Appendix I

Sediment Dynamics and Sediment Budget Analysis

ESA

LOS CERRITOS WETLANDS RESTORATION PROGRAMMATIC EIR

Sediment Dynamics Analysis Technical Report

Prepared for
Los Cerritos Wetlands Authority

April 2020

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SECTION 1
Introduction

This Sediment Dynamics Analysis Technical Report assesses potential effects of the Los Cerritos Wetlands (LCW) Restoration Program on long-term deposition, erosion, and sediment transport patterns in the San Gabriel River, Haynes Cooling Channel, and the restored wetlands for the purpose of assessing potential environmental impacts for the proposed program. The analysis builds on the results of other analyses, including the Hydrodynamic Modeling Technical Report (ESA 2020) and Water and Sediment Quality Technical Report (ESA 2019) developed for the LCW Restoration Plan Program Environmental Impact Report (PEIR), and the Conceptual Restoration Plan's (CRP) Watershed Impacts Report (Everest 2012).

This analysis includes hydrodynamic modeling, geomorphic analyses, and estimates of potential changes in onsite and off-site erosion and deposition. The analyses assess both existing and proposed program conditions to evaluate potential changes due to the program.

Section 1 presents the historic context, existing conditions, and proposed program. Section 2 presents geomorphic analyses for the riverine, tidal, and coastal sediment transport processes. Section 3 compares LCW to local reference sites and lastly, Section 4 summarizes the results and overall morphological development that is expected for the LCW under restored conditions.

1.1 Project Background

Until the late 1800s, the LCW spanned approximately 2,400 acres and consisted of a network of meandering streams, vegetated wetlands, and upland areas. Historically, the program area was almost entirely (88.5%) tidal vegetated wetland, with a few natural streams and intertidal flat channels in both the north and the south **(Figure 1-1**) (Stein et. al 2007; Tidal Influence 2012).

Beginning in the late 1800s, the site began to undergo significant alterations due to agriculture (cattle and beet farming), the demands of a growing population, and oil production. Oil was first discovered at the LCW at the Seal Beach Oil Field in 1923. The development of oil production operations, paired with channelization of the San Gabriel River, resulted in substantial dredge and fill of the LCW. The program area contains oil wells, and network of oil-production tanks and pipes. Today, nearly all of the program area has been converted from its historic wetland habitat, though a few remnant and degraded historic habitats remain. Given the land use history of the LCW, sediment contamination at the site is an important consideration for restoration. The history of the LCW can be used to guide the design of the restoration; however, existing constraints must be considered as well. For example, although the LCW was historically a tidal vegetated wetland, much of the site only receives tidal action through culverts, affecting the LCW tidal processes.

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SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program Sediment Dynamics Report

Figure 1-1
Historic Project Area Habitats

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1.2 Existing Conditions

Today, three major channels are present in the program area: Los Cerritos Channel, San Gabriel River, and the Haynes Cooling Channel. A remnant historic tidal wetland, called Steamshovel Slough, is also present, and drains to the Los Cerritos Channel. For purposes of organizing this report and discussion, the proposed program has been separated into 4 areas (South, Isthmus, Central, and North) and 17 individual sites (**Figure 1-2**).

1.2.1 South Area

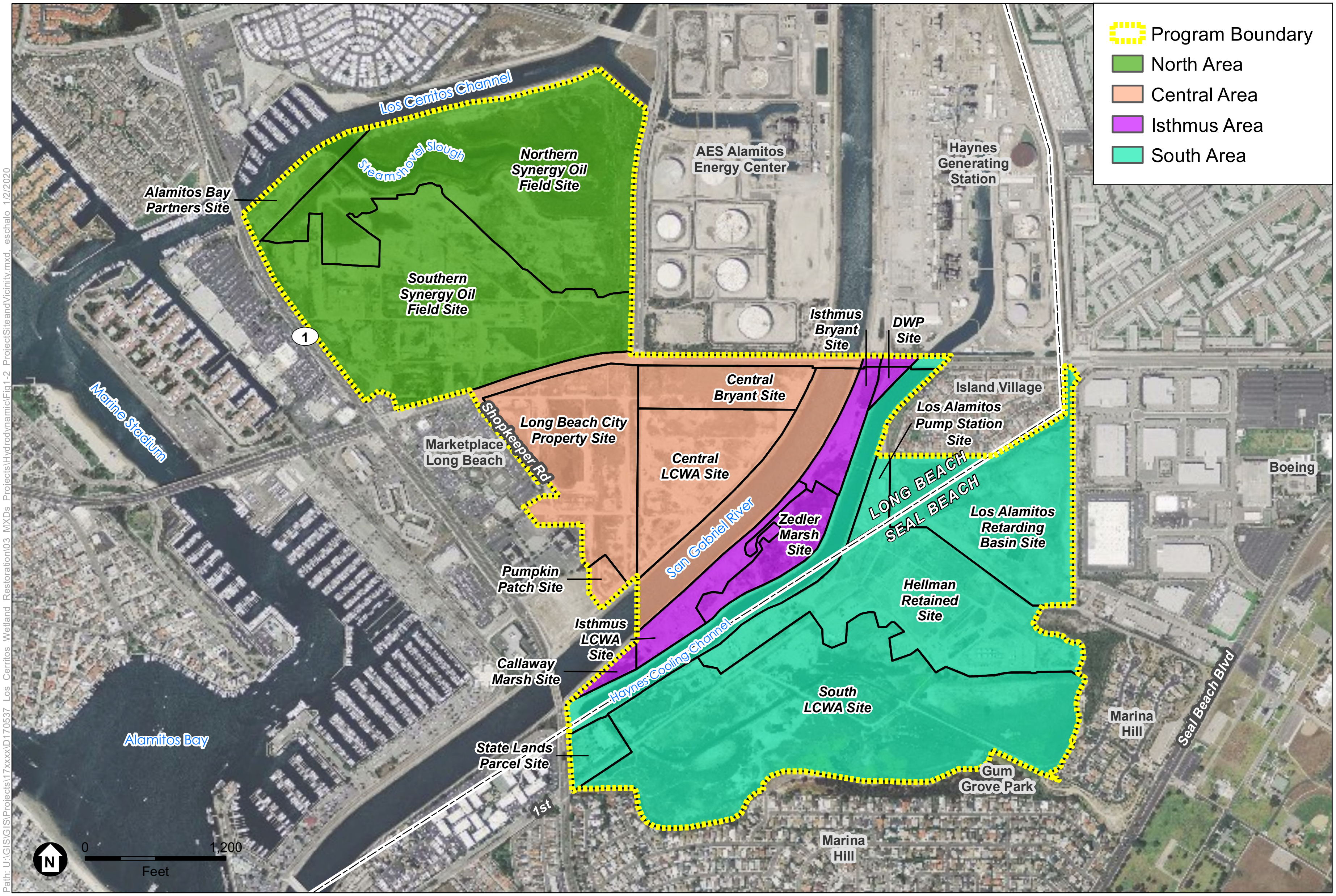
The South Area includes the following individual sites: Haynes Cooling Channel, State Lands Parcel, South LCWA, Hellman Retained, Los Alamitos Pump Station, and Los Alamitos Retarding Basin. For the purpose of this analysis, discussion of the South Area in this technical report focuses on the Haynes Cooling Channel, the South LCWA site, and the Hellman Retained site. The State Lands Parcel is not exposed to inundation, so it is not discussed in this report. The Los Alamitos Pump Station and Retarding Basin were not included in the modeling efforts because sufficient data was not available. The following paragraphs describe the areas that were considered for this study.

The Haynes Cooling Channel is a waterway used by the Haynes Generating Station located north of the program area to bring in water from the Pacific Ocean via 7 culverts in the Alamitos Bay Marina to cool the power plant through a method called once-through cooling. Once the water is used, it is discharged into the San Gabriel River slightly upstream of where the river crosses under 2nd Street. Once the modernization project for the Haynes Generating Station is completed (by 2029), the Haynes Cooling Channel will be decommissioned and no longer be in use for the Haynes Generating Station. Currently, there is no conduit that connects any of the program area sites to Haynes Cooling Channel.

The South LCWA site contains multiple former sumps, landfills, and contaminated areas from prior oil operations, and is currently owned and maintained by the LCWA. Some areas of tidal southern coastal salt marsh still persist on the site but other areas were converted by previous land owners from coastal salt marsh habitat to primarily ruderal uplands with no tidal connections. Former access roads still bisect the site and cause ecological and hydrological fragmentation. 1st Street runs parallel to Haynes Cooling Channel.

The Hellman Channel is a small, muted tidal channel that connects to the San Gabriel River through a culvert that goes around the southern end of the Haynes Cooling Channel and above the culverts connecting the cooling channel to the Alamitos Bay Marina. The Hellman Channel runs through the South LCWA site with three culverts running under the existing access roads. One culvert runs under 1st Street, and the other two run under remnant oil infrastructure roads. Culvert dimensions are further discussed in Section 2.1.2.

The Hellman Retained site is an active oil field with substantial oil operation infrastructure (pipelines, pumps, tanks, and roadways). Historically, the site was primarily coastal salt marsh habitat; today the parcel is composed mostly of ruderal wetlands with no tidal connection.



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SOURCE: Mapbox, LCWA

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Figure 1-2
Project Site and Local Vicinity

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1.2.2 Isthmus Area

The Isthmus Area includes the following hydrologically connected sites: Callaway Marsh, DWP, Zedler Marsh, Isthmus LCWA, and Isthmus Bryant. The DWP is not exposed to inundation, so it is not discussed in this report.

The Callaway Marsh site is a vacant site with a heavily degraded perched salt marsh, tidally connected to the San Gabriel River by a three-foot-wide culvert with a gate, which mutes the water levels reaching the site.

The Zedler Marsh site is a 12-acre restoration site owned and managed by the LCWA and is currently being enhanced and restored as part of the LCWA Stewardship Program. The site contains tidal salt marsh and surrounding habitat. The site receives muted tidal circulation via a three-foot wide culvert connection to the San Gabriel River.

The Isthmus LCWA site is an active oil field maintained and operated by Signal Hill Petroleum, Inc. who own the mineral rights. The oil operation infrastructure includes 4 active oil wells and 1 idle oil well. The site contains a mix of disturbed ruderal habitats.

The Isthmus Bryant site is a privately owned vacant site. The site contains salt flat and alkali meadow wetland habitat types but is fragmented both ecologically and hydrologically by the access road that bisects the site. The site is adjacent to Zedler Marsh and two culverts in the access road allow some hydrologic connection between the area adjacent to Zedler Marsh and the area northwest of the road during major high water level events.

1.2.3 Central Area

The Central Area includes the following hydrologically connected individual sites: Pumpkin Patch, Long Beach City Property, Central LCWA, Central Bryant, and the San Gabriel River.

The Long Beach City Property site is an active oil field with oil storage tanks and associated oil production infrastructure, such as pipelines. A majority of the site is disturbed, and vegetation is generally sparse. Existing roads and oil well pads severely fragment the site ecologically and hydrologically. The site contains southern coastal brackish marsh habitat where urban stormwater runoff is directed via storm drains onto the salty soils of former tidally influenced areas. There is a perched culvert at the southern tip of the property that receives tidal waters during major high tide events, but the majority of the site is non-tidal.

The Central LCWA site is an active oil field with oil operation infrastructure (roadways, wells, power lines, pipelines, and pumps), which severely fragment the site ecologically and hydrologically. The site is composed of a mixture of native and non-native wetland habitats. The Central LCWA site is disconnected from any tidal action.

The Central Bryant site is a privately owned, vacant site. Stormwater runoff supports mulefat scrub and other wetland habitats on parts of the site. The site is comprised of southern coastal salt marsh, alkali meadow, salt flat, and ruderal wetland and upland habitats and is disconnected from tidal action.

1.2.4 North Area

A project-level EIR was prepared for the City of Long Beach to evaluate the environmental effects associated with the Los Cerritos Wetlands Oil Consolidation and Restoration Project. The PEIR for the proposed Los Cerritos Wetlands Restoration program relies on the technical analysis, impact discussion, and mitigation measures documented in the Los Cerritos Wetlands Oil Consolidation and Restoration Project EIR. Therefore, a sediment dynamics analysis of the North Area is not included in this report.

1.3 Related Studies

1.3.1 Watershed Impacts Report

As part of the CRP, Everest International Consultants developed a Watershed Impacts Report in 2012. The report summarizes the watershed activities that have the potential to affect or impede the restoration of the LCW. The watershed impacts were assessed as follows:

- Local drainage areas and storm water sources were defined for each parcel in the Los Cerritos Wetlands Complex;
- Existing hydrologic and hydraulic connections were defined between the wetlands and rivers;
- Pollutant sources were identified;
- Long-term water quality improvements anticipated from planned watershed efforts were evaluated;

The Watershed Impacts Report provides context to the sediment dynamics assessment by defining the existing hydrologic and hydraulic connectivity of the site and identifying watershed inputs to the wetland system.

1.3.2 Water and Sediment Quality Technical Report

In parallel to this report, ESA developed a Water and Sediment Quality Technical Report. The purpose of the investigation was to:

- Summarize and assess available data on the water and sediment quality within the LCW near-term program areas;
- Assess potential restoration program impacts;
- Analyze the potential impact of flows from the watershed on the restoration program; and
- Develop a framework for adaptive management and monitoring to address potential impacts.

The water and sediment quality of the LCW is connected with the sediment dynamics at the site. Areas that accrete sediment may be susceptible to accumulation of contaminants. Conversely, areas that erode sediment may contribute to degraded water quality.

1.3.3 Hydrodynamic Modeling Technical Report

In parallel to this report, ESA developed a Hydrodynamic Modeling Technical Report. ESA constructed a 2-D HEC-RAS model for the LCW to support the restoration planning process. The model was developed to characterize the hydrodynamic response of the restoration, as well as to inform the preliminary restoration design, 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. The hydrodynamics of the site drive much of the sediment dynamics and influence where areas are expected to erode or accrete.

1.4 EIR Restoration Program

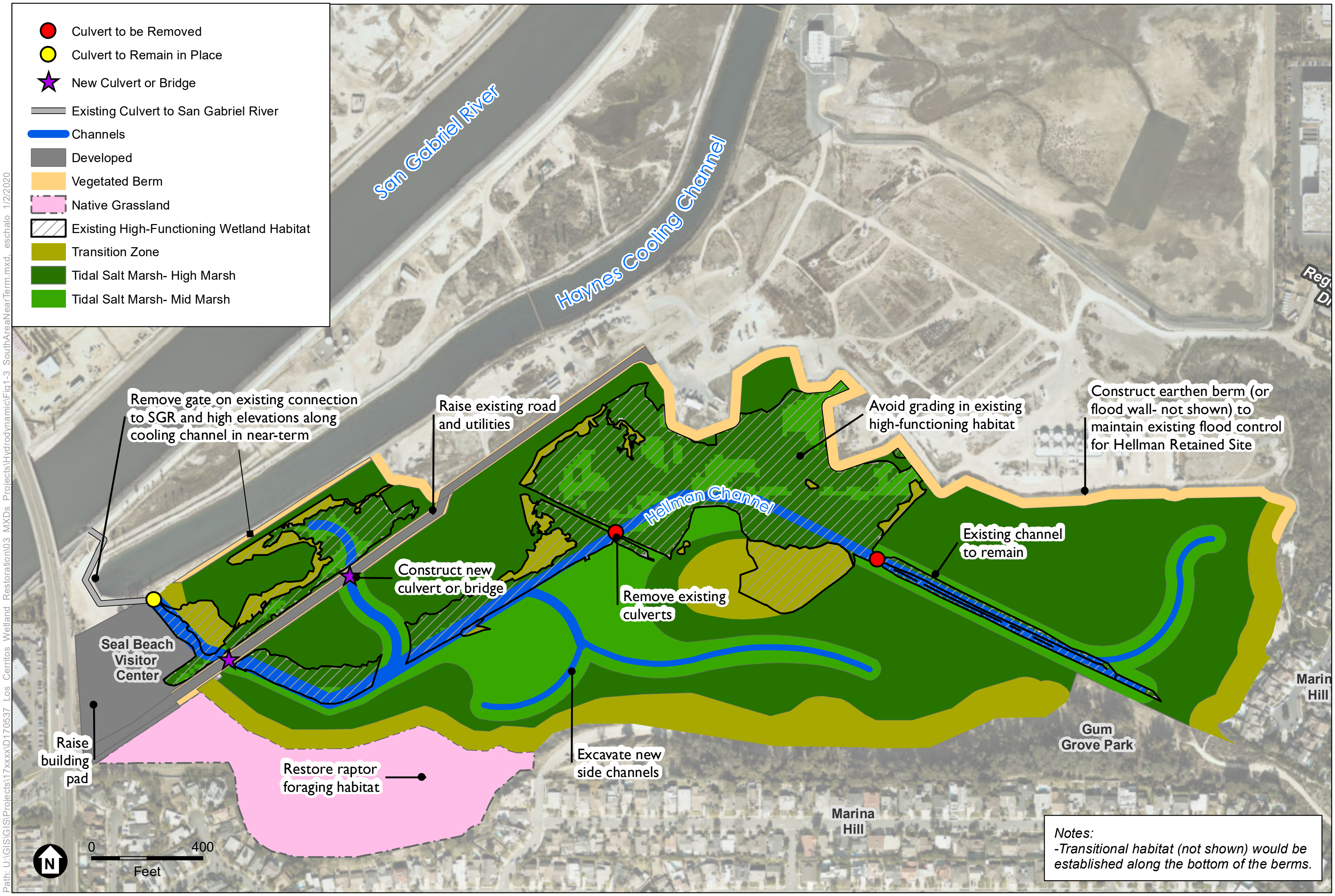
The proposed program would restore wetland, transition, and upland habitats throughout the program area. This would involve remediation of contaminated soil and groundwater, grading, revegetation, construction of new public access opportunities (including trails, visitor centers, parking lots, and viewpoints), construction of flood management facilities (including earthen levees and berms, and walls), and modification of existing infrastructure and utilities.

1.4.1 South Area

Ecosystem restoration in the South Area would occur in three phases based on land and oil lease ownership. The near- and mid-term phases of the program in the South Area would be mostly focused on the South LCWA and State Lands Parcel sites and would provide the conditions necessary for the expansion of coastal salt marsh habitat and associated hydrologic, biogeochemical, and habitat functions. Additional design and analysis is needed for the long-term phase of the program in the South Area, so analysis of that phase is not included in this report.

Near-term activities would include (**Figure 1-3**):

- Remediating soils (e.g., on-site treatment, excavation and removal, or cap in place) that have been impacted by oil operations;
- Grading the South LCWA site, including excavation to create channels and revegetation of native plants to support a diversity of marsh, transitional, and upland habitats;
- Constructing a new earthen berm or flood wall along the Hellman property boundary on the South LCWA site to protect the Hellman site from flooding;
- Raising 1st Street on the South LCWA site out of the floodplain by placing it on fill;
- Building a Seal Beach Visitor Center and associated parking on an existing raised building pad on the State Lands Parcel site;
- Removing the gate on the existing culvert connecting the South LCWA site to the San Gabriel River and removing the culverts under the former access roads. The existing culvert under 1st Street would either be improved or replaced with a bridge; and
- Restoring native grassland for raptor foraging habitat on South LCWA site.



SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Sediment Dynamics Technical Report

Figure 1-3
Proposed South Area Near-Term Restoration

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Mid-term activities would include (**Figure 1-4**):

- Excavating a channel connecting the Hellman Channel directly to the Haynes Cooling Channel and lowering the berm along the Haynes Cooling Channel to increase the tidal range in the South LCWA site; and
- Modifying the Los Alamitos Retarding Basin management operations to enhance the habitat value in the basin (e.g., change pumping operations to maintain ponding for shorter or longer time).

1.4.2 Isthmus Area

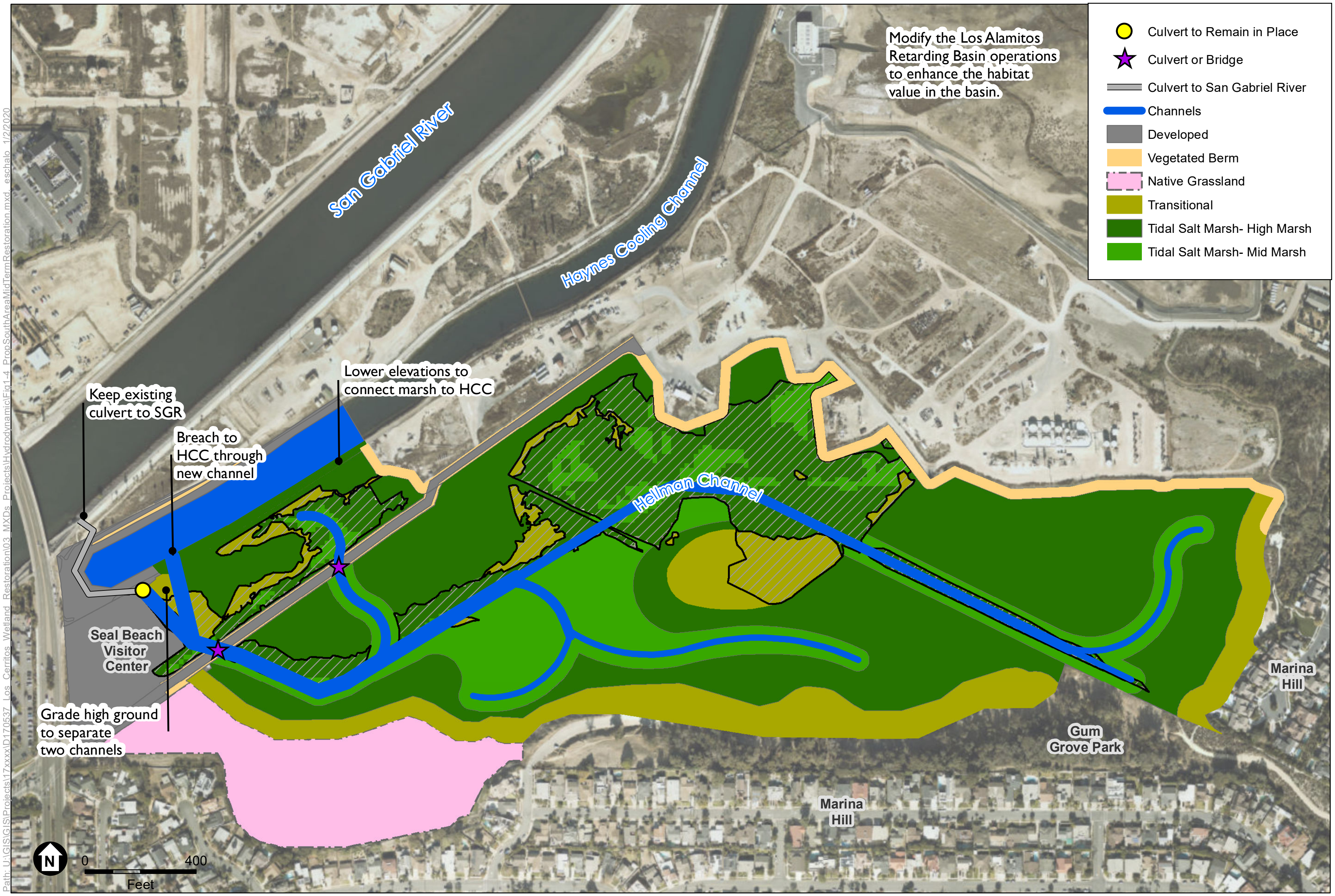
In the near-term, the proposed program would extend the restoration currently present on the Zedler Marsh site north into the Isthmus Bryant site and the portion of the DWP site west of the oil access road (**Figure 1-5**). The Callaway Marsh site and the rest of the DWP site would be enhanced in the mid-term, once the Haynes Cooling Channel is decommissioned by LADWP and no longer in use for the Haynes Generating Station. Additional design and analysis is needed for the long-term phase of the program in the Isthmus Area, so analysis of that phase is not included in this report.

1.4.3 Central Area

Ecosystem restoration in the Central Area would occur in two phases based on land and oil lease ownership. The Central LCWA site is available for restoration immediately, and discussions between Bryant Dakin, LLC and the LCWA on acquisition of the Central Bryant site for restoration are on-going. The program assumes that both of these properties would be available for restoration in the near-term. Oil operations operated by Signal Hill Petroleum, Inc. are expected to remain until agreements for decommissioning are made. The Long Beach City Property site and the Pumpkin Patch site would be available for restoration in the long-term, once the oil infrastructure is removed as part of the Los Cerritos Wetlands Oil Consolidation and Restoration Project.

The near-term phase of the program would be focused on the Central LCWA and Central Bryant sites and would provide the conditions necessary for the reestablishment of coastal salt marsh habitat and associated hydrologic, biogeochemical, and habitat functions (**Figure 1-6**). Near-term activities would include:

- Relocating or modifying oil infrastructure and remediation of soils on the Central LCWA site;
- Grading of the sites, including channels, and revegetation of native plants to support a diversity of salt marsh species;
- Removing segments of the existing levee (e.g., breaching the levee and/or lowering a segment) that currently separates the San Gabriel River from non-tidal portions of the Central LCWA and Central Bryant sites.
- Constructing a new earthen levee (Perimeter Levee) along 2nd Street from the San Gabriel River to the intersection with Studebaker Road to protect areas to the north from flooding;
- Constructing a new interim earthen levee (Interim Levee) along the western boundary of the Central LCWA site to protect the areas to the west from flooding and to provide continued access to the wells on the Central LCWA site;



SOURCE: ESRI,LCWA

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Figure 1-4
Proposed South Area Mid-Term Restoration

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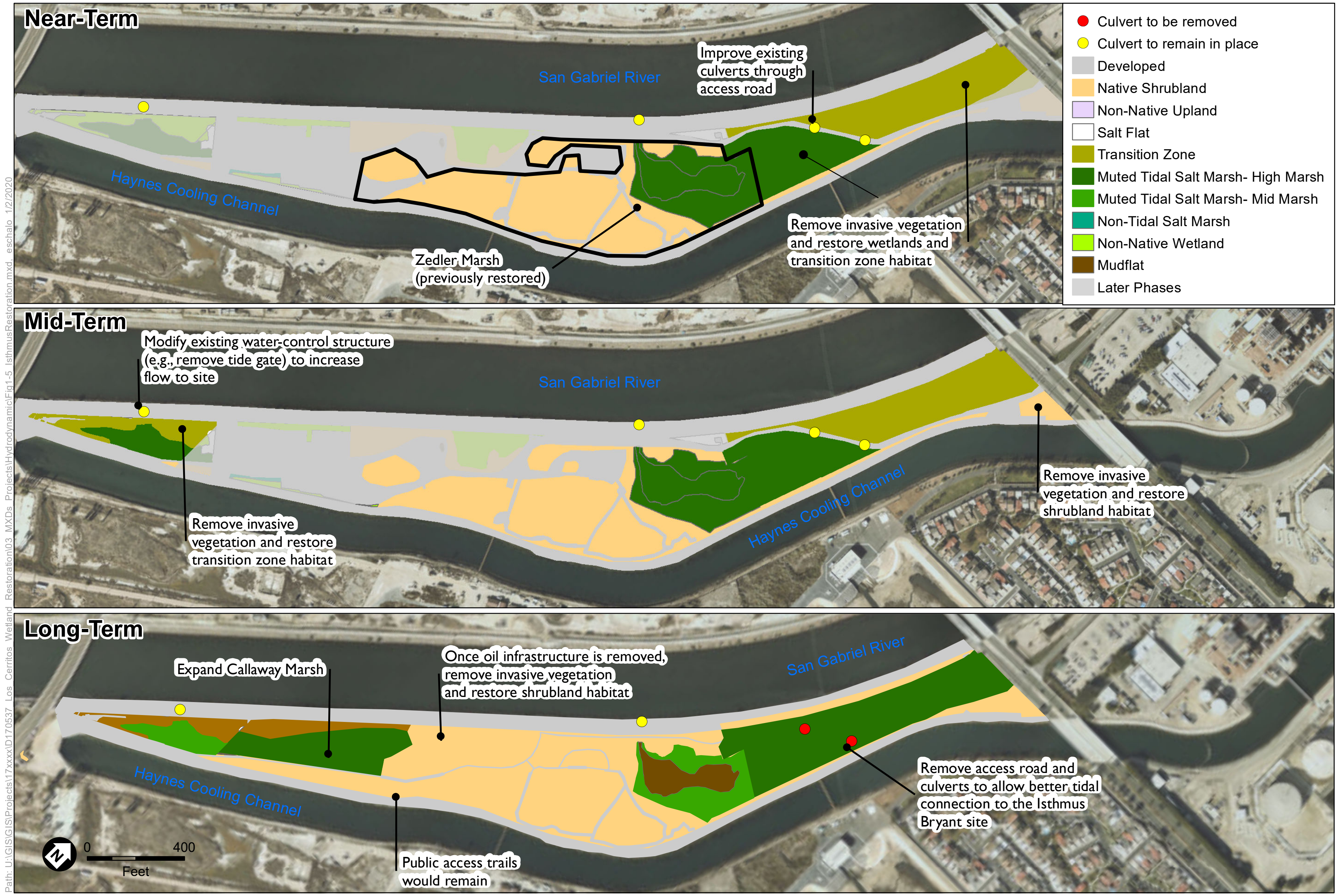

SOURCE: Mapbox, LCWA, NOAA, ESA

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Figure 1-5
Proposed Isthmus Area Restoration

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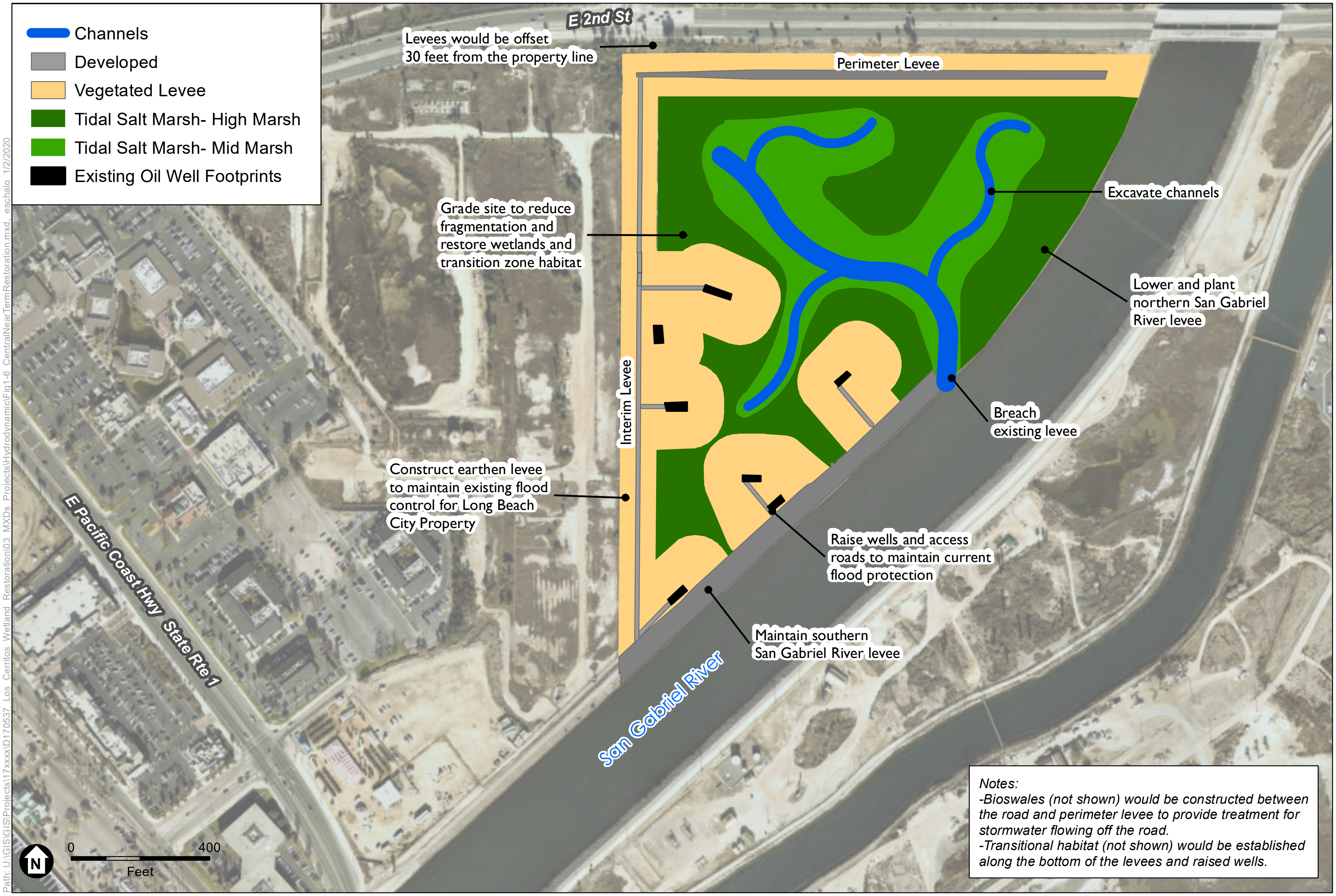

SOURCE: NOAA, ESA, LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Sediment Dynamics Technical Report

Figure 1-6
Proposed Central Area Near-Term Restoration

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Providing flood protection for the existing wells on the Central LCWA site by raising the well pads out of the floodplain; and

Constructing public trails on levees, including accessible ramps, and viewpoints.

In the long-term, the Long Beach City Property site and the Pumpkin Patch site would be restored to tidal salt marsh, including (**Figure 1-7**):

Grading the Long Beach City Property site, including channels, to support a diversity of salt marsh species;

Removing the northern segment of the Interim Levee on the Central LCWA site to connect the restored habitats on the Central LCWA site to the non-tidal portions of the Long Beach City Property site.

Constructing a new earthen levee (Perimeter Levee) along 2nd Street between the intersection with Studebaker Road to Shopkeeper Road on the Long Beach City Property site and then along Shopkeeper Road to the existing San Gabriel River levee on the Long Beach City Property and Pumpkin Patch sites to protect areas to the north and west from flooding; and

Constructing public trails on levees, accessible ramps, stairs, and viewpoints.

1.4.4 North Area

A project-level EIR was prepared for the City of Long Beach to evaluate the environmental effects associated with the Los Cerritos Wetlands Oil Consolidation and Restoration Project. The project applicant, Beach Oil Minerals Partners (BOMP), proposes to consolidate existing oil operations and implement a wetlands habitat restoration project in portions of the North and Central Areas within the program area and on one property outside the program area. The PEIR for the proposed Los Cerritos Wetlands Restoration program relies on the technical analysis, impact discussion, and mitigation measures documented in the Los Cerritos Wetlands Oil Consolidation and Restoration Project EIR. Therefore, a sediment dynamics analysis of the North Area, including the Los Cerritos Channel is not included in this report.

Notes:
-Levee boundary in Pumpkin Patch site will be adjusted to meet specifications of the Los Cerritos Wetlands Oil Consolidation and Restoration Project.
-Bioswales (not shown) would be constructed between the road and perimeter levee to provide treatment for stormwater flowing off the road.
-Transitional habitat (not shown) would be established along the base of the levees and raised wells.

SOURCE: NOAA, ESA, LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Sediment Dynamics Technical Report

Figure 1-7
Proposed Central Area Long-Term Restoration

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SECTION 2

Sediment Processes and Geomorphic Analysis

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

2.1 Sediment Transport from the Watershed

During a storm event, the San Gabriel River conveys flood water and sediment from the watershed to the ocean. A review of the amount and size of the sediment, as well as the historic scour and deposition, can help determine where channel sediment is typically transported.

2.1.1 Sediment Yield (Sediment Supply)

Sediment yield estimates for the San Gabriel River vary in the literature (Table 2-1). Brownlie and Taylor (1981) and Willis and Griggs (2003) looked at the natural/historic and current (post-watershed-modification) yield of sand-sized material[1] (sand yield) of multiple Southern California rivers with dams. Brownlie and Taylor found a 67% reduction in sand yield from the natural sand yield to the current sand yield for the Los Angeles and San Gabriel Rivers combined. Willis and Griggs found a current sand yield of 59,250 cy based on sediment yield of adjacent basins, and determined a natural sand yield of 181,800 cy using the estimated 67% reduction in sand flux caused by dams, as estimated by Brownlie and Taylor. Brownlie and Taylor also summarized a quantitative survey of the San Gabriel River following a flood event in 1938, which indicated a storm deposit of 273,400 cy of generally sand-sized material for an approximately 30-year storm (storm with a 3% chance of occurrence every year).

Inman and Jenkins (1999) estimated an average annual sediment yield of 47,100 cy (36,000 m^3) using a sedimentation curve from a reference watershed and flow rates from the San Gabriel River.[2]

1 Sand-sized material is a grain size diameter generally between 0.062 mm – 2.0 mm. Some coastal studies focus on sand-sized material because it would typically be large enough to remain on beaches.

2 Inman and Jenkins provided sediment yield in tons/yr. Sherman, et. Al (2002) provided the results in volume, which is cited here.

TABLE 2-1
SAN GABRIEL RIVER SEDIMENT YIELD ESTIMATES

Source	Natural Average Sand Yield (no dams) (cy/yr)	Current Average Sand Yield (cy/yr)	Post-flood Sand yield (cy)	Method/Source	Note
Brownlie, W.R. and Taylor, B.D., 1981			273,400 (30-yr event)	Post-flood sand yield estimated by a survey of San Gabriel River Delta near the mouth by LA County Flood Control District.	Survey conducted by Los Angeles County Flood Control District following 1938 flood event. Brownlie and Taylor assume the return event of the 1938 storm is 30 years.
Inman, D.L. and Jenkins, S.A. 1999.		47,100		Based on suspended sediment rating curve of a similar watershed and gauge data at USGS 11088000 (data from 1944-1995).	Total load
Willis and Griggs, 2003	181,800	59,250		Current average sand yield determined from sediment yield of adjacent basin. Natural average sand yield determined from current average sand yield and applying the Brownlie and Taylor 67% reduction factor.	

Sediment yield estimates for the Haynes Cooling Channel were not readily available and are not expected to be substantial since the channel is not expected to have extreme water levels due to rainfall runoff events because it is not connected to the San Gabriel River or a large watershed.

2.1.2 Sediment Size

As part of the Integrated Receiving Water Impacts Report 1994-2005 for Los Angeles County, Weston Solutions, Inc. (Weston) sampled sediment sizes in the San Gabriel Estuary over seven stations. The stations were located along the San Gabriel River, with the most downstream station located at the mouth of the San Gabriel River and the most upstream station located at the 2nd Street bridge. Weston found that sand was the dominant sediment constituent at all sample stations. The median grain size sampled ranged from 0.243 mm to 0.624 mm.

Sediment sizes for the Haynes Cooling Channel were not readily available.

2.2 Channel Scour and Deposition

The locations of fluvial scour and deposition in a channel are dependent on sediment yield or availability (Section 2.1.1), sediment size (Section 2.1.2), channel dimensions and materials, storm events, and tidal action. The effect of waves on channel morphology for the San Gabriel River is considered negligible due to the jetties at the mouth that limit wave-driven coastal sediment transport and deposition upstream of the mouth.

This section examines historic data (Section 2.2.1) and channel hydraulic geometry relationships (Section 2.2.2) to predict how the San Gabriel River could change in response to project conditions.

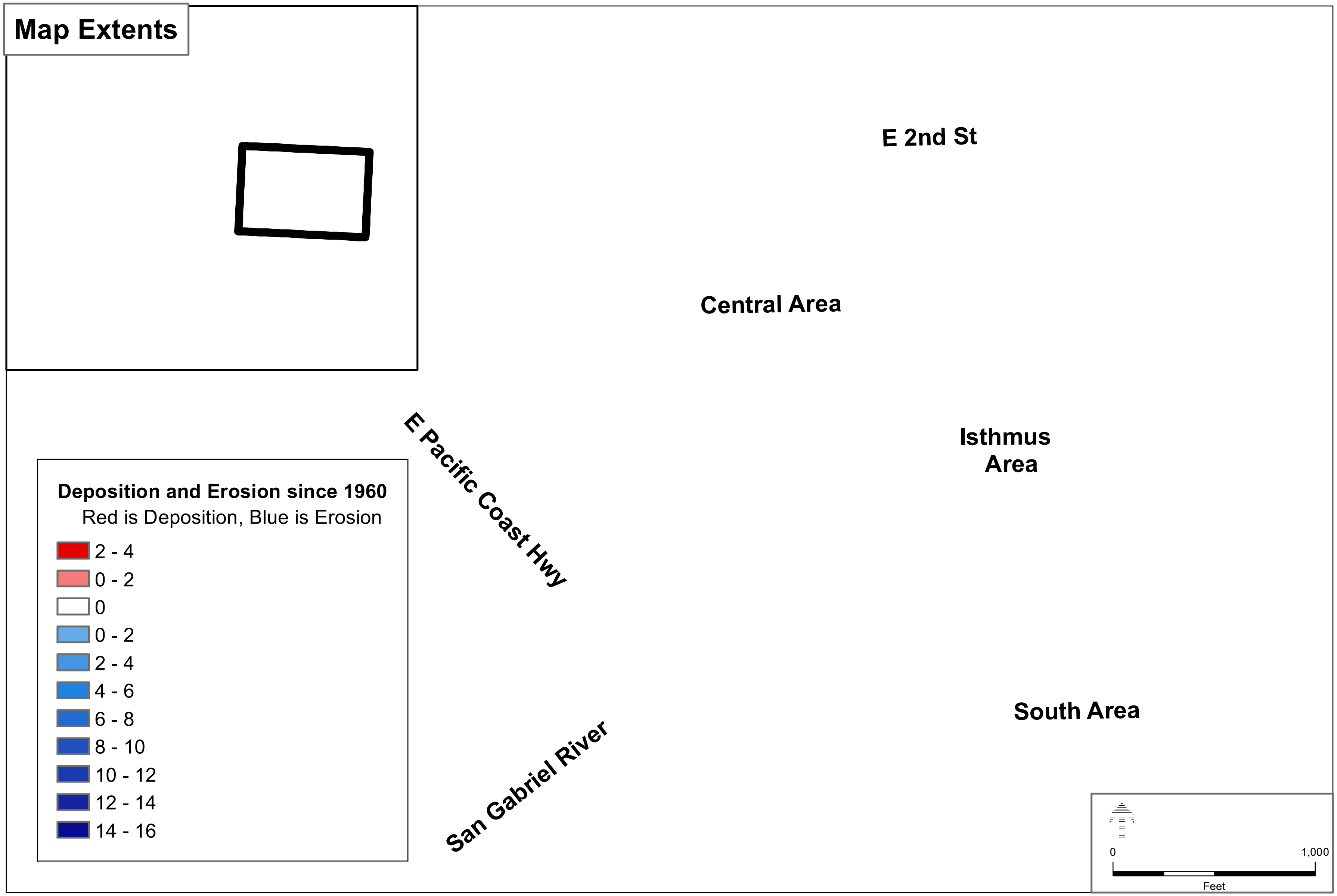
2.2.1 Historic Data

Change in bathymetric surveys over time can help identify locations of scour and deposition. The San Gabriel River as-built survey from 1960 and a 2019 survey by Cinquini & Passarino, Inc. were compared to look at deposition and scour within the channel. **Figure 2-1** shows the deposition (positive values) and scour (negative values) since the 1960 as-built survey. Compared to the 1960 survey, the San Gabriel River has generally scoured in the vicinity of the program site, with erosion depths up to 14 feet in some areas. The most significant channel bed scour is on the northeastern side of the channel along the Isthmus Area near Zedler Marsh. This indicates velocities in the San Gabriel River are higher on the outside of the channel bend, which is typical of natural systems. Additionally, the overall scour indicates that the channel is sediment supply limited rather than transport limited (i.e., there is more erosive power than sediment available to be moved).

2.2.2 Hydraulic Geometry

Within and around the LCW, the channels were designed to contain flood flows or to transport cooling water to power plants. Channels that are tidally influenced (like all of the channels in the LCW) adjust from their constructed designs to accommodate the tidal flow moving through the channel, if they are not constrained by armoring. For example, an undersized channel tends to scour because the restricted flow area creates higher velocities, which can erode the channel bottom or edges. The channel will continue scouring until it begins to approach dimensions that are in equilibrium with the tidal flow. Conversely, an oversized channel may fill in with sediment (assuming sufficient sediment supply) because tidal flows are slower, allowing sediment to drop out of suspension.

The proposed restoration in the LCW will increase tidal current velocities downstream of the project area, as more flow moves in and out of the sites. Based on other restoration experience (Williams et. al 2002), it is anticipated that increased tidal velocities will result in channel deepening until a new channel geometry occurs, which is in equilibrium with the system's tidal prism (the volume of water between MLLW and MHHW). Empirical tidal channel hydraulic geometry relationships (PWA 1995) were applied to estimate an anticipated amount of channel down-cutting and scour along the main channel and in the Haynes Cooling Channel following tidal restoration. The relationships relate tidal prism to channel cross-sectional area, width, and depth. The results for each channel are presented below.



SOURCE: ESRI (background imagery)

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Figure 2-1
San Gabriel River Bathymetric Changes 1960-2019

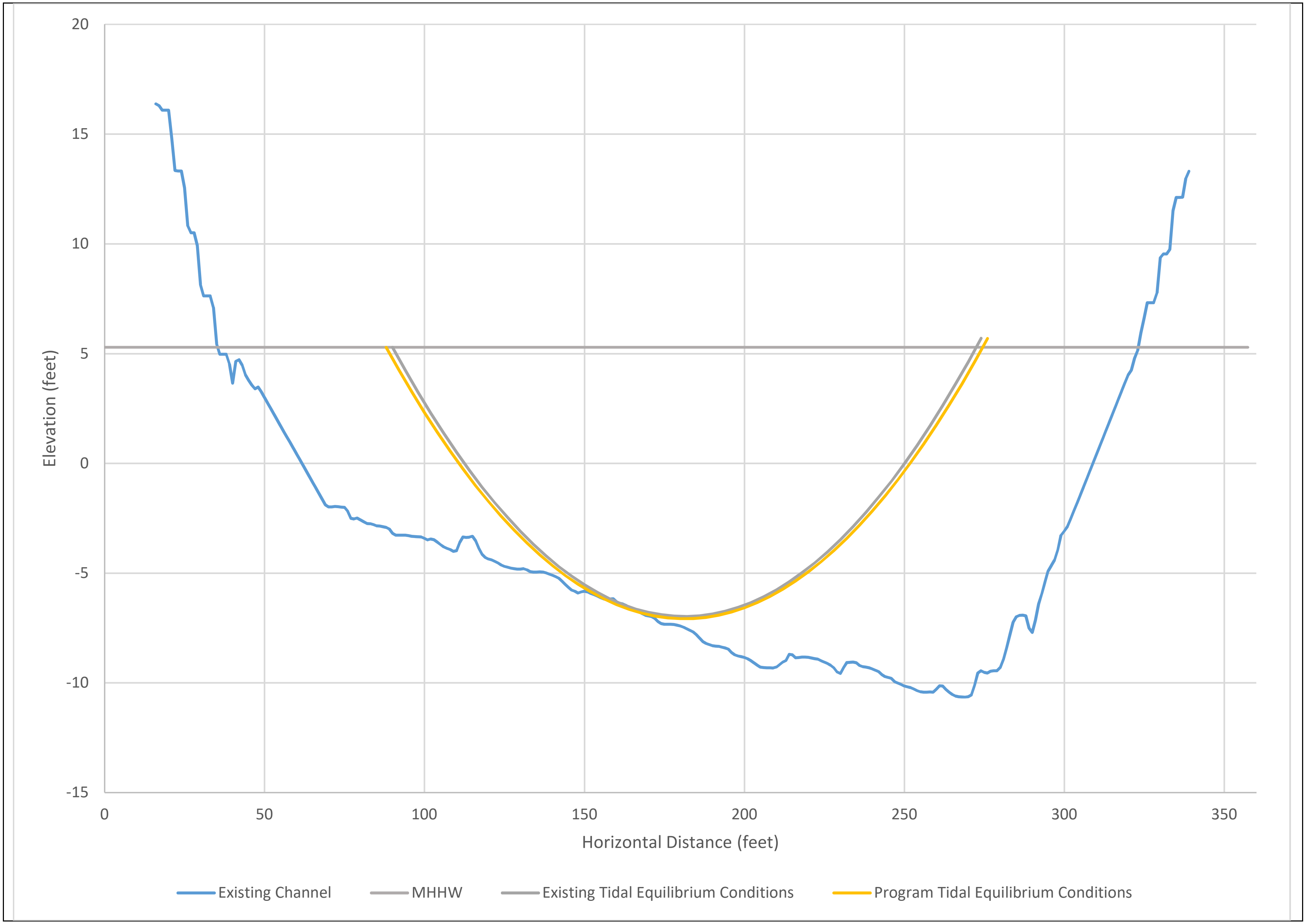
San Gabriel River

The existing San Gabriel River channel is sized to carry both fluvial and tidal flows and is consequently much larger than would be predicted for an exclusively tidal channel (**Figure 2-2**). Under existing conditions, the San Gabriel River has a tidal prism (from MLLW to MHHW) of approximately 550 acre-feet from the mouth to the College Park Drive Bridge and a tidal prism of 317 acre-feet from the Pacific Coast Highway Bridge (at the downstream end of the program area) to the College Park Drive Bridge. Based on just the tides moving in and out of the channel, hydraulic geometry relationships predict the channel should be approximately 120 feet narrower and approximately the same depth as compared to existing conditions just downstream of the Central Area (Table 2-2, **Figure 2-3**). The cross section shown in Figure 2-2 for the existing channel is based on the 2019 field survey.

TABLE 2-2
SAN GABRIEL RIVER (SGR) CHANNEL DIMENSIONS

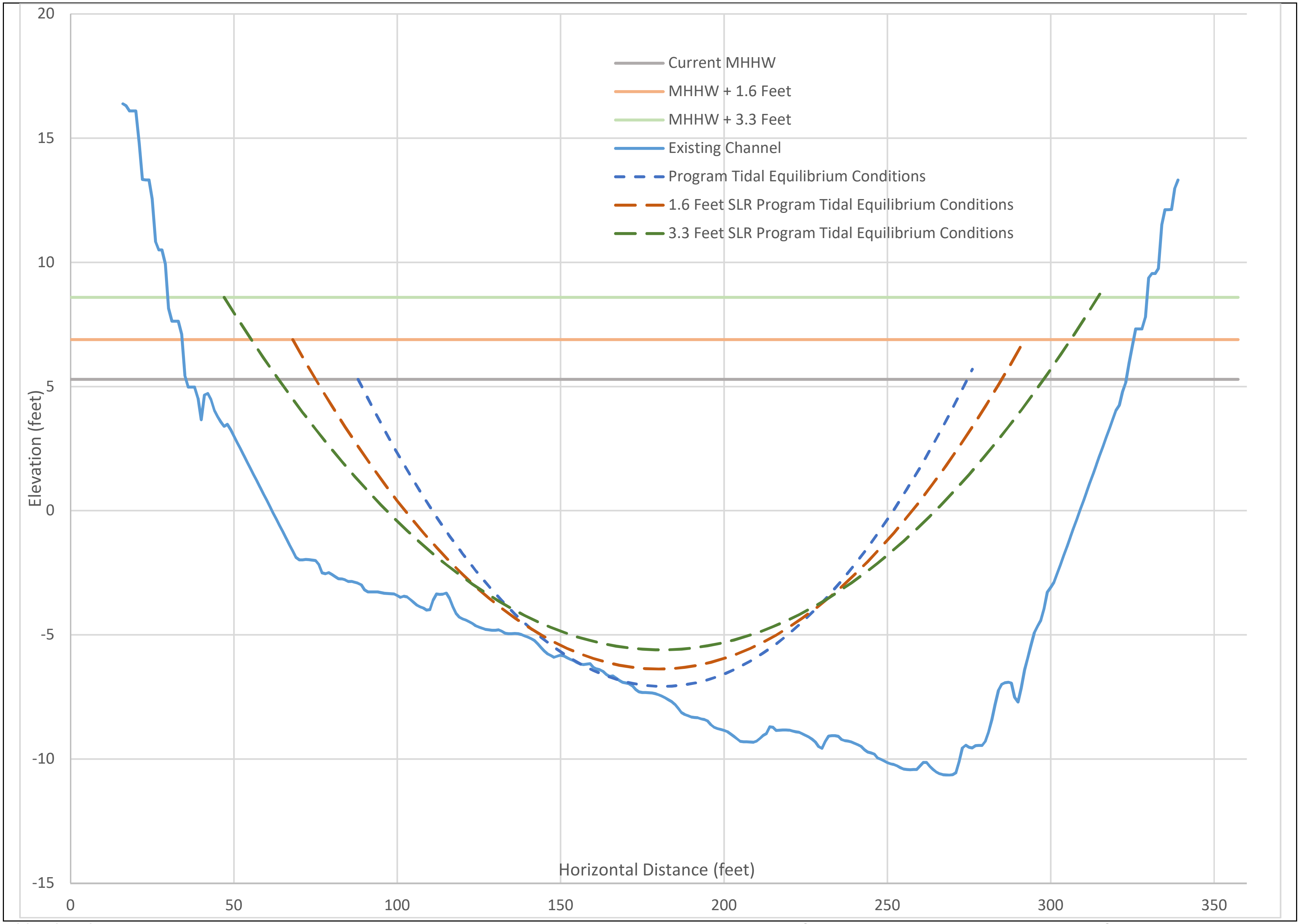
	Tidal Prism (ac-ft)	Channel Width at MHHW (ft)	Channel Depth below MHHW (ft)	Channel Cross-Sectional Area below MHHW (ft^2)
Existing Conditions				
Measured channel existing conditions	n/a	305	12.0	3,363
Estimated based on tidal influence in the channel alone	317	183	12.3	1,302
Estimated based on tidal influence of channel and culvert connections*	322	184	12.3	1,314
Program Conditions				
SGR with Central Area long-term restoration	325	185	12.3	1,322
SGR with South Area mid-term restoration	327	185	12.3	1,328
SGR with both Central Area long-term and South Area mid-term restoration	332	187	12.4	1,342
Future Conditions				
Restored site with 1.7 feet of sea-level rise	494	224	13.3	1,737
Restored site with 3.3 feet of sea-level rise	726	267	14.2	2,229

* San Gabriel River Channel plus Zedler, Callaway, and South LCWA Marshes.



SOURCE: ESA 2020

Figure 2-2
Equilibrium Channel Conditions



SOURCE: ESA 2020

Los Cerritos Wetlands Restoration Plan Program Sediment Dynamics Report

Figure 2-3
Equilibrium Channel Conditions with Sea-Level Rise

The San Gabriel River is tidally connected by culverts to two marshes in the Isthmus Area, Callaway Marsh and Zedler Marsh. These marshes receive muted tidal flows from the San Gabriel River, however they have comparatively small tidal prisms (1.8 ac-ft and 0.1 ac-ft, respectively). Another culvert connects the river to the Long Beach City Property site (Central Area) at the highest tides and during flood flows. However, the tidal prism under existing conditions is negligible since the culvert is set around MHHW and only the highest water levels enter the site.

Another culvert connects the river to the South LCWA site (South Area), although the culvert has a flap gate on it, which limits how much water flows into the site. The existing tidal prism in the South LCWA site is 2.8 ac-ft, since the existing grades are quite high (mostly above MHHW except in and along the Hellman Channel). The total existing tidal prism in the San Gabriel River (river channel + Zedler Marsh + Callaway Marsh + South LCWA marsh) is 322 ac-ft, which corresponds to a 1,314 ft^2 channel, 12.3 ft wide at MHHW, and with a channel thalweg elevation of -7.0 feet NAVD.

For program conditions, both the Central Area and South LCWA site would be graded to create mid- and high marsh, which are generally around MHHW. This means the restored tidal prism of the Central Area (6 acre-feet) and the South Area (8 acre-feet) would be comparatively small and is not expected to have a noticeable impact on the channel, since the tidal prism of the San Gabriel River is so much larger. The hydraulic geometry analysis suggests that the equilibrium tidal channel for the program conditions could be up to 3 feet wider and 0.1 feet deeper than the channel projected for existing conditions by the hydraulic geometry relationships. This is still dramatically smaller than the actual channel.

In the future, sea-level rise will also increase the tidal prism at the site in addition to restoration (Figure 2-3). Future sea-level rise scenarios of 1.7 feet and 3.3 feet were analyzed, based on State guidance (OPC 2018- see the hydrodynamic report for more details, ESA 2020). Under project conditions, 1.7 feet of sea-level rise is anticipated to increase the tidal prism to 494 acre-feet and make the equilibrium tidal channel 37 feet wider and 1 foot deeper the no sea-level rise scenario. With 3.3 feet of sea-level rise, the tidal prism increases to 726 acre-feet and the equilibrium channel is 80 feet wider and 2 feet deeper than the no sea-level rise scenario. However, the hydraulic geometry analysis shows that even with 3.3 feet of sea-level rise, the existing San Gabriel River is large enough to convey the full tidal prism.

Haynes Cooling Channel

The Haynes Cooling Channel is a trapezoidal channel approximately 145 feet wide (at MHHW) by 16 feet deep (below MHHW) that carries cooling water to the Haynes Generating Station. It is connected to the Alamitos Bay Marina by seven, 8-foot-diameter culverts with a total conveyance area of 352 ft^2. Under existing conditions, the channel has a tidal prism of 112 acre-feet, which would correspond to an equilibrium tidal channel 113 feet wide and 10.2 feet deep and with a cross-sectional area of 662 ft^2 (**Table 2-3, Figure 2-4**). The conveyance area of the existing culverts is approximately 53% of the area of the equilibrium channel, indicating that tidal flows experience some restriction through the connection. Under existing conditions, the Haynes Generating Station pumps water up the channel, forcing water through the constriction.

TABLE 2-3
HAYNES COOLING CHANNEL DIMENSIONS

	Tidal Prism (ac-ft)	Channel Width at MHHW (ft)	Channel Depth below MHHW (ft)	Channel Cross-Sectional Area below MHHW (ft^2)
Existing Conditions				
Culvert to Alamitos Bay Marina	-	-	-	352
Measured channel existing conditions	n/a	145	16.0	1,733
Estimated based on tidal influence in the channel	112	113	10.2	662
Program Conditions				
Haynes with South Area mid-term restoration	120	116	10.3	691
Future Conditions				
Restored site with 1.7 feet of sea-level rise	207	150	11.4	987
Restored site with 3.3 feet of sea-level rise	344	190	12.5	1,374

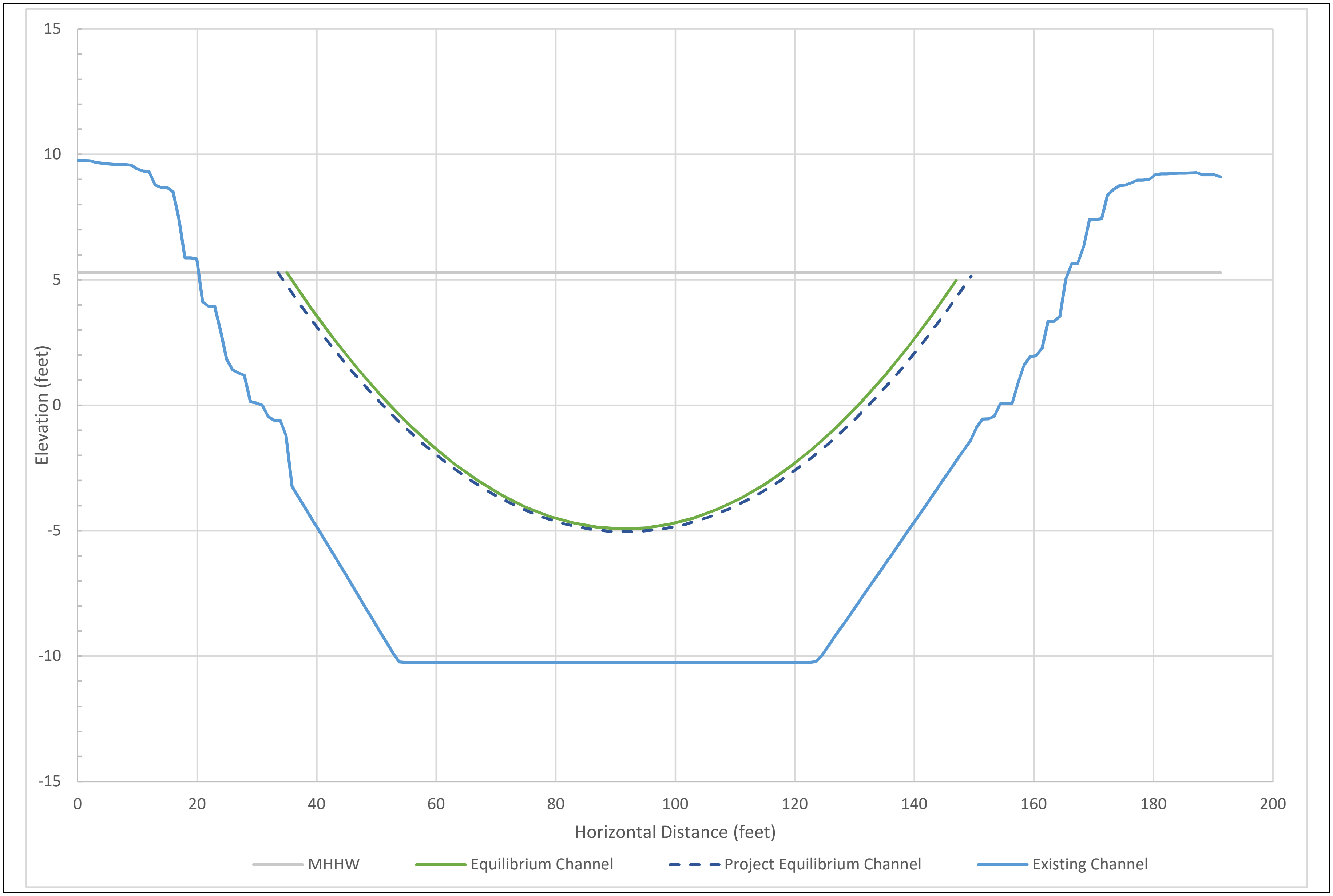
For program conditions, the South LCWA site would be connected to the Haynes Cooling Channel in the mid-term, once the channel is decommissioned and pumping stops. This would increase the tidal prism to 120 ac-ft, which would require a 116 ft wide and 10 ft deep channel. This is still within the range of the existing channel, so no scour would be expected.

With 1.7 feet of sea-level rise, the tidal prism increases to 207 acre-feet and the equilibrium channel becomes 34 feet wider and 1 foot deeper than the predicted existing conditions equilibrium channel, but the actual existing channel could still convey the flow (**Figure 2-5**). With 3.3 feet of sea-level rise, the tidal prism increases to 344 acre-feet and the equilibrium channel becomes 74 feet wider and 2 feet deeper than existing conditions equilibrium channel. The actual existing channel would still be able to convey the flow based on the cross-sectional area, but would be narrower and deeper than predicted by the hydraulic geometry relationships.

The predicted cross-sectional area in the channel is much greater than the cross-sectional area of the culverts that connect the channel to the marina, even without restoration. This means the velocities in the culverts will be higher than in the channel, in order to convey the tidal flow. As a result, sediments are less likely to settle out and block the culvert. The increase in tidal prism as a result of the restoration (and sea-level rise) would further increase velocities through the culverts. This would further lower the likelihood of sedimentation in the culverts.

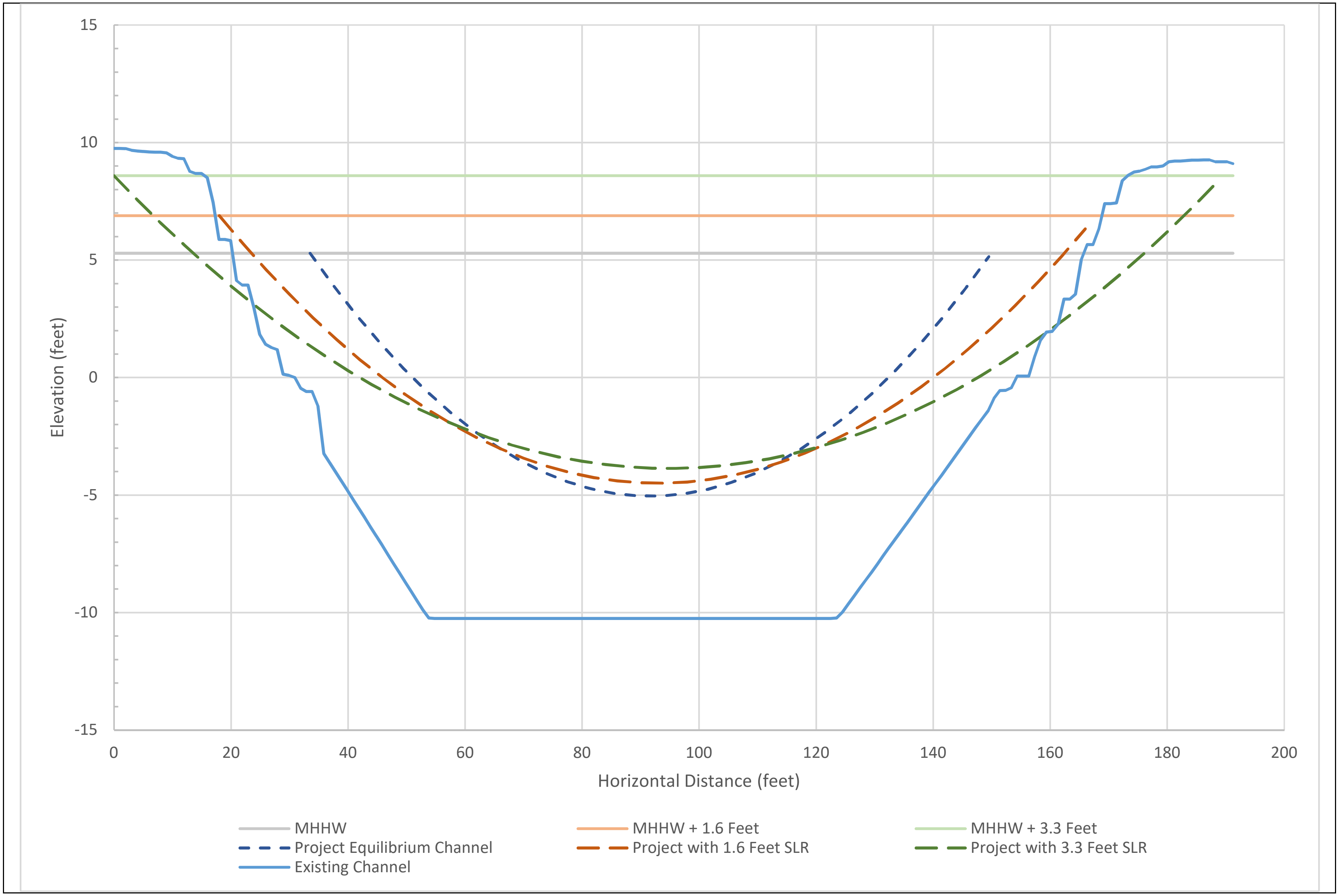
2.2.3 Channel Scour

Some erosion in the San Gabriel River is expected during major storm events. The hydrodynamic modeling (Section 1.3.3) calculated where the highest areas of shear stress are expected to occur during the 100-year event (**Figure 2-6**). The model results show that the proposed program is expected to decrease shear stress in the San Gabriel River, so less channel erosion would be expected during a 100-year event.



SOURCE: ESA 2020

Figure 2-4
Haynes Cooling Channel Equilibrium Conditions



SOURCE: ESA 2020

Figure 2-5

Haynes Cooling Channel Equilibrium Conditions with Sea-Level Rise

Existing

Full Breach

Shear Stress (Pa)

- 0-0.18 (no erosion expected)
- 0.18-0.80 (low erosion expected or no erosion expected with vegetation)
- 0.80 - 40 (medium erosion expected or low erosion expected with vegetation)
- > 40 (high erosion expected, vegetation ripped from soil)

N

0 1,000
Feet

SOURCE: ESRI

Figure 2-6
Modeled Shear Stress during a 100-Year Storm Event

In the Haynes Cooling Channel, the shear stress would increase from less than 2 Pa to up to 10 Pa near the Los Alamitos Pump Station. This is equivalent to a difference of roughly 2 inches of scour over the course of the storm.

2.3 Marshplain Scour and Deposition

Under existing conditions, the culvert connections to the Central Area, Callaway Marsh, Zedler Marsh, and the South Area protect the existing habitats from major tidal scour by muting the tides, which limits tidal velocities. Similarly, the culverts limit how much sediment can enter the wetlands, so deposition is limited.

2.3.1 Tidal Processes

For project conditions, the tidal channels would be sized to convey the tidal prism of the marsh using hydraulic geometry relationships (Section 2.2.2), so the marshplain is not expected to erode under tidal conditions, once vegetated. Additionally, little sediment is expected to come into the marshes during typical tidal conditions, since sediment sources, such as mudflats, are limited in the area and the watershed sediment supply is minimal during typical tidal conditions, so marshplain deposition is expected to be minimal.

Post-construction and before vegetation establishment, some channel sloughing and sediment transport is expected. The project design is expected to use marshplain slopes to guide the flow of tidal water to the channel tributaries before discharging to the river/channel. 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. Further discussion of each site is presented below.

South Area

In the near-term, restoration of the South Area would involve removing the gate on the culvert connecting the site to the San Gabriel River. This would increase the amount of flow entering the site, but since flow would still be limited by the culvert, increased erosion of the marshplain is not expected. Additionally, new tidal channels would be excavated across the site. The tidal channels would be designed using hydraulic geometry relationships to be appropriately sized to accommodate the restored tidal flow.

In the mid-term, restoration of the South Area would involve connecting the site to the Haynes Cooling Channel by removing the berm along the channel to allow for sheet flow across the marsh. The marshplain is expected to be vegetated by this time, which would help hold sediments in place. Erosion is not expected to increase at the site as a result of this additional tidal connection.

Isthmus Area

In the mid-term, restoration of the Isthmus Area could involve removing the gate on the culvert connecting Callaway Marsh to the San Gabriel River. This would increase the amount of flow entering the site, but since flow would still be limited by the culvert, increased erosion of the marshplain is not expected.

Central Area

In the near-term, restoration of the Central Area would involve connecting the Central LCWA and Central Bryant sites to the San Gabriel River by breaching the existing San Gabriel River levee to allow for full tidal influence into the site. Additionally, new tidal channels would be excavated across the site. The tidal channels would be designed using hydraulic geometry relationships to be appropriately sized to accommodate the restored tidal flow. Once vegetated, the site is not expected to erode under tidal conditions.

In the long-term, tidal channels would be extended onto the Long Beach City Property site and designed to accommodate tidal flows. Once vegetated, the site is not expected to erode substantially under tidal conditions.

2.3.2 Extreme Event Processes

Under mid-term restored conditions, the South LCWA site would be connected to the Haynes Cooling Channel. Due to the small watershed that drains into the channel, the Haynes Cooling Channel does not experience dramatic increases in water levels or suspended sediment due to riverine events. Therefore, the South Area is not susceptible to substantial scour or deposition due to storm events on the Haynes Cooling Channel. Additionally, high fluvial flows and sediment loads in the San Gabriel River are limited from entering the South Area by the culvert connection between the two, although some erosion is expected.

Under restored conditions, the culvert connections to Callaway Marsh and Zedler Marsh protect the existing habitats from fluvial scour by limited the flows into the sites, which limits velocities. Similarly, the culverts limit how much sediment can enter the wetlands, so deposition is limited.

In the restored Central Area, the direct connection to the San Gabriel River makes the site susceptible to both scour and deposition. The following sections describe these processes in greater detail.

Marshplain Scour

On the marshplain and along the channel banks of healthy marshes, some erosion is expected during major storm events. The hydrodynamic modeling (Section 1.3.3) calculated where the highest areas of shear stress are expected to occur during the 100-year event (Figure 2-6). 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:

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

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

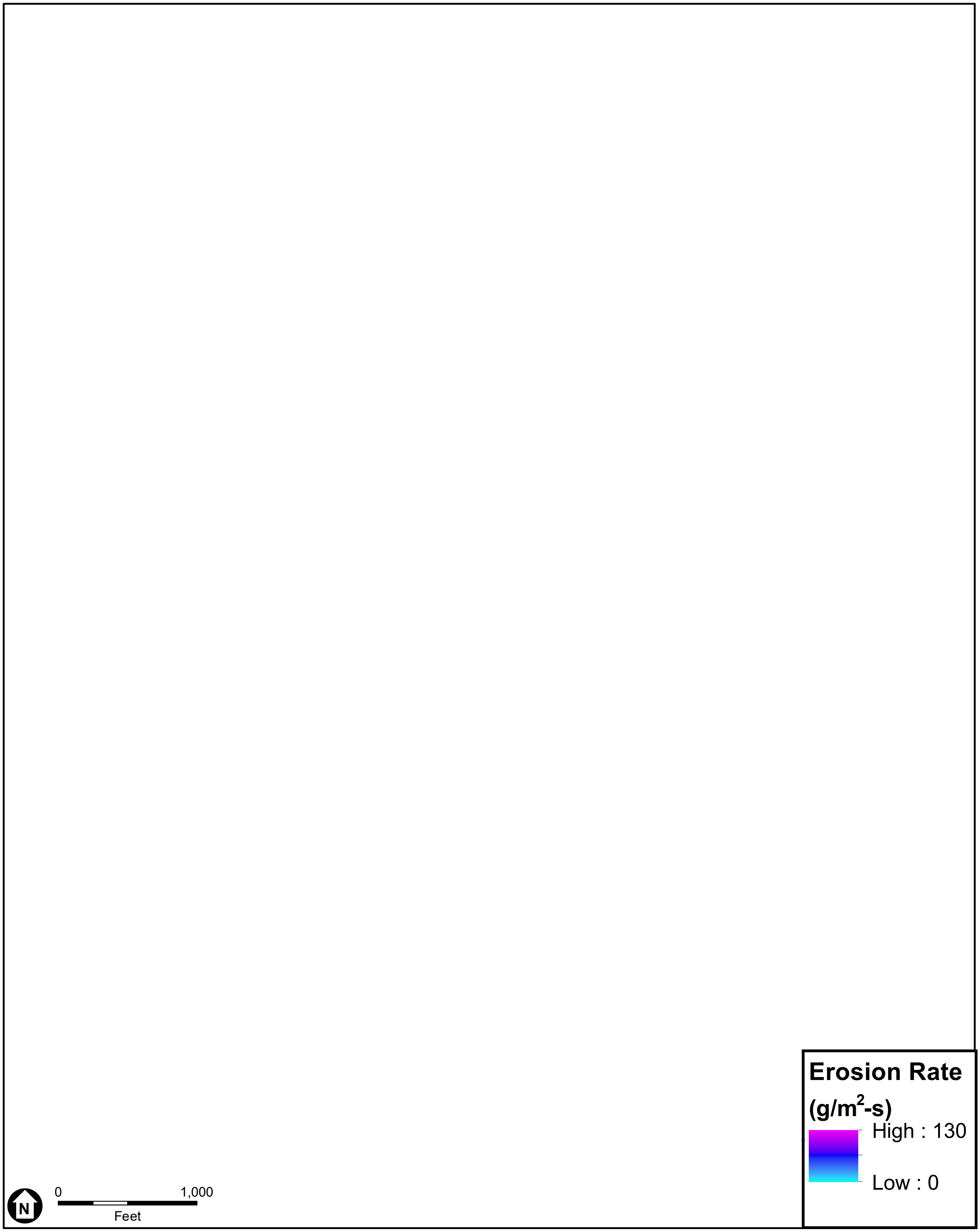
Table 2-4 shows the critical shear stresses values found in the literature. Ganthy (2011) and Simon and Hanson (2001) offer estimates of critical shear stress for other sites.

TABLE 2-4
CRITICAL SHEAR STRESS RANGES

Method	Critical Shear Stress (Pa)	Source
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)

As shown in Figure 2-6, shear stress less than 0.18 Pa would be less than the most conservatively low critical shear stress applied by Ganthy, so no erosion would be expected in these areas. Once areas are vegetated, erosion on the marsh will be limited by vegetation, as the roots will help hold the sediment in place. The critical shear stress would jump to at least 0.80 Pa, assuming full vegetation cover, so areas between 0.18 and 0.80 Pa would be expected to have some erosion if unvegetated, but would not be expected to erode if vegetated. Fischenich (2001) estimated the critical shear stress before erosion of short vegetation would occur to be 40 Pa and tall vegetation to be 65 Pa. So areas between 0.8 and 40 Pa would be expected to erode at slower rate if vegetation is established and a faster rate for just bare earth. Above 40 Pa, vegetation would be ripped out and erosion would increase.

Combining the equations above with the estimates of critical shear stress provides a method to calculate an erosion rate from the modeled shear stresses. **Figure 2-7** presents the maximum erosion rates (Ganthy equation with a critical shear stress of 0.18 Pa) spatially at the peak of the 100-year storm. The highest shear stresses appear at the downstream end of the Haynes Cooling Channel through the culverts and at the mouth of the restored South and Central Area marsh channels.



SOURCE: ESRI

Los Cerritos Wetlands Restoration Plan Program EIR Sediment Dynamics Technical Report

Figure 2-7

Modeled Erosion Rate during a 100-Year Storm Event

ESA

Shear stress time series with a triangular distribution were then estimated to approximate the total erosion over the course of the storm. A maximum erosion duration of 3.25 hours was extracted from model outputs based on the amount of time the shear stress at the site was above the 0.18 critical shear stress value. Assuming no vegetation on the marsh, the analysis shows erosion of up to 24 inches (2 feet) at the channel mouths over the duration of the 100-year storm (**Table 2-5**). While this is a substantial amount of erosion, it would be limited to the darkest pink areas in Figure 2-7.

TABLE 2-5
MAXIMUM EROSION USING GANTHY (2011)

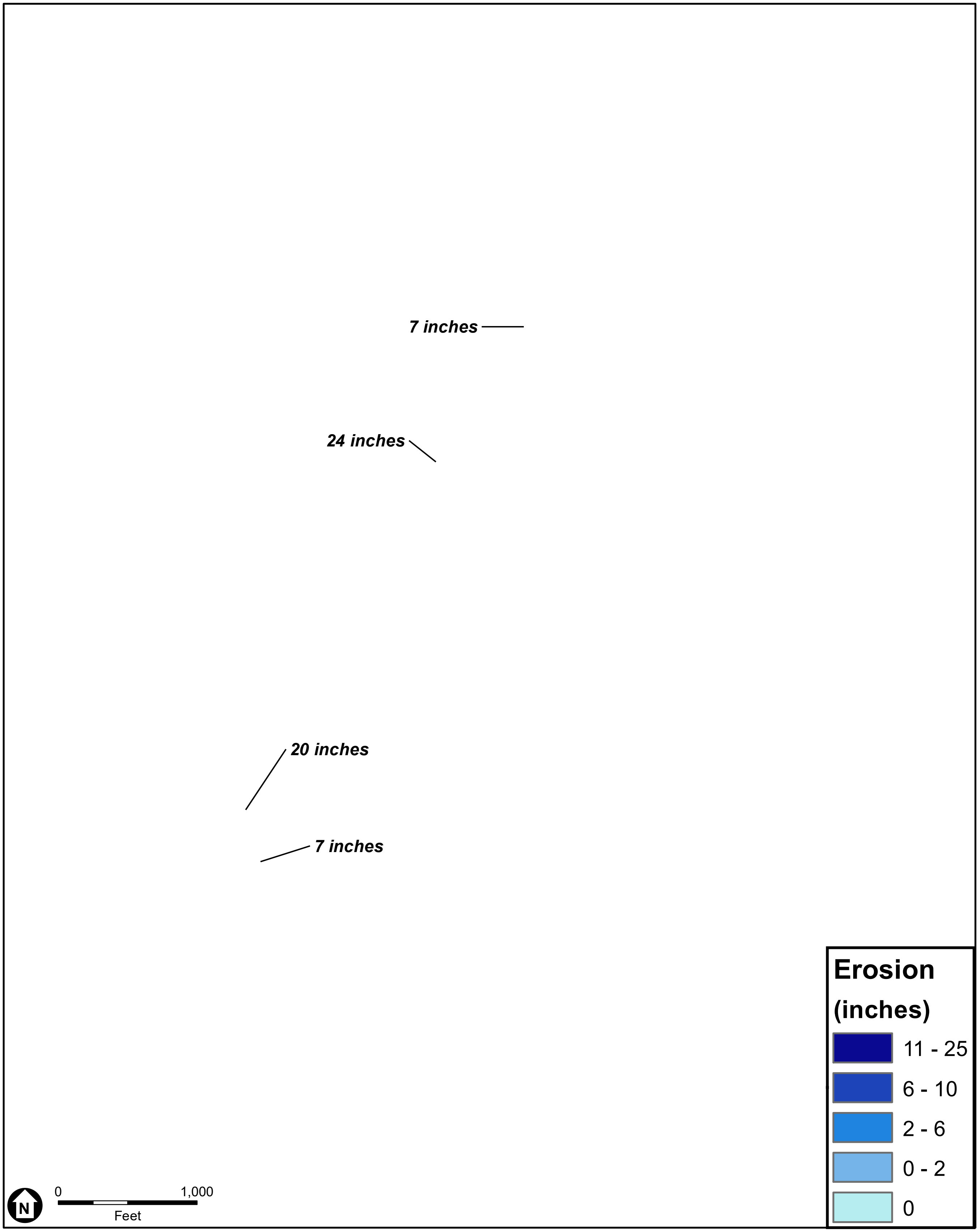
	No vegetation	With Vegetation
Location (Figure X)	**100-year erosion (in)**	**100-year erosion (in)**
South and Central Area channel mouths	24	23
Central Area interior	10	2
South Area interior	<1	0

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.

In the marsh interiors, shear stress and predicted erosion are considerably lower. The Ganthy equation predicts a maximum of 10 inches of erosion in the interior of the Central Area and along the banks of the primary channel of the South Area, assuming vegetation has not yet established at the site.

During a 100-year event, the erosion analysis shows that even under such extreme conditions and using conservatively high assumptions, the highest shear stresses are limited to areas at the mouths and banks of the restored marsh channels and are estimated to cause 2 ft or less of erosion (**Figure 2-8**). Additionally, once vegetated, erosion on the marsh will be less. This would reduce the highest estimated amount of erosion on the marshplain to 2 inches under the 100-year storm, assuming short vegetation (Table 2-5). Additionally, the project design may include armoring at key points, and these estimates do not consider any armoring, which would decrease channel bank erosion.

The map of erosion (Figure 2-8) was used to analyze the total volume of sediment that would be eroded from each area. During the 100-year event, approximately 5,000 cy and 1,800 cy would erode from the Central Area and South LCWA site marshplains, respectively. Most of the erosion in the Central Area would occur at the mouth and banks of the restored marsh channel, near the culvert, and at the northeast corner of the site where the San Gabriel River first expands into the Central Area. Most of the erosion in the South Area would occur at the mouth and banks of the Hellman Channel. The resulting erosion map was used to analyze the habitats that would remain in the Central Area after a 100-yr event (**Figure 2-9**). During the 100-year event, erosion would possibly lower elevations along the breach from high marsh elevations to mid marsh elevations and transition zone to high marsh elevations. At the mouth of the channel a small area would possibly convert from mid marsh to low marsh and from low marsh to mudflat.



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SOURCE: ESRI

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Figure 2-8
Modeled Erosion during a 100-Year Storm Event

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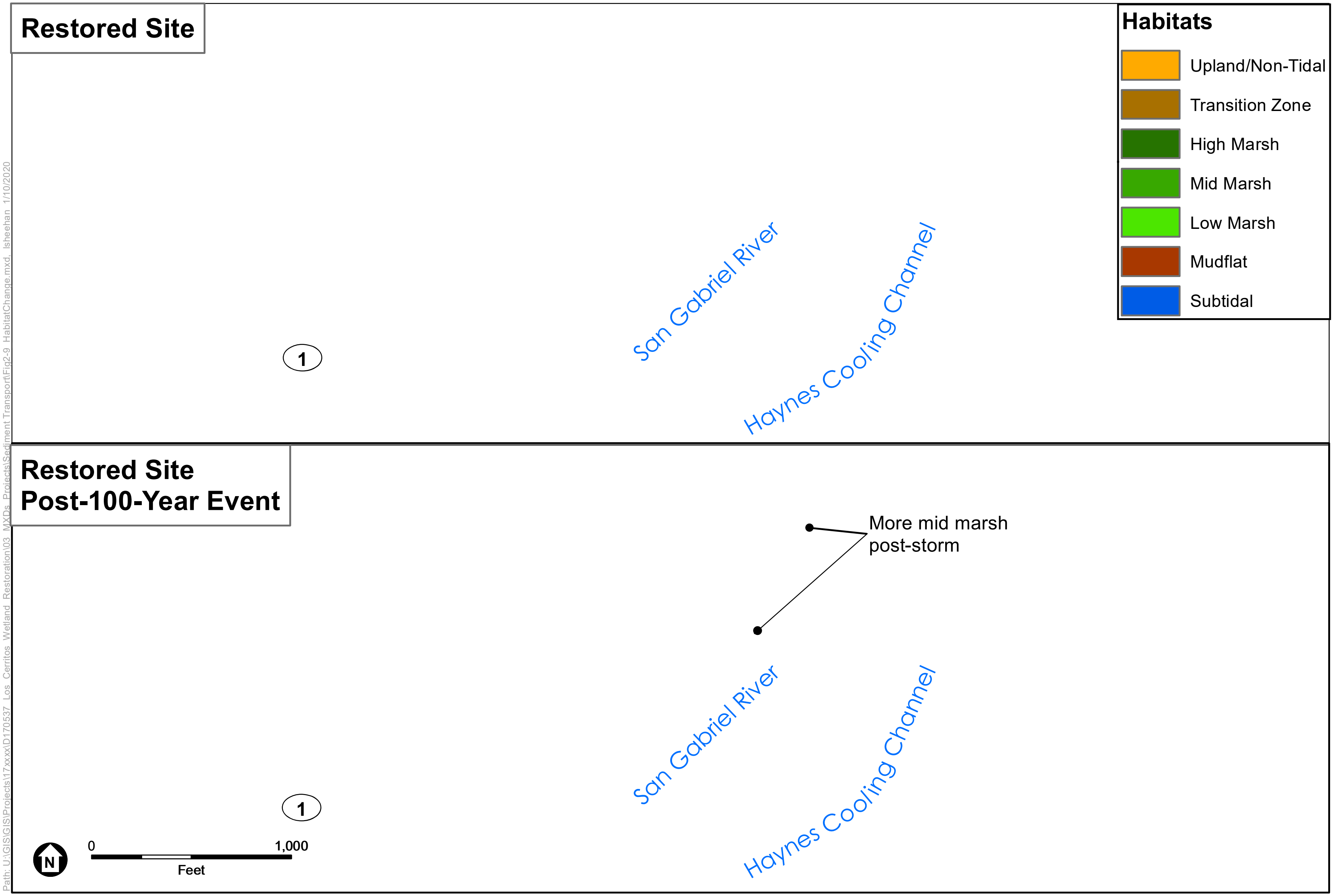

SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

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Figure 2-9
Habitats Pre- and Post-100-Year Event

ESA

Marshplain Deposition

The South Area is not expected to experience deposition despite its slower velocities because it is hydraulically connected to the Alamitos Bay Marina, rather than the San Gabriel River, and consequently has less sediment supply. As in the Isthmus Area, the South Area is also connected to the San Gabriel River through a culvert, which limits the amount of sediment that can enter the site.

In certain areas of the Central Area marsh where the velocities are slow, some deposition is expected during storm events. The culvert connections are expected to limit deposition in the Isthmus and South Areas. 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 approximate the amount of sediment being deposited at different locations in the Central Area, the estimate of 0.64% was applied to the total sediment yield to estimate the volume of deposition. The total sediment yield of the 30-year storm event has been estimated to be 273,400 cy (Brownlie and Taylor 1981). If 0.64% of this sediment were to deposit across the Central Area, it would have an average thickness of approximately 0.2 inches. If the sediment were to deposit in just the areas where erosion is not expected (roughly one third of the site), the average thickness would be approximately 0.6 inches.

Marsh vegetation has been shown to be able to grow through several inches of sedimentation, so this amount of deposition on the marsh is not likely to impact the existing habitats. Additionally, deposition is a natural marsh process and will provide the marsh the ability to move up in the tide frame to accommodate to sea-level rise in the future.

For long-term sedimentation, the 50,000 cy/year sediment yield estimate of the San Gabriel River would result in marsh deposition of 320 cy/year, or 0.1 inches/year across the portion of the site that is not expected to erode. This amount of sedimentation could help the marsh keep up with sea-level rise.

The larger the storm, the larger the sediment load that it typically carries. However, in terms of marshplain deposition, larger storms may result in more erosion and less deposition. Storms around and larger than the 30-year event would likely result in erosion of the marsh during the storm, with only the most protected areas receiving sediment deposition. In more frequent storm events, the velocities would be lower, so deposition is more likely to occur, although the sediment load could be lower.

2.4 Coastal Sediment Transport

The historic longshore transport in the San Pedro Littoral Cell, which extends from Point Fermin in the northwest to Dana Point at the southeast, is generally toward the southeast. The Newport Submarine Canyon is at the southeastern end of the cell and acts as a sediment sink.

Historic processes in the littoral cell have been disrupted by the San Pedro-Long Beach port complex, dam construction, channelization of the Los Angeles and San Gabriel Rivers and the construction of a series of coastal structures. Prior to the dam construction, the Santa Ana, San Gabriel, and Los Angeles Rivers often changed course and their watersheds provided abundant sediment to local beaches. Following the extensive construction of dams, pavement, and channelization, the sediment deliveries from the San Gabriel and Los Angeles river basins are now substantially reduced (see discussion in Section 2.1).

The San Gabriel River flowed into Alamitos Bay from 1868 until 1933-1935, when its new flood channel outlet was constructed. The new construction included levees and stone jetties at its mouth. The east and west jetties for the new San Gabriel River mouth were completed in 1932 and 1933, respectively. The west jetty was extended in 1940-1941 to slow the shoaling of the outlet. A new bay entrance was dredged in 1945-1946. This separated the Alamitos Bay from the San Gabriel River ocean outlet, resulting in three stone jetties at the bay entrance and its adjacent river mouth outlet.

The Long Beach Detached Breakwater protects most of the coast from ocean waves, resulting in relatively little longshore transport in the vicinity of the site (USACE 1986). However, northwest longshore transport at Seal Beach has led to accumulation of sand at the San Gabriel River mouth east jetty and erosion at the Anaheim Bay west jetty according to Wiegel (2009). Many of the beaches in the San Pedro Littoral Cell are nourished with sands annually to combat erosion (Orme et al 2011). In the vicinity of the program at Belmont Shore Beach and Seal Beach, nourishment began in 1940s, with much of the material coming from Alamitos Bay. A history of dredge events for Alamitos Bay from 1933-2002 is provided in **Table 2-6**.

TABLE 2-6
DREDGE EVENTS AT ALAMITOS BAY AND SAN GABRIEL RIVER

Date[1]	Location	Destination	Quantity (cy)	Source[2]
1944-1946	Alamitos Bay	Seal Beach	800,000	1
1945	Alamitos Bay	East Belmont Shore	800,000	1
1946	Alamitos Bay	Alamitos Bay peninsula	628,000	1
1950	Alamitos Bay	Alamitos Bay Peninsula shore	540,000	1
1954	Long Beach Marina	Seal Beach	800,000	1
1959	San Gabriel River	Seal Beach	225,000	1
1967	San Gabriel River	Seal Beach	70,000	1
1950s-1970s	Alamitos Bay, San Gabriel River mouth	East Belmont Shore	Not included	1
1994-2002	Alamitos Bay	Local Beaches	18,300[3]	2

1 Indicates year project was started

2 Quantities in Source 2 were provided in cubic meters. They were converted to cubic yard for this table.

3 This volume represents annual volumes.

SOURCES:

1. Wiegel 2009, San Pedro Bay Delta, in Southern California Shore and Shore Use Changes During Past 1-1/2 Centuries from a Coastal Engineering Perspective

2. USACE Los Angeles District 2004. Los Angeles Regional Dredged Material Management Plan Feasibility Study, Baseline Conditions (F3) Report

Due to jetties at the mouth of the San Gabriel River, coastal sediment transport is not expected to have a substantial impact on the sediment dynamics at the LCW.

SECTION 3
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 LCW restoration provides insight into how future LCW habitats are anticipated to persist in the near-term. This section describes conditions at the Anaheim Bay Wetlands, just south of the Los Angeles County border in Orange County, and the San Elijo Lagoon wetlands, in northern San Diego County.

3.1 Anaheim Bay

The Anaheim Bay wetlands are located within Seal Beach National Wildlife Refuge, entirely within the boundaries of the Naval Weapons Station Seal Beach (**Figure 3-1**). Prior to western settlement, the Anaheim Bay 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 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 440,960 acres at LCW, and receive limited inflows from the Bolsa Chica and Wintersburg flood control channels as well as local runoff (**Table 3-1**; CDFG and USFWS 1976).

TABLE 3-1
REFERENCE SITE CHARACTERISTICS

Site	Watershed Area (acres)	100-Yr Streamflow (cfs)	Sediment Supply (cy/yr)	Inlet Condition	Depositional or Erosional?
LCW	440,960	55,900	50,000	Open	Expected to be stable
Anaheim Bay	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	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

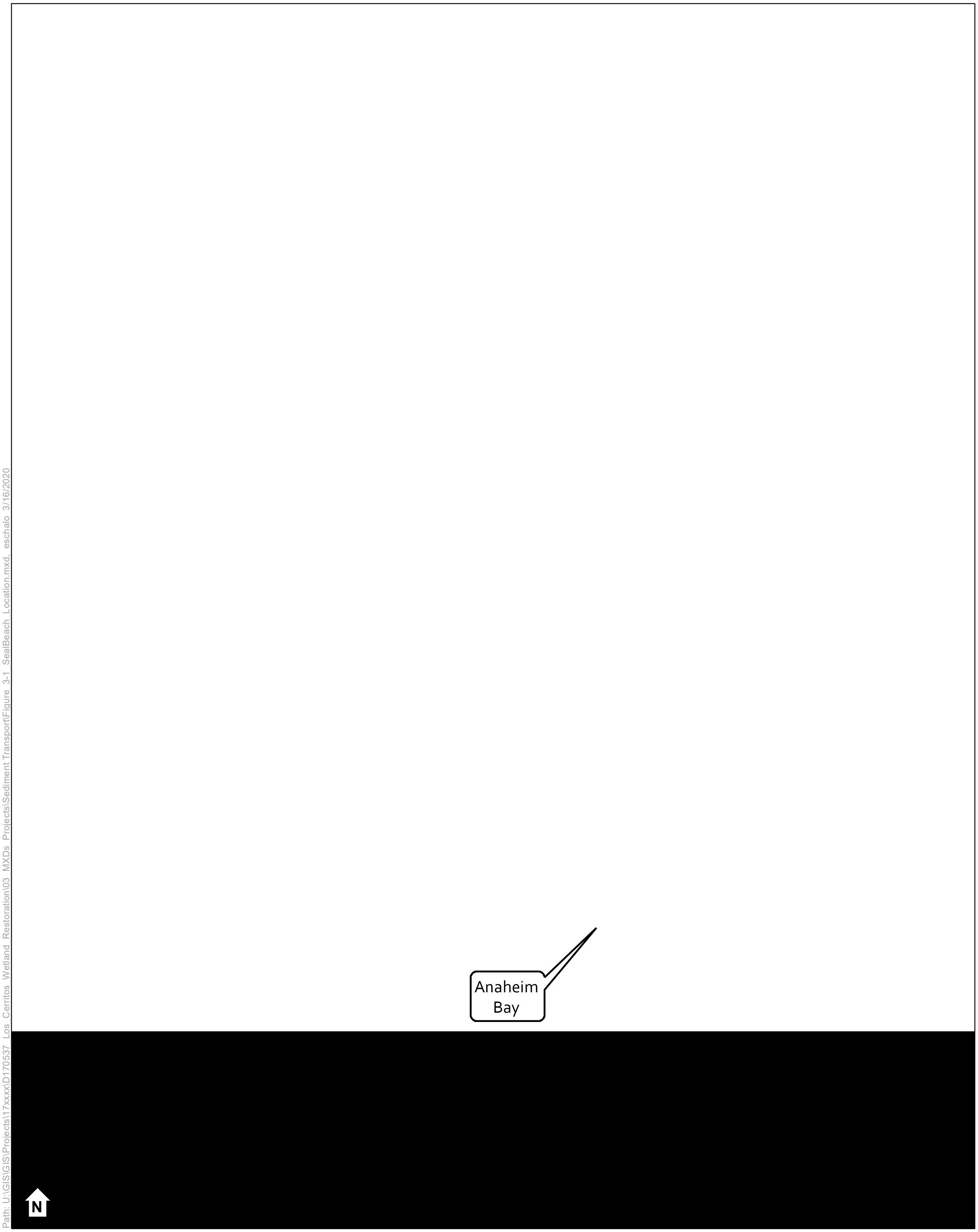
3 Moffatt & Nichol 2012

3 Laton et al 2002

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 3-2**). 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 Anaheim Bay 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 LCW, the tidal channels will be sized to correspond to equilibrium conditions to avoid erosion (Section 2.2.2). At Anaheim Bay, additional erosion has occurred in Forrestal Pond, where the deeper water and longer fetch length has allowed waves to erode the northeast corner. At LCW, the fetch within the site is not large, so erosion due to wind waves in not expected.

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). San Gabriel River, although sediment poor, is still expected to contribute some sediment to the marsh (Section 2.3.2).



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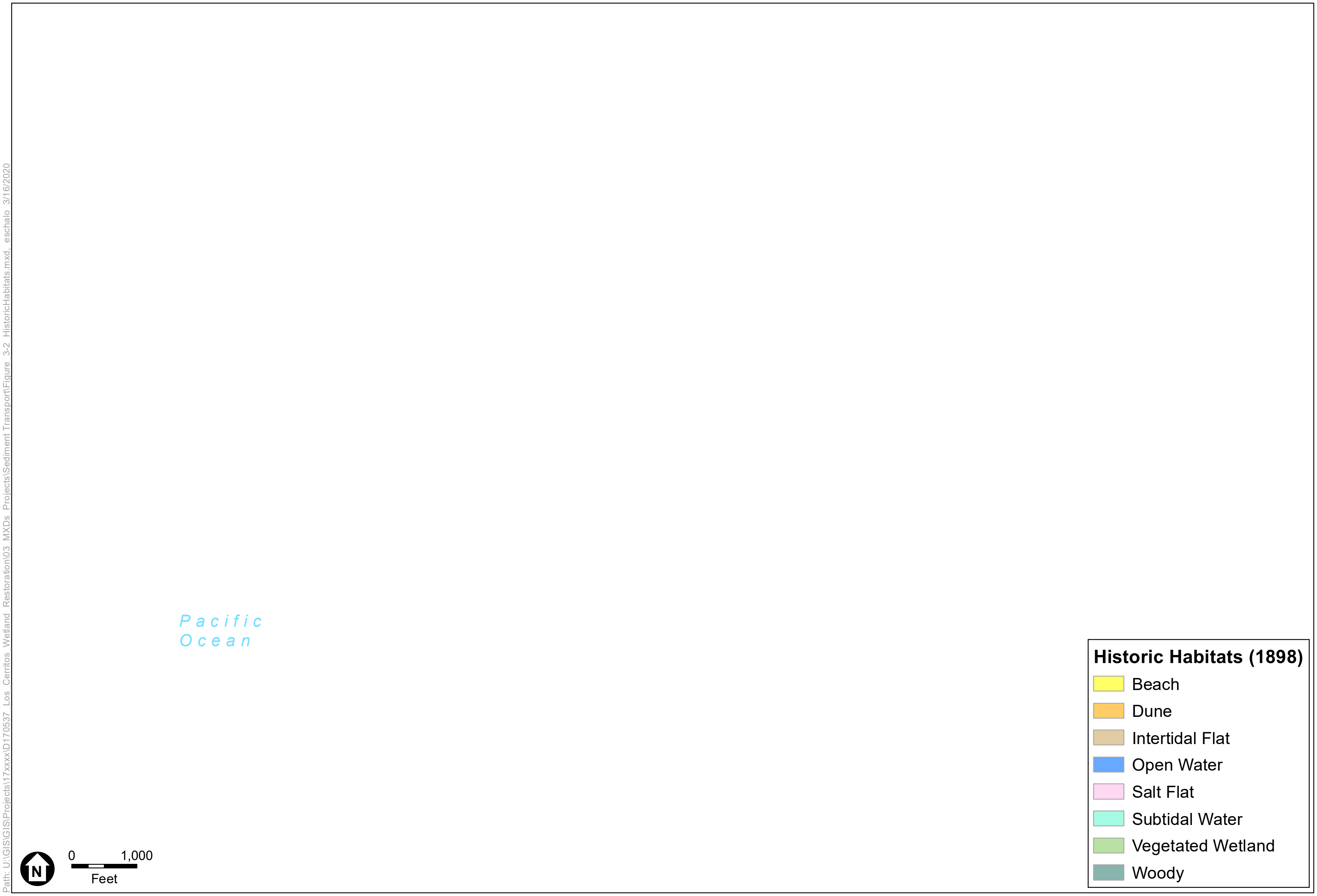
SOURCE: ESRI

Figure 3-1
Location of Anaheim Bay



SOURCE: ESRI, 2019; SFEI 2011

Los Cerritos Wetlands Restoration Plan Program Sediment Dynamics Report

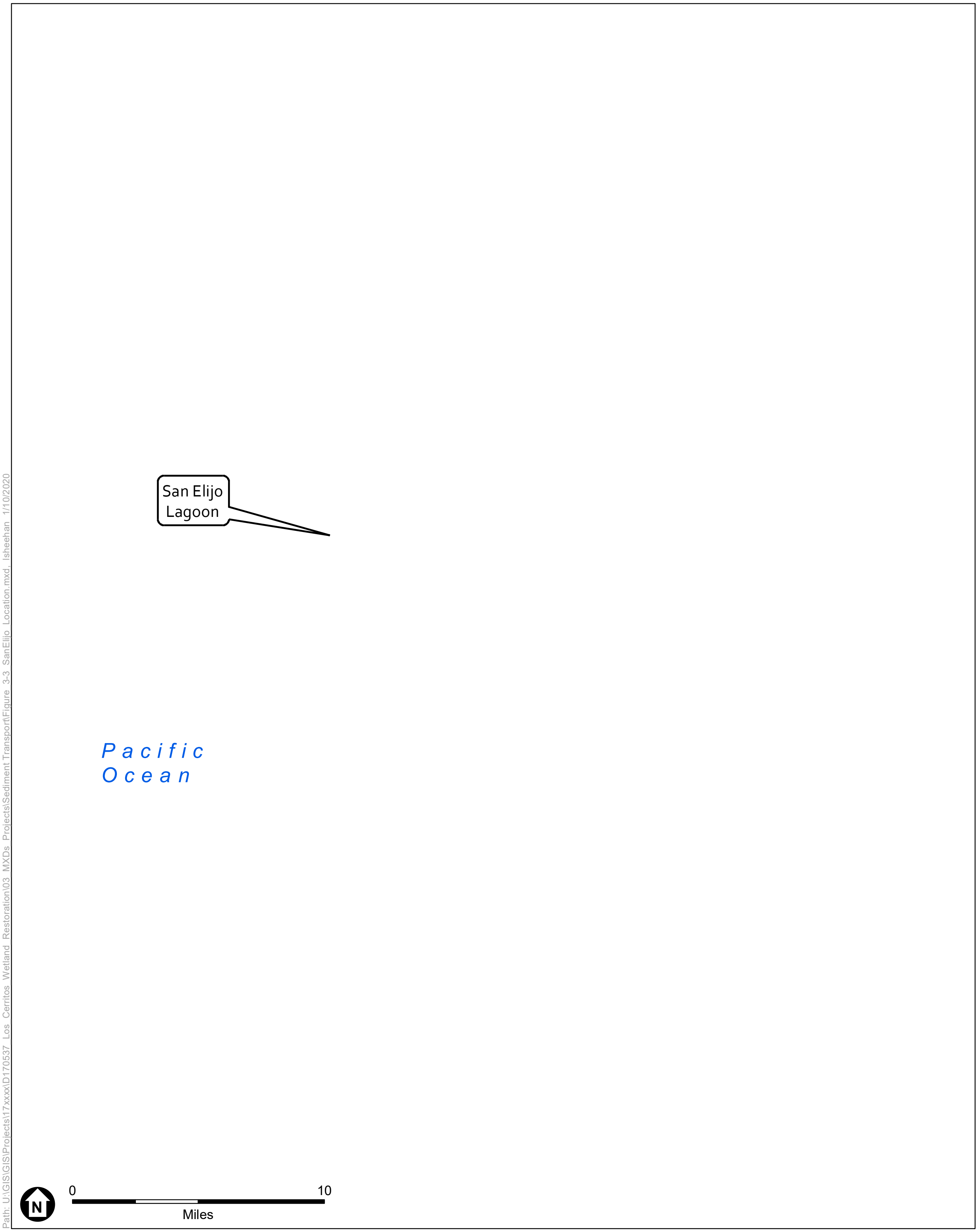
Figure 3-2
Anaheim Bay Historic Habitats

ESA

3.2 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 Nature Collective (**Figure 3-3**). 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 Peñasquitos lagoons to the south (Grossinger et al. 2011). The primary freshwater inflow to the lagoon is Escondido Creek, which has a watershed of approximately 54,000 ac (SELC 2013).

Like the LCW and Anaheim Bay, 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 3-4**, 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 the San Gabriel River also has an anchored inlet, this may indicate that channel migration at LCW will be minimal.

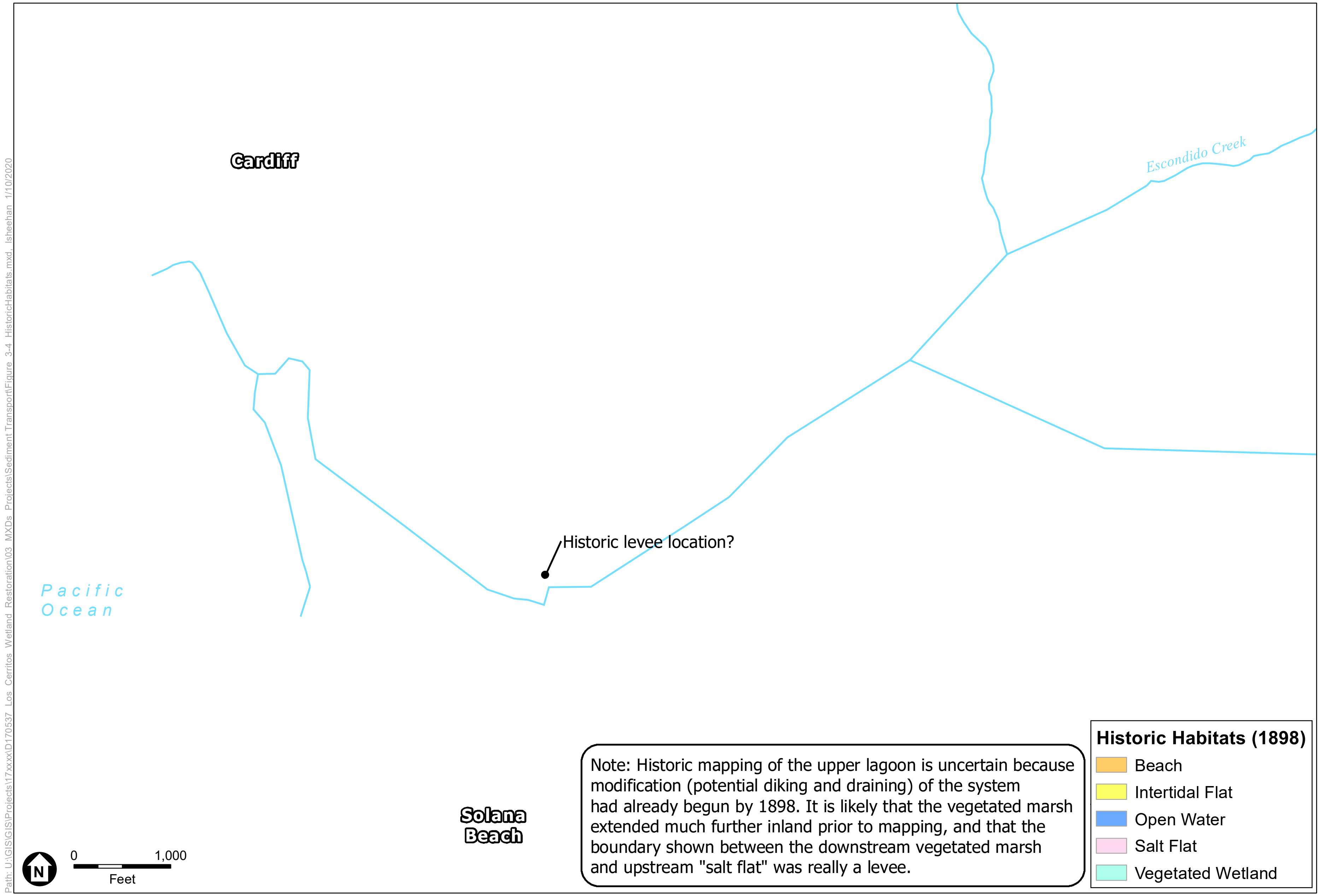


SOURCE: ESRI

Los Cerritos Wetlands Restoration Plan Program Sediment Dynamics Report

Figure 3-3
San Elijo Lagoon Location

ESA



SOURCE: ESRI, 2019; SFEI 2011

Los Cerritos Wetlands Restoration Plan Program Sediment Dynamics Report

Figure 3-4
San Elijo Lagoon Historic Habitats

ESA

SECTION 4
Conclusions

The sediment dynamic analyses assess both existing and proposed program conditions to evaluate potential changes due to the program. Under existing conditions, storm events in the existing San Gabriel River transports approximately 50,000 cy of sediment per year on average from the San Gabriel River watershed.

4.1 Channels

4.1.1 San Gabriel River

Under existing conditions, the San Gabriel River is oversized for the tidal prism it conveys, since it also must transport large riverine flood events. In the absence of large riverine flood events, the channel would be expected to fill in with sediment during typical tides (i.e., under non-storm conditions) until the channel reached equilibrium with the tidal scour and deposition processes. However, sediment in the system is limited during non-storm conditions, since the jetties at the mouth of the river keep the majority of coastal sediment from reaching the site. Any deposition that does occur under non-storm events is likely flushed from the system during a storm. Comparing surveys from 1960 and 2019 shows that the reach of the San Gabriel River in the vicinity of the site is erosional, with up to 14 feet of channel scour in some locations.

Under program conditions, the channel is expected to respond to similar dynamics. The increase in tidal prism due to the program is small compared to tidal prism of the river itself and since the channel is oversized for tidal conditions, no scour is expected in the channel due to the increased tidal prism of the restoration. Additionally, the hydrodynamic modeling shows that shear stresses are expected to decrease under program conditions, which will lessen the erosion in the channel during a 100-year event.

4.1.2 Haynes Cooling Channel

The geomorphology of the constructed Haynes Cooling Channel is driven by the tidal flows from the Alamitos Bay Marina. Under existing conditions, the constructed channel is much larger than would be predicted to convey the tidal prism of the channel, which would indicate that the channel could fill with sediment until it reaches an equilibrium with tidal scouring if adequate sediment supply were available. However, the sediment supply from the Alamitos Bay Marina is low.

Under mid-term program conditions, the Haynes Generating Station would stop pumping water up the channel and the Haynes Cooling Channel would be connected to the South LCWA site.

Even with the additional tidal prism from the restored South LCWA site, the Haynes Cooling Channel would be oversized. This means the channel could fill in with sediment until it reaches equilibrium with the tidal scour and deposition processes. However, sediment in the system is limited from the Alamitos Bay Marina. Additionally, the hydrodynamic modeling shows that the shear stresses are expected to increase slightly under program conditions during a 100-year riverine event, which could scour out deposited sediment in the channel.

The sediment dynamics analysis shows that the culverts connecting the channel to the Alamitos Bay Marina are undersized to convey the tidal prism of the restored site. This means that the velocities in the culverts will be higher than in the rest of the Haynes Cooling Channel, indicating that the potential for sedimentation in the culverts (and the need for increased maintenance) is low.

4.2 Restored Wetlands

The sediment dynamic analysis shows that some wetland deposition could occur during more frequent storm events. During larger storm events, based on conservatively high estimates of potential wetland erosion, a small amount of sediment could be eroded from restored wetlands along the San Gabriel River and along the restored channels during more extreme storm events (up to 6,800 cy of erosion during the 100-year event). During a 100-year event, results show 0 to 7 inches of erosion in the Central Area wetlands, with erosion at the breach up to 24 inches. During a 100-year event, the model results show 0 to 2 inches of erosion could occur in the South Area, with up to 20 inches of erosion near the mouth of the Hellman Channel.

This pattern of erosion could lower high marsh areas to elevations where mid marsh would re-establish following the event, causing a conversion from high marsh to mid marsh habitat. The potential for habitat conversion due to erosion is relatively small in the South Area. In the Central Area, the results show the potential to convert some of the high marsh to mid marsh habitat along the San Gabriel River and near the breach. 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 program design may include armoring, and these estimates do not consider any armoring, which would decrease channel bank erosion. Furthermore, the degree of erosion estimated for the program 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.

REFERENCES

Brownlie, W. and B. Taylor. 1981. Sediment Management for Southern California Mountains, Coastal Plains and Shoreline, Part C, Coastal Sediment Delivery by Major Rivers in Southern California. Environmental Quality Laboratory, California Institute of Technology. EQL Report No. 17-C. February 1981.

Environmental Science Associates. 2019. Los Cerritos Wetlands Restoration Programmatic EIR, Sediment and Water Quality Investigation Technical Report. September 2019.

Environmental Science Associates. 2020. Los Cerritos Wetlands Restoration Programmatic EIR, Hydrodynamic Modeling Technical Report. January 2020.

Everest. 2012. Los Cerritos Wetlands Conceptual Restoration Plan Watershed Impacts Reports. February 2012.

Orme, A.R., Griggs, G.B., Revell, D.L., Zoulas, J.G., Grandy, C.C., Koo, H. 2011. Beach Changes along the southern California coast during the twentieth century: A comparison of natural and human forcing factors. Fall 2011.

PWA 1995. Design Guidelines for Tidal Channels in Coastal Wetlands. Prepared for the USACE.

Sherman, Douglas J., Barron, Kamron M., and Ellis, Jean T. 2002. Retention of Beach Sands by Dams and Debris Basins in Southern California. Journal of Coastal Research. SI 36: 662-674.

Southern California Coastal Water Research Project (SCCWRP). 2007. Historical Ecology and Landscape Change of the San Gabriel River and Floodplain, SCCWRP Technical Report #499. Available: http://greenvisions.usc.edu/documents/SGRreport.pdf.

SFEI, SCCWRP, CSUN. 2011. Historical Wetlands of the Southern California Coast. January 2011.

Tidal Influence. 2012. Los Cerritos Wetlands Habitat Assessment Report: Habitat Types & Special Status Species. Prepared for: Los Cerritos Wetlands Authority. August 31, 2012.

U.S. Army Corps of Engineers (USACE), Los Angeles District. 1986. Coast of California Storm and Tidal Wave Study; Southern California Coastal Processes Data Summary. February 1986.

USACE, Los Angeles District. 1988. Coast of California Storm and Tidal Wave Study Annual Report. 1988.

USACE, Los Angeles District. 2004. Los Angeles Regional Dredged Material Management Plan Feasibility Study, Baseline Conditions (F3) Report. August 2004.

USACE, Los Angeles District. 2011. Los Angeles County Drainage Area, San Gabriel River, San Jose Creek, Compton Creek, Upper Rio Hondo, Coyote Creek, Verdugo Wash, Arroyo Seco HEC RAS Hydraulic Models Final Report. February 2011.

Weston Solutions, Inc. 2005. Integrated Receiving Water Impacts Report 1994-2005 for Los Angeles County Final Report. August 2005. Available: https://dpw.lacounty.gov/wmd/NPDES/1994-05_report/contents.html.

Wiegel, Robert L. 2009. San Pedro Bay Delta, in Southern California Shore and Shore Use Changes During Past 1-1/2 Centuries from a Coastal Engineering Perspective. December 2009.

Williams, P., M. Orr, and N. Garrity. 2002 Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects. Restoration Ecology, Vol 10: 3, 577-590. September 2002.

Willis, C.M. and Griggs, G.B. 2003. Reductions in Fluvial Sediment Discharge by Coastal Dams in California and Implications for Beach Sustainability. Journal of Geology. 111:167-182.