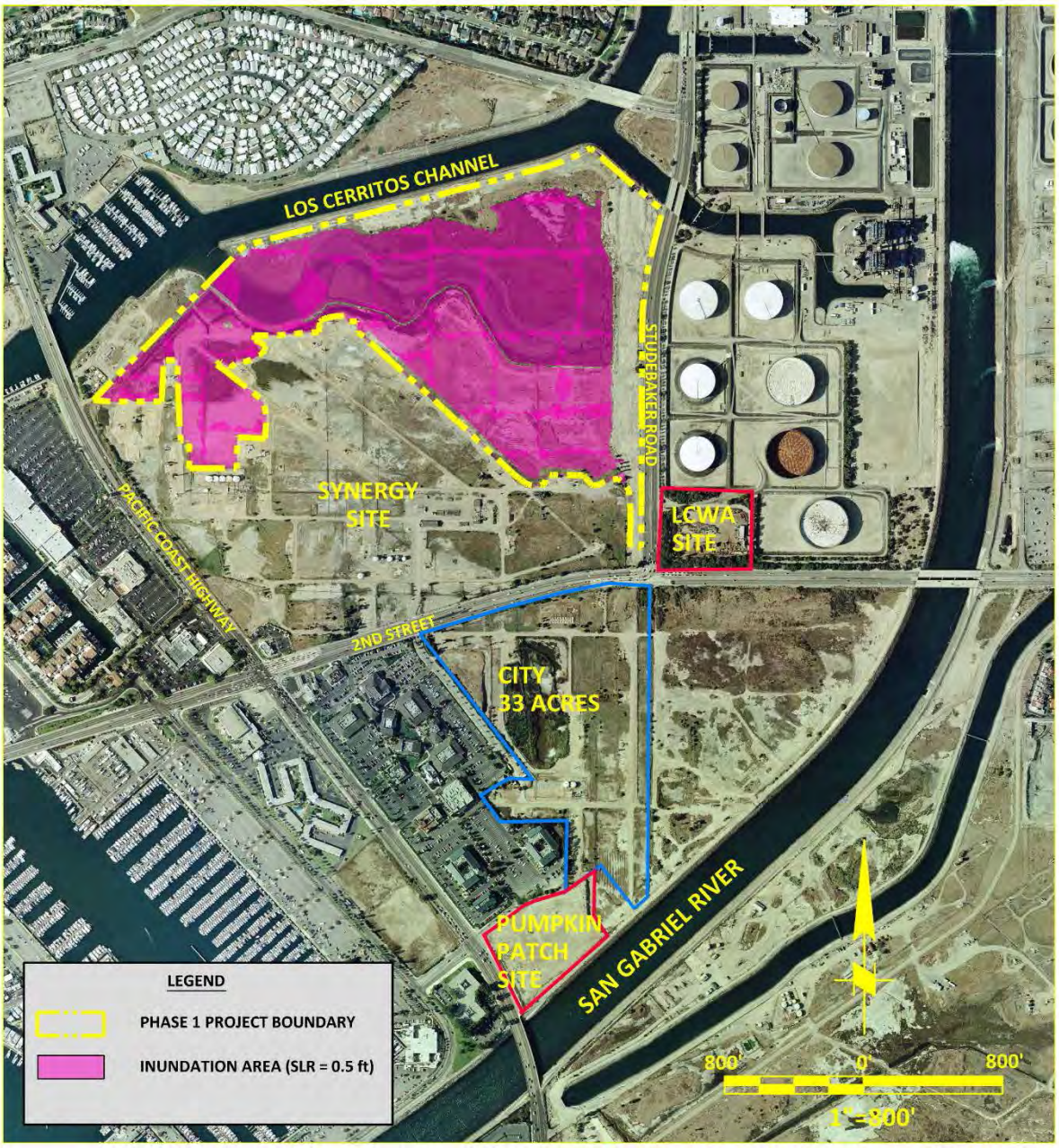


Figure 4-18: Possibly Inundated Area with 0.5 Feet SLR, Proposed Project Conditions

Figure 4-19: Possibly Inundated Area with 2.6 Feet SLR, No-Project Existing Conditions

Figure 4-20: Possibly Inundated Area with 2.6 Feet SLR, Proposed Project Conditions

Figure 4-21: Possibly Inundated Area with 2.6 Feet SLR and 50-Year Stormflow, No-Project Existing Conditions

Figure 4-22: Possibly Inundated Area with 2.6 Feet SLR and 50-Year Stormflow, Proposed Project Conditions

4.3 Impacts of Proposed Restoration to Steamshovel Slough

4.3.1 Habitat Impacts

The potential impacts of the proposed restoration to Steamshovel Slough are assessed by comparing the tidal range and inundation frequency in the slough under the current sea level

condition for both existing and proposed conditions. The average spring tidal range in the slough is 5.97 feet under the existing no-project condition and 5.82 feet under the proposed condition. The range shown in Table 4-12 is reduced by 2.5%, which is relatively small. The comparison of inundation frequency between with and without project conditions is shown in Figure 4-23. The low tide is muted 0.1 feet more under the proposed project condition due to an increase in the tidal prism, but the high tide is not affected.

Overall, there is a slight impact with a tidal range reduction of 2.5%, but the impact is very small compared to additional intertidal habitat being created in the proposed restoration project, and more than offset by proposed new habitat areas. Also, this impact will be slightly reduced under the SLR condition with improvement in overall tidal circulation and exchange.

Table 4-12: Comparison of Tidal Range in Steamshovel Slough

Condition	Tidal Elevation (ft, NGVD)		Tide Range (ft)	Tide Range Percent Change
	High Tide	Low Tide		
Existing No-Project	4.28	-1.69	5.97	N/A
Proposed Project	4.27	-1.55	5.82	2.5%

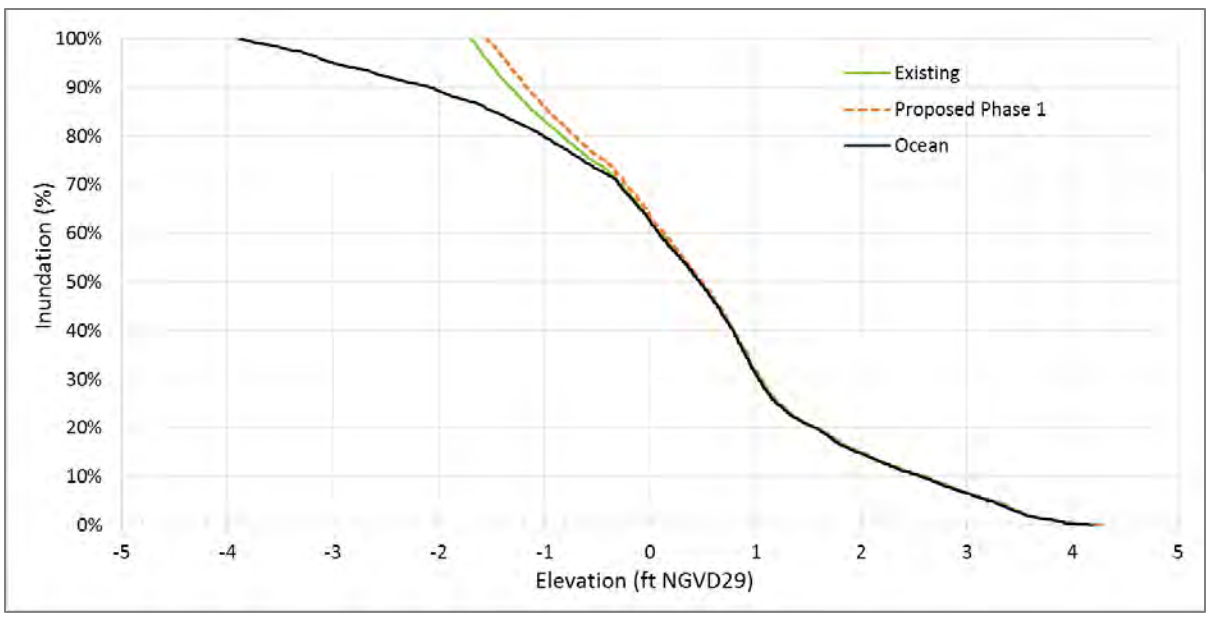


Figure 4-23: Comparison of Inundation Frequency Between Existing No-Project and Proposed Project Conditions

4.3.2 Potential Scour Impacts

To determine extreme tide velocities, an AdH model run was performed by applying the measured highest tidal series (shown in Figure 3-8) at the model ocean boundary for the no SLR condition. Under the SLR conditions, the velocity will be slightly reduced due to the water depth increase. Tidal velocities under both the TEA and extreme tide conditions under the current time horizon were extracted from the AdH model results. Figure 4-24 shows locations where velocities are

extracted and are compared between existing no-project and proposed Phase 1 project conditions. Velocities under both the TEA tide and extreme tide conditions are shown in Table 4-13. With the proposed restoration, both peak flood and ebb tide velocities would increase in the main channel of Steamshovel Slough. Although these velocities may be high enough to mobilize loose sandy materials and may cause some minor channel adjustment to form new equilibrium conditions, these velocities are not high enough to cause wide-spread erosion nor would require erosion and/or bank protection. Similarly, velocities at Points 3, 4 and 5, where the proposed marsh connects to the Steamshovel Slough, are all less than 1.5 fps and therefore non-erosive. Peak flood and ebb velocity distributions for both the TEA and extreme tidal conditions are presented in Figure 4-25 through Figure 4-28. Velocities at locations away from the main channel and connections are lower than those in the main channel. Therefore, no erosion protection countermeasures are required for the proposed restoration project.

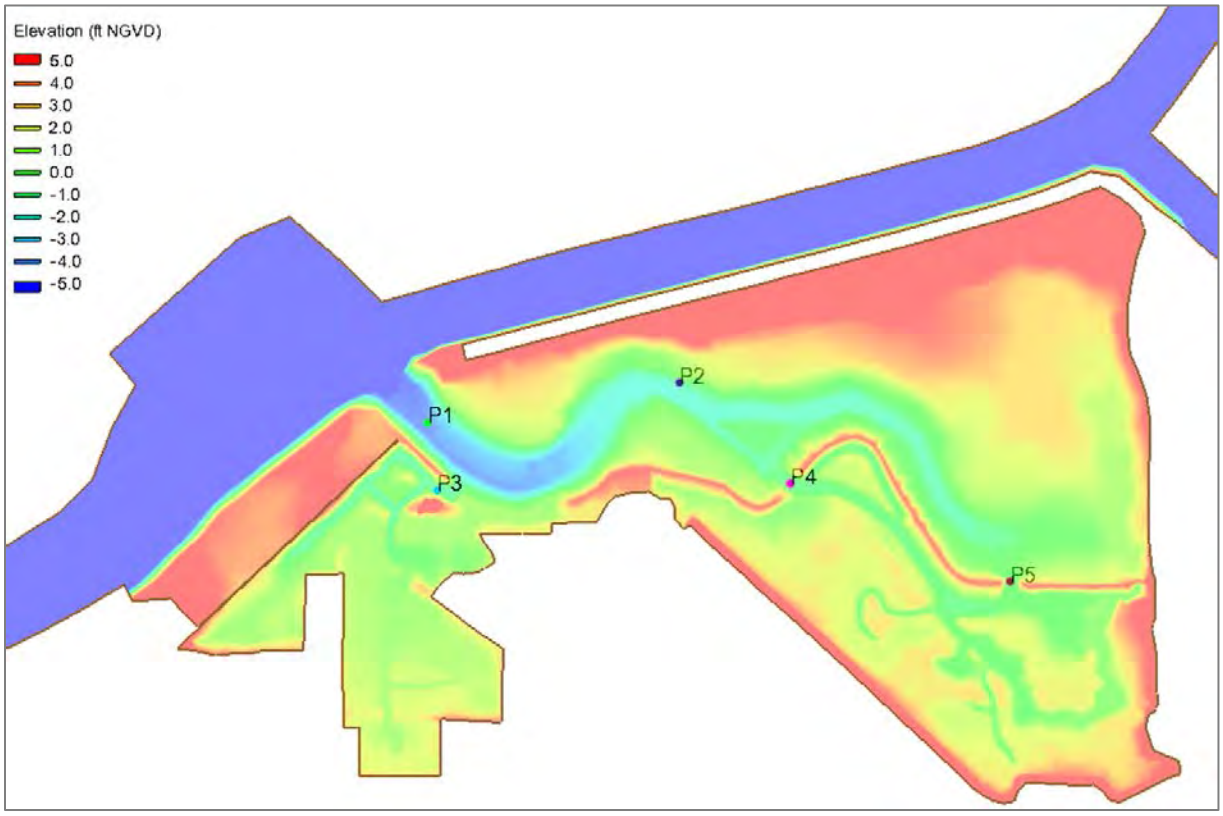
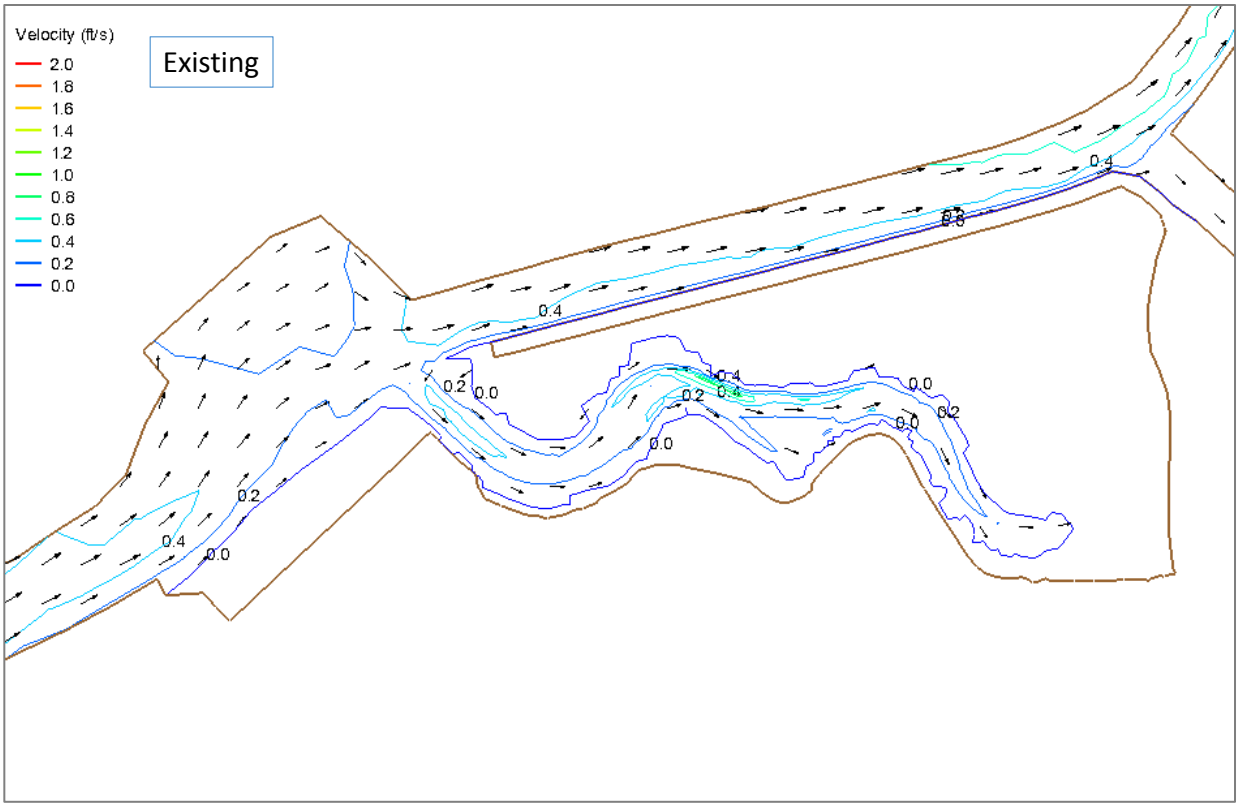


Figure 4-24: Velocity Gage Locations

Table 4-13: Comparison of Velocity Between Existing and Proposed Project Conditions

Point	TEA Tide - Existing		TEA Tide - Phase 1		Extreme Tide - Existing		Extreme Tide - Phase 1	
	Peak Flood (ft/s)	Peak Ebb (ft/s)	Peak Flood (ft/s)	Peak Ebb (ft/s)	Peak Flood (ft/s)	Peak Ebb (ft/s)	Peak Flood (ft/s)	Peak Ebb (ft/s)
P1	0.60	0.83	1.15	1.55	0.71	0.99	1.30	1.79
P2	0.86	1.13	1.19	1.65	0.93	1.28	1.21	1.96
P3	N/A	N/A	1.06	1.21	N/A	N/A	1.18	1.36
P4	N/A	N/A	1.07	1.28	N/A	N/A	1.18	1.39
P5	N/A	N/A	0.74	0.67	N/A	N/A	0.87	0.76

Note: N/A indicates no data available



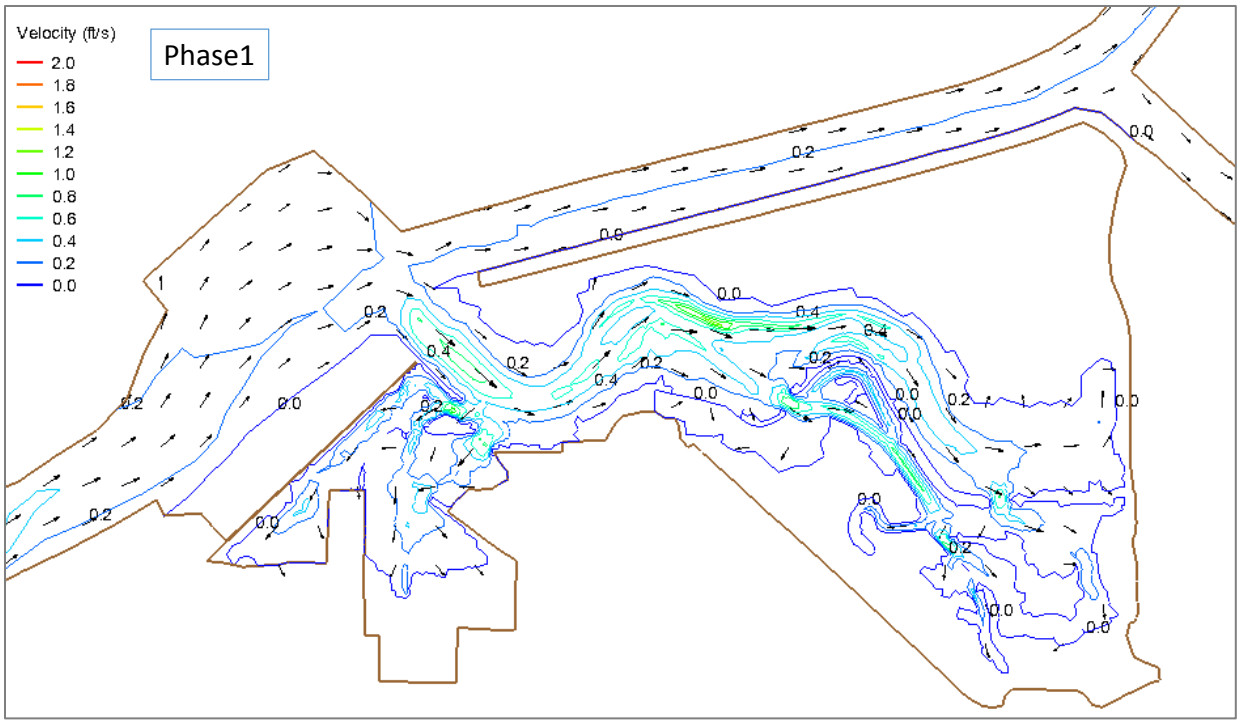
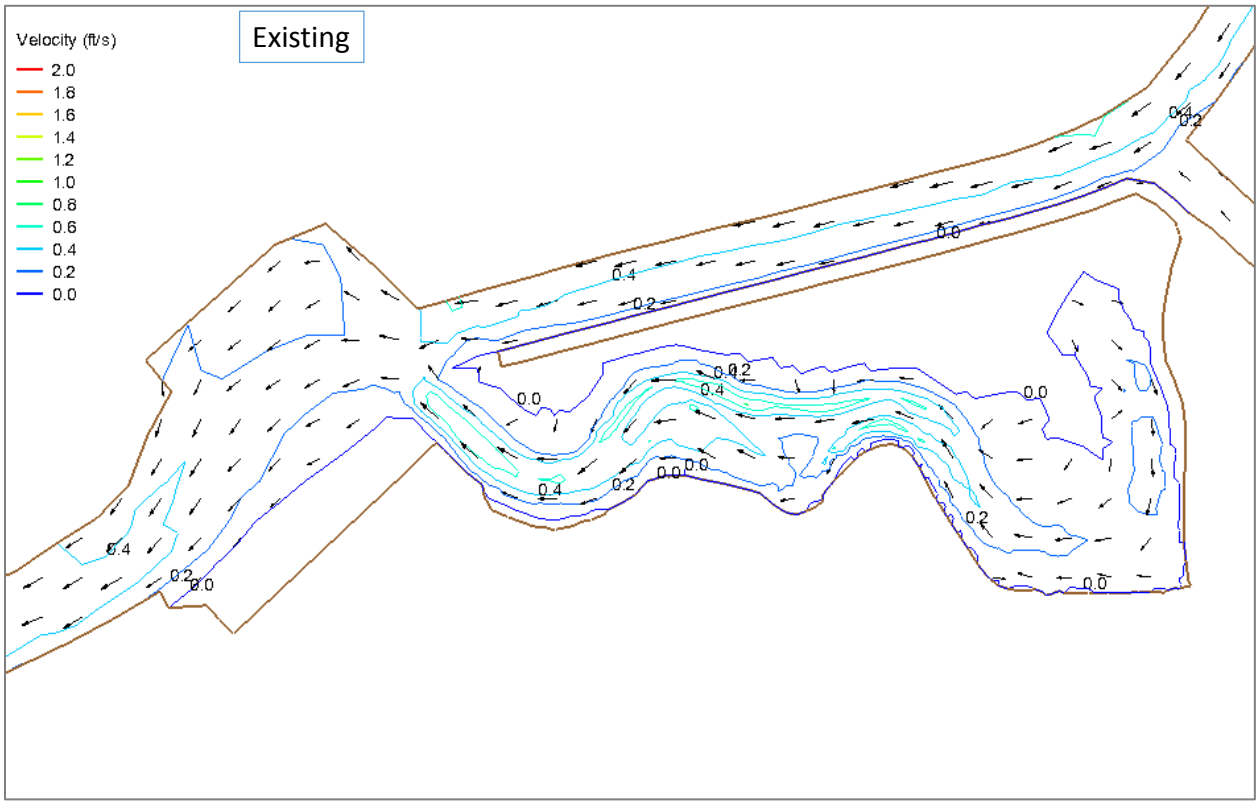


Figure 4-25: Peak Flood Velocity Comparison under TEA Tide Condition (Existing Top and Phase 1 Bottom)



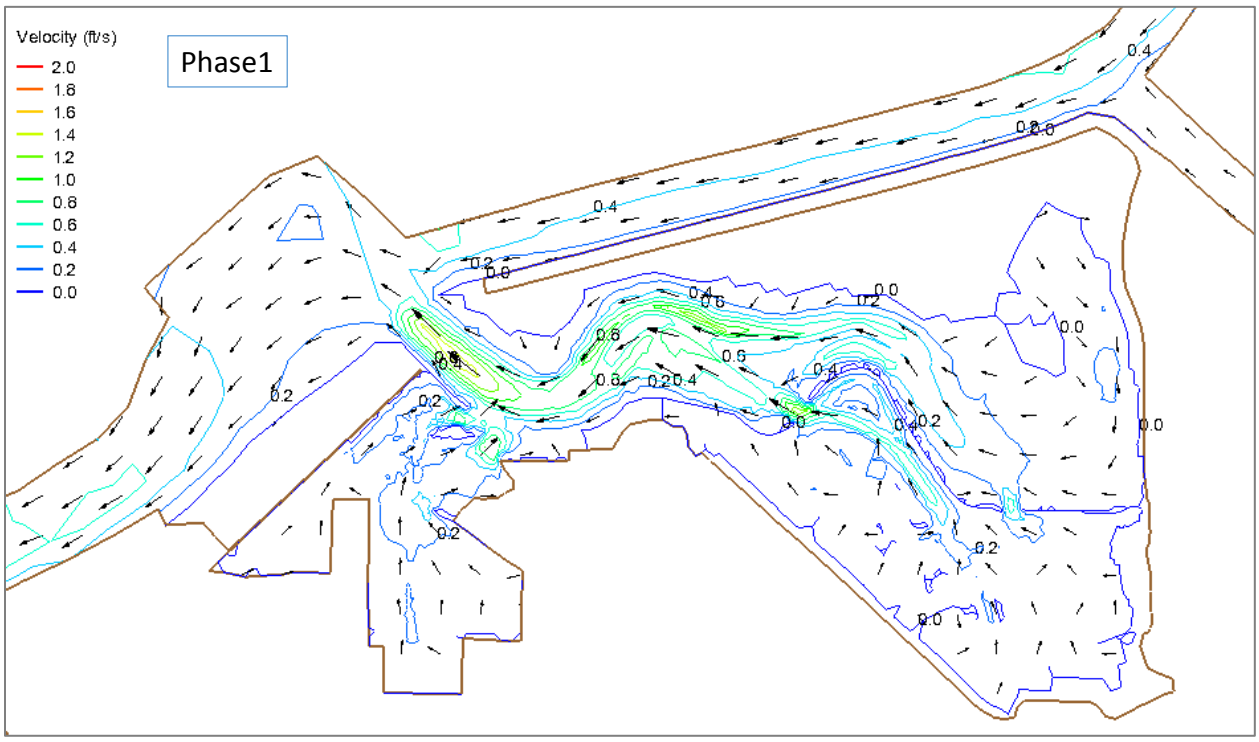


Figure 4-26: Peak Ebb Velocity Comparison under TEA Tide Condition (Existing Top and Phase 1 Bottom)

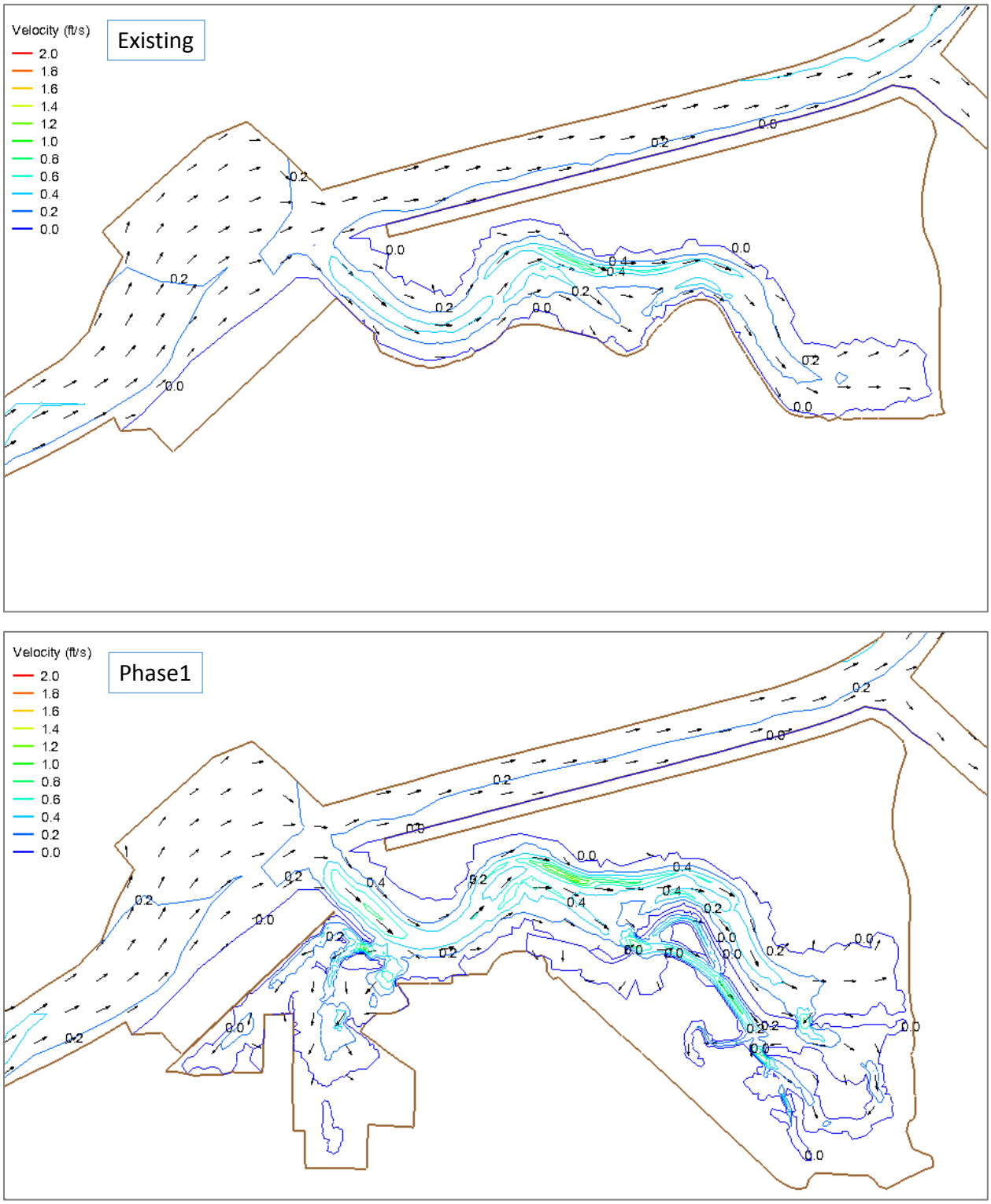
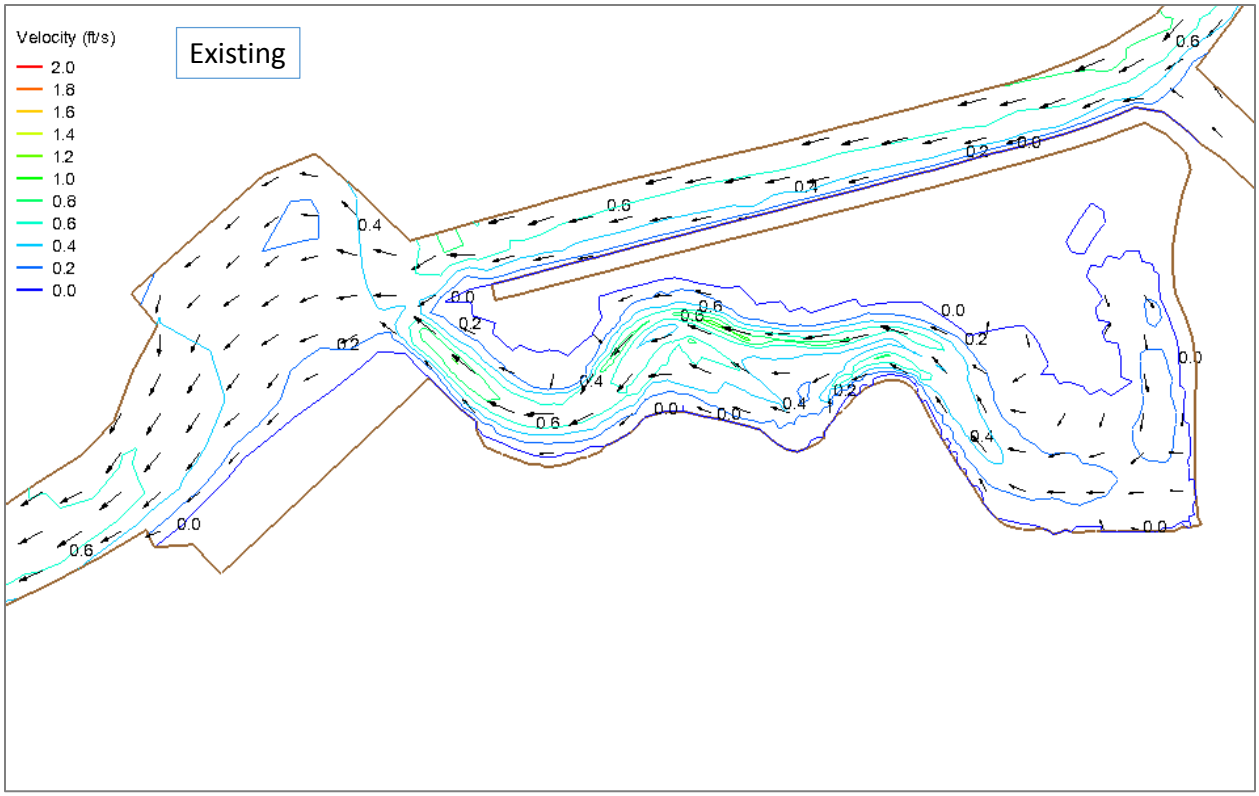


Figure 4-27: Peak Flood Velocity Comparison under Extreme Tide Condition (Existing Top and Phase 1 Bottom)



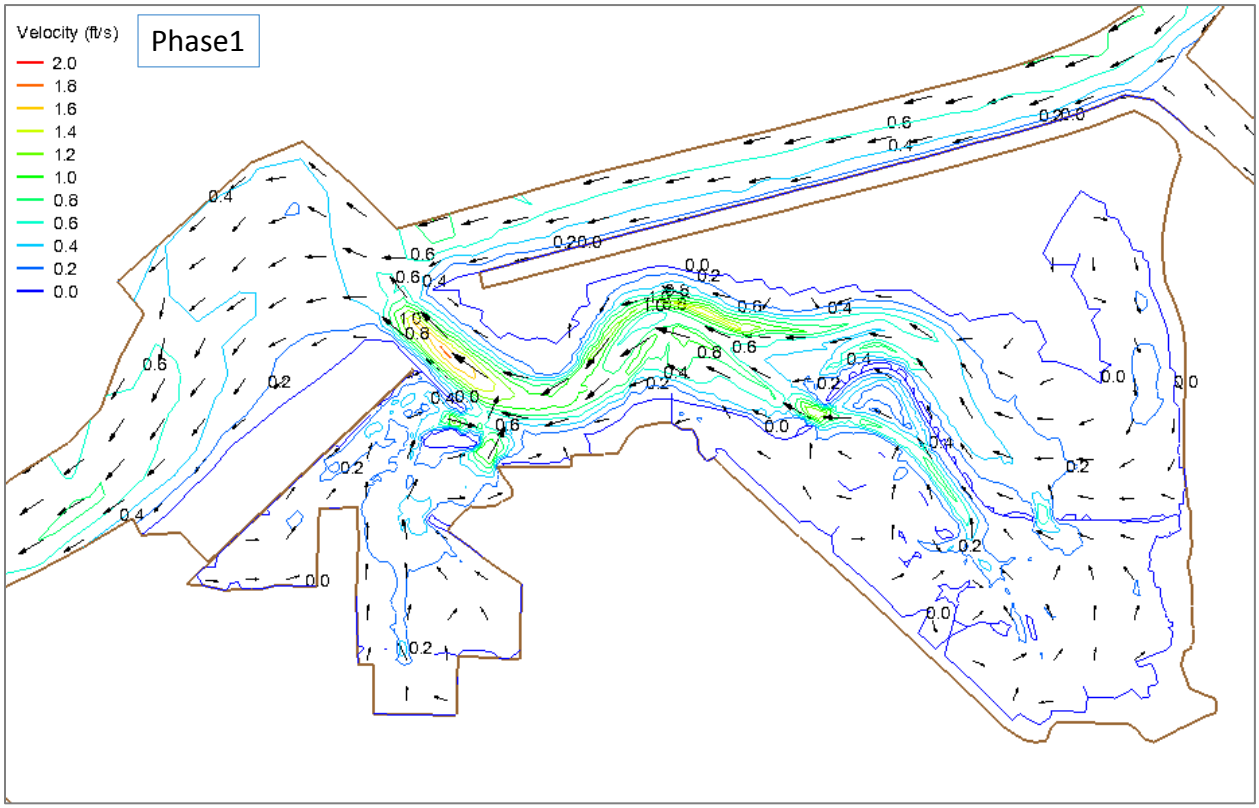


Figure 4-28: Peak Ebb Velocity Comparison under Extreme Tide Condition (Existing Top and Phase 1 Bottom)

5.0 CONCLUSIONS

AdH 2-D numerical models were created to simulate hydraulic conditions under both the existing and proposed project conditions for wetland and interim berm design, and for assessing potential SLR impacts to the proposed project and adjacent properties. The following three SLR scenarios were modeled for both the existing and the proposed project conditions to assess flood risk impacts to the adjacent roadways and development:

a. The lower bound of SLR projection of 0.5 feet in year 2060,
b. The upper bound of SLR projection of 2.6 feet in year 2060, and
c. The upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm.

Comparison indicates that the proposed project would not change tide and storm water levels in the proposed project site and in its vicinity under all three SLR scenarios modeled. Under the worst case of the upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm condition, modeling results showed possible inundation of one lane of 2nd Street. However, the proposed Synergy project would erect an interim berm and sea wall within the project area that would prevent any flooding of 2nd Street. This condition could be a significant benefit under wet weather conditions in the future. In summary, the proposed project would not result in any impacts to the remaining Synergy property in Phase 2, the LCWA site at the northeast corner of the Studebaker Road and 2nd Street, the Pumpkin Patch site, and City's 33 acres between 2nd Street and the San Gabriel River under the projected SLR conditions in year 2060.

Based on modeling results under the worst case of the upper bound of SLR projection of 2.6 feet in year 2060 together with a 50-year fluvial storm condition, a crest elevation of 9.0 feet NGVD29 is recommended for the interim berm. Analyses of FEMA 1% base flood elevation, NOAA 1% extreme tide elevation and measured highest tide elevation indicate that the FEMA 1% base flood elevation is higher than both the measured extreme tide and 1% high elevations. Adding the upper bound of SLR projection of 2.6 feet in year 2060 to the FEMA 1% base flood elevation, the resulting elevation is 0.8 feet lower than the recommended interim berm crest elevation. Therefore, the crest elevation of +9.0 feet NGVD29 would provide sufficient flood protection in the interim condition before year 2060.

Six SLR scenarios including 1-, 2-, 3-, 4-, 5- and 5.5-foot were modeled to assess potential SLR impacts to the marsh habitat. The SLR would change both the tidal range and tidal inundation frequencies in the proposed salt marsh. The salt marsh habitats would evolve as a result of these changes. The habitat elevation breaks for each habitat category would shift upward. The intertidal habitat acreage would initially increase from 57.1 acres under the no SLR condition to 63.4 acres with a 2-foot SLR due to tidal range increase, and then it decreases to 41.6 acres with a 5.5-foot SLR. The area decrease is due to some intertidal area converting to subtidal habitat with further SLR. The vegetated marsh area would generally decrease as some marsh habitats would convert to mudflat or subtidal due to the increased inundation frequency. Overall, salt marsh will evolve from a diverse range of habitats to be more subtidal and mudflat after sea level rises.

6.0 REFERENCES

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Appendix A

Existing Synergy Site Topography (Dulin and Boynton 1996)

160' 0' 160' 320'

SCALE: 1"=160'

NOTES:

1. ALL UNITS ARE IN FEET.
2. ALL ELEVATIONS ARE IN REFERENCE TO THE NATIONAL GEODETIC VERTICAL DATUM (NGVD) 1929.
3. DATE OF SURVEY: 1996.

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Appendix B

RMA2 Model Calibration Results

(Alamitos Bay Circulation Study, M&N 2007)

The measured tidal elevations were compared with the model-predicted tidal elevations. Figure B-1 shows locations where field data were collected as a part of the 2007 study. Figure B-2 through B-4 in the following pages show the water level comparison at Alamitos Bay entrance, at Los Cerritos Channel under the 7th Street Bridge, and at the San Gabriel River under the Westminster Street Bridge. The measured water levels and their phases matched very well with the model-simulated tides, except for an anomaly in the San Gabriel River gauge, in which the recorded water level shifted upward after 10-days of the record due to gauge malfunction. However, the first 10-days of the record were sufficient for calibrating the model at the River location.

Two S-4ADW current meters were deployed at Mother's Beach and 2nd Street Bayshore as shown in Figure B-1. The meter at Mother's Beach malfunctioned. The measured currents at 2nd street Bayshore were compared with the model simulated currents and are illustrated in Figure B-5. The current meter recorded currents in the channel about one foot above the channel bed. The model simulated currents are vertically averaged velocities in the middle of the channel. Current ranges and phases generally matched well. As the measured and predicted tidal conditions and current conditions matched well, it was concluded that the data missing from Mother's Beach were not critical to the study.

Figure B-1: Gauge Locations

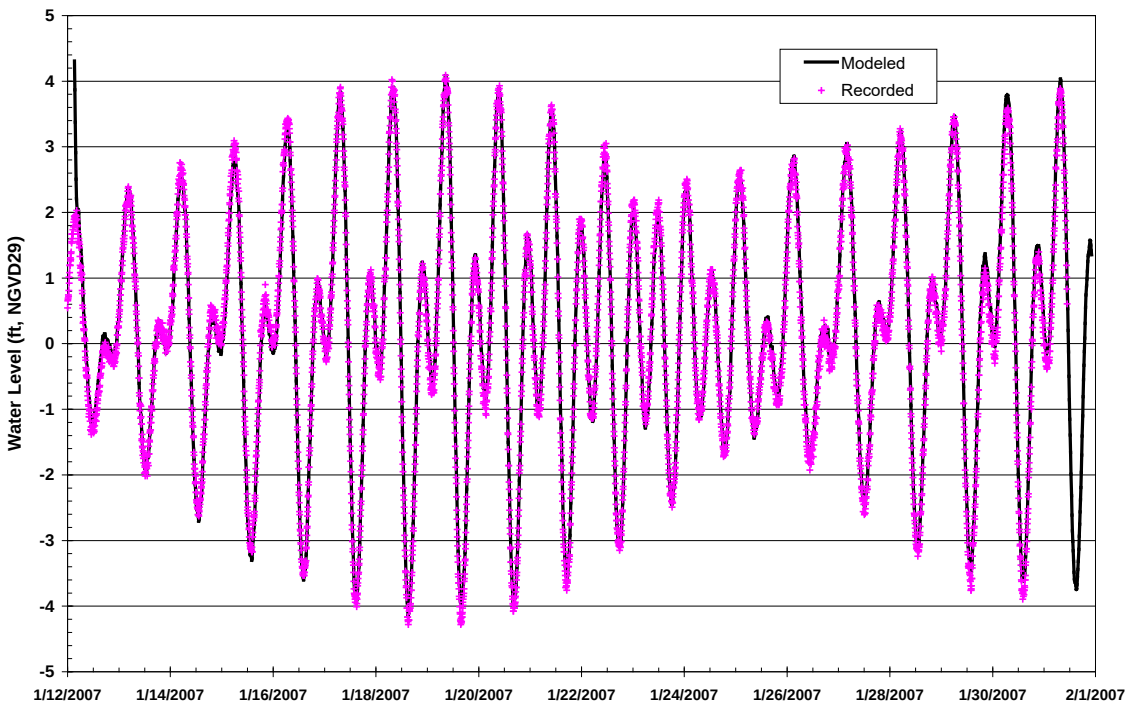

Figure B-2: Water Level Comparison at Alamitos Bay Entrance

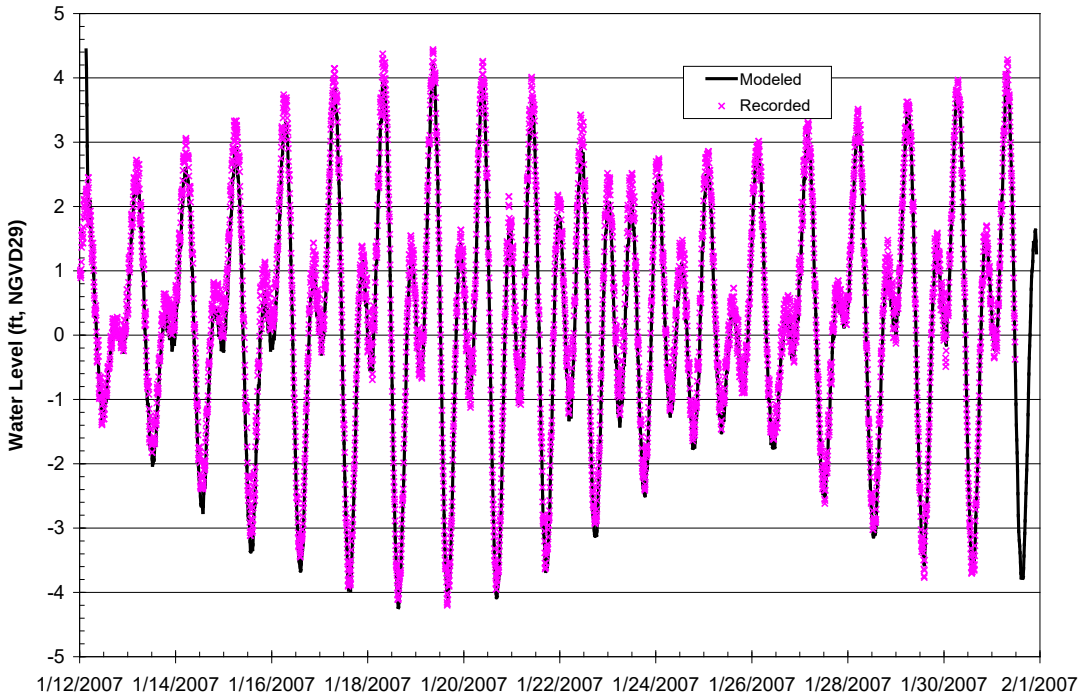

Figure B-3: Water Level Comparison at Cerritos Channel at the 7th Street Bridge

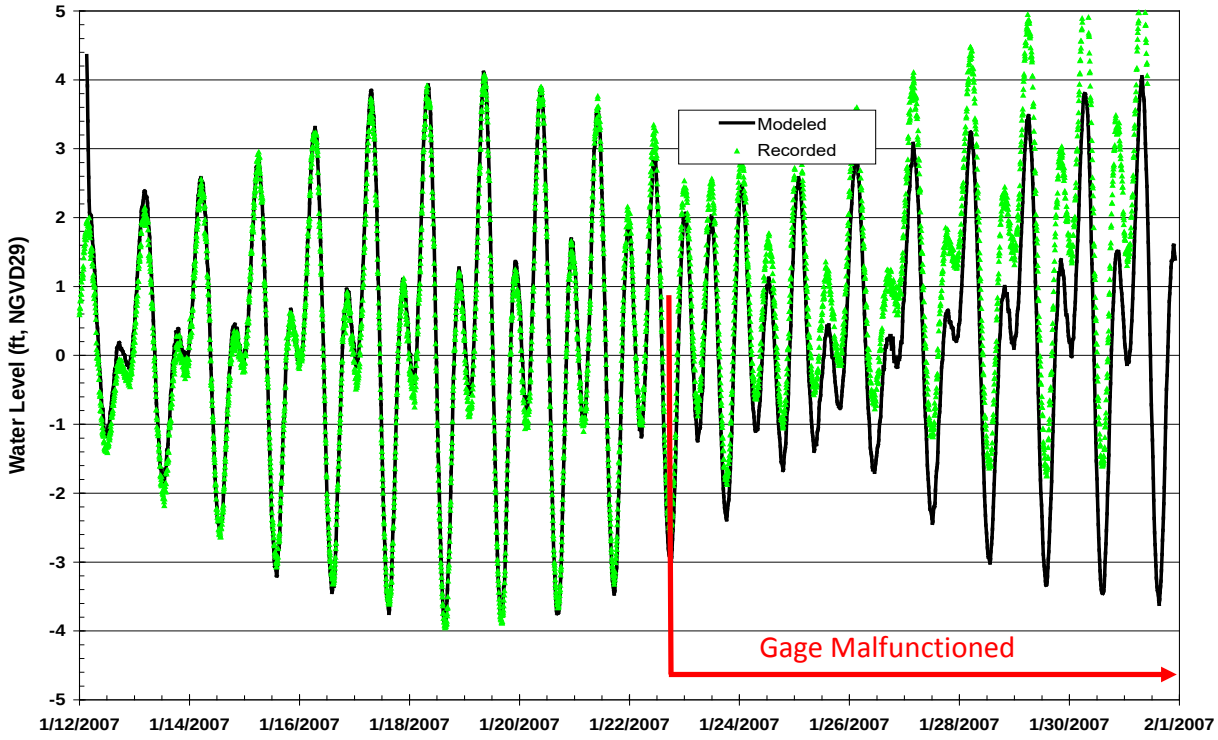

Figure B-4: Water Level Comparison at San Gabriel River at Westminster Street Bridge

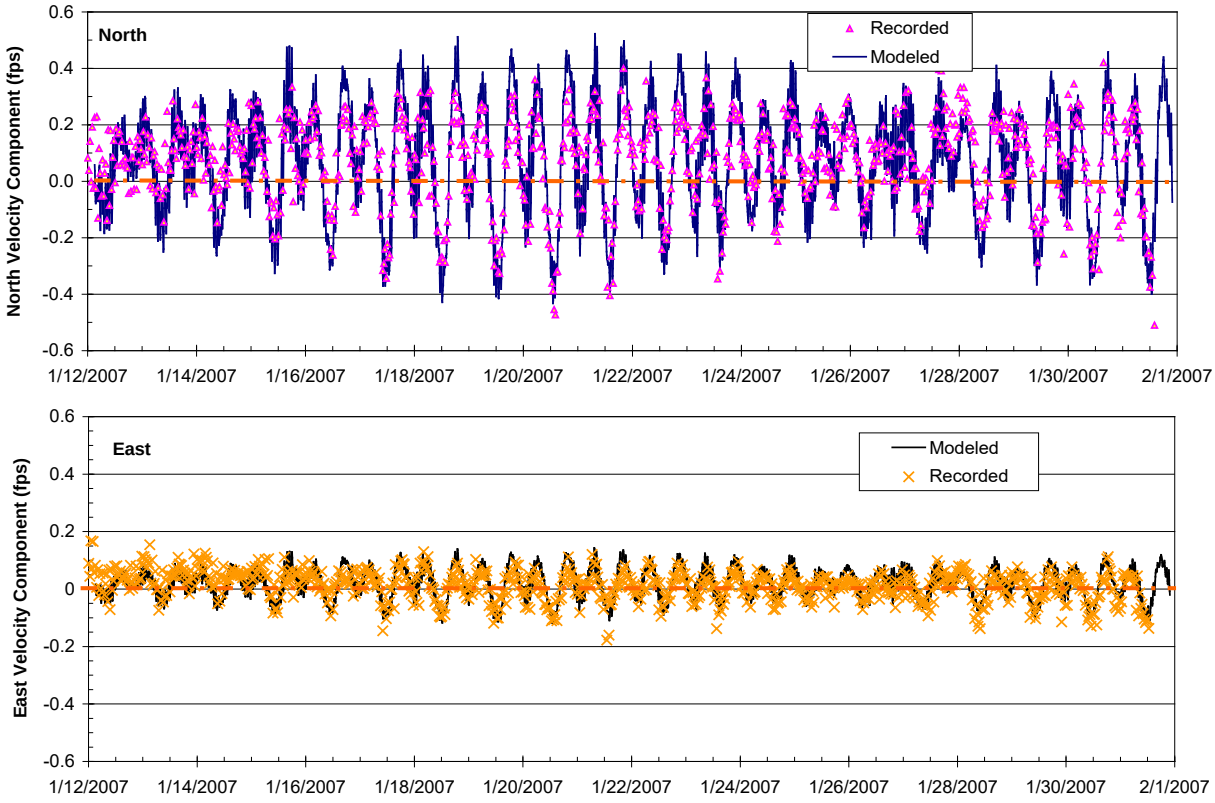

Figure B-5: Currents Comparison at 2nd Street Bayshore