Appendix H

Hydrodynamic Modeling Technical Report

ESA

LOS CERRITOS WETLAND RESTORATION PLAN PROGRAM ENVIRONMENTAL IMPACT REPORT

Hydrodynamic Modeling Technical Report

Prepared for
Los Cerritos Wetlands Authority

May 2020

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SECTION 1
Introduction

This report documents the hydrodynamic modeling of the Los Cerritos Wetlands (LCW) Restoration Project. This modeling report describes the modeling performed to analyze the potential hydrology effects of the proposed restoration program relative to existing 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) (Moffatt & Nichol 2015 and Stein et. al 2007).

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 Long Beach Oil Field in 1921 and at the Seal Beach Oil Field shortly after. 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.

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 channel, 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).

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SOURCE: ESRI,LCWA

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Figure 1-1
Historic Project Area Habitats

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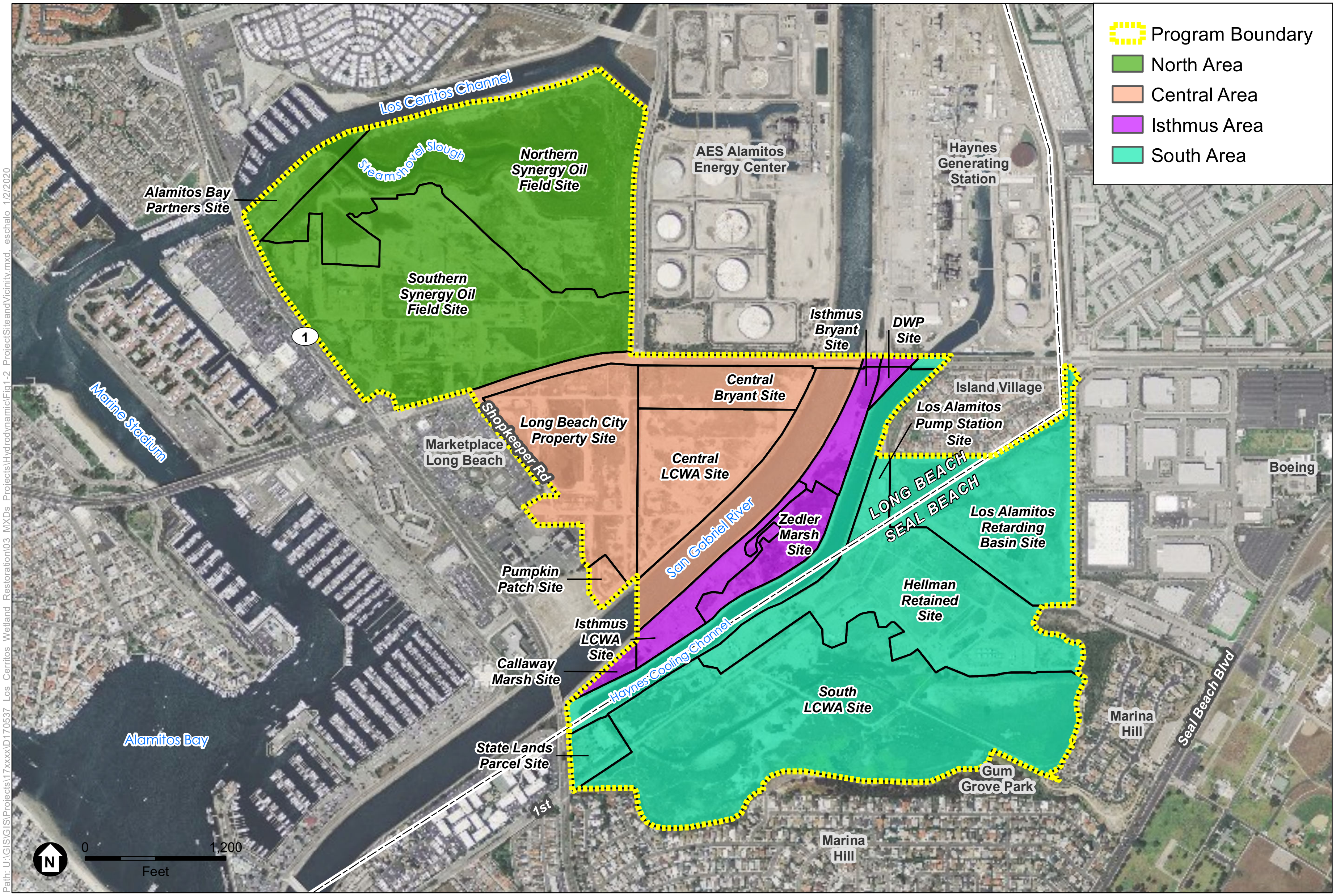

SOURCE: Mapbox, LCWA

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Figure 1-2
Project Site and Local Vicinity

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. Some discussion of the State Lands Parcel is included in Section 3.3, *Future Conditions with Sea-Level Rise*, but in most cases, the site is not exposed to inundation. 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 complete (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 State Lands Parcel site contains the remnant building foundation of what was once a music venue called the Airport Club and Marina Palace. Major habitat types include ruderal uplands and southern coastal salt marsh with muted tidal connection in the channel that runs along the south of the parcel.

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. Additionally, 1st Street runs parallel to Haynes Cooling Channel through the marsh.

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 developed areas and ruderal wetlands with no tidal connection.

1.2.2 Isthmus Area

The Isthmus Area includes the following hydrologically connected sites: Callaway Marsh, DWP, Zedler Marsh, Isthmus LCWA, and Isthmus Bryant. Some discussion of the DWP is included in Section 3.3, Future Conditions with Sea-Level Rise, but in most cases, the site is not exposed to inundation.

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.

The DWP site is a vacant site. The site contains upland wetland habitat types, with no hydrologic connection.

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.

The AES Alamitos Energy Center is adjacent to the North Area. The center uses water from the Los Cerritos Channel for 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.

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 hydrodynamic analysis of the North Area is not included in this report.

1.3 Previous Hydraulic Modeling

Previous modeling for the Los Cerritos Wetlands Restoration Plan area was conducted in 2007 by Moffatt & Nichol (M&N) for the Alamitos Bay Circulation Study. In 2011, this model was applied to the Los Cerritos Wetlands Conceptual Restoration Plan (CRP) for its Hydrologic and Hydraulic Baseline Report. Also in 2011, the United States Army Corps of Engineers (USACE) updated the Los Angeles County Department of Public Works HEC RAS model for the San Gabriel River. These reports and their results are summarized in the following sections.

1.3.1 Moffatt & Nichol (2007) Alamitos Bay Circulation Study

As part of the Alamitos Bay Circulation Study, M&N used a RMA2 hydrodynamic model to evaluate the hydraulic circulation conditions and patterns in Alamitos Bay. The hydrodynamic model included the San Gabriel River, Alamitos Bay, Marine Stadium, Colorado Lagoon, Los Cerritos Channel, the Haynes Cooling Channel outfall (not including the channel itself), the AES Corporation outfalls, and the nearshore ocean. The Circulation Study demonstrated that the dominant existing circulation pattern is water generally flowing upstream along both the Haynes Cooling Channel and Los Cerritos Channel, then returning downstream via the San Gabriel River once discharged by the generating stations. The study noted that this circulation pattern was influenced by the AES and Haynes Generating Stations operations.

1.3.2 Moffatt & Nichol (2011) Los Cerritos Wetlands Conceptual Restoration Plan

As part of the CRP, M&N applied the RMA2 hydrodynamic model from the Circulation Study to evaluate the hydrology of the LCW. The existing model was expanded to include the Haynes Cooling Channel and the Hellman Channel. As part of the modeling effort, a tide gauge was deployed in Hellman Channel to gather water level data for model calibration. Water levels were measured from July 15 to September 9, 2011 between the 1st Street culvert and the second culvert in the South LCWA site. The model assessed both tidal hydrodynamics and flood hydrodynamics during a 100-year storm event, which was coupled with an extreme high tide series, for existing conditions and the conceptual restoration alternatives. The 100-year storm event hydrograph used for the modeling was obtained from a Los Angeles County Drainage Area (LACDA) study performed by the USACE in 1991 (USACE 1991).

The CRP modeling demonstrated that the Alamitos Bay, San Gabriel River, and Haynes Cooling Channel have full tidal ranges (e.g., no tidal muting). The study also showed the Central, Isthmus, and South Areas receive muted tidal circulation through the existing culverts and evaluated restoration alternatives.

1.3.3 USACE (2011) Los Angeles County Drainage Area

In 2011, the USACE obtained a HEC-RAS model of the San Gabriel River from the Los Angeles County Department of Public Works, converted it from NGVD to NAVD, and georeferenced it. This model of the San Gabriel River stretches from the Pacific Ocean to Siphon Road (near Whittier Narrows). USACE used a 100-yr event discharge of 44,600 cfs at the Coyote Creek Confluence, just upstream of the project site.

1.4 EIR Restoration Program

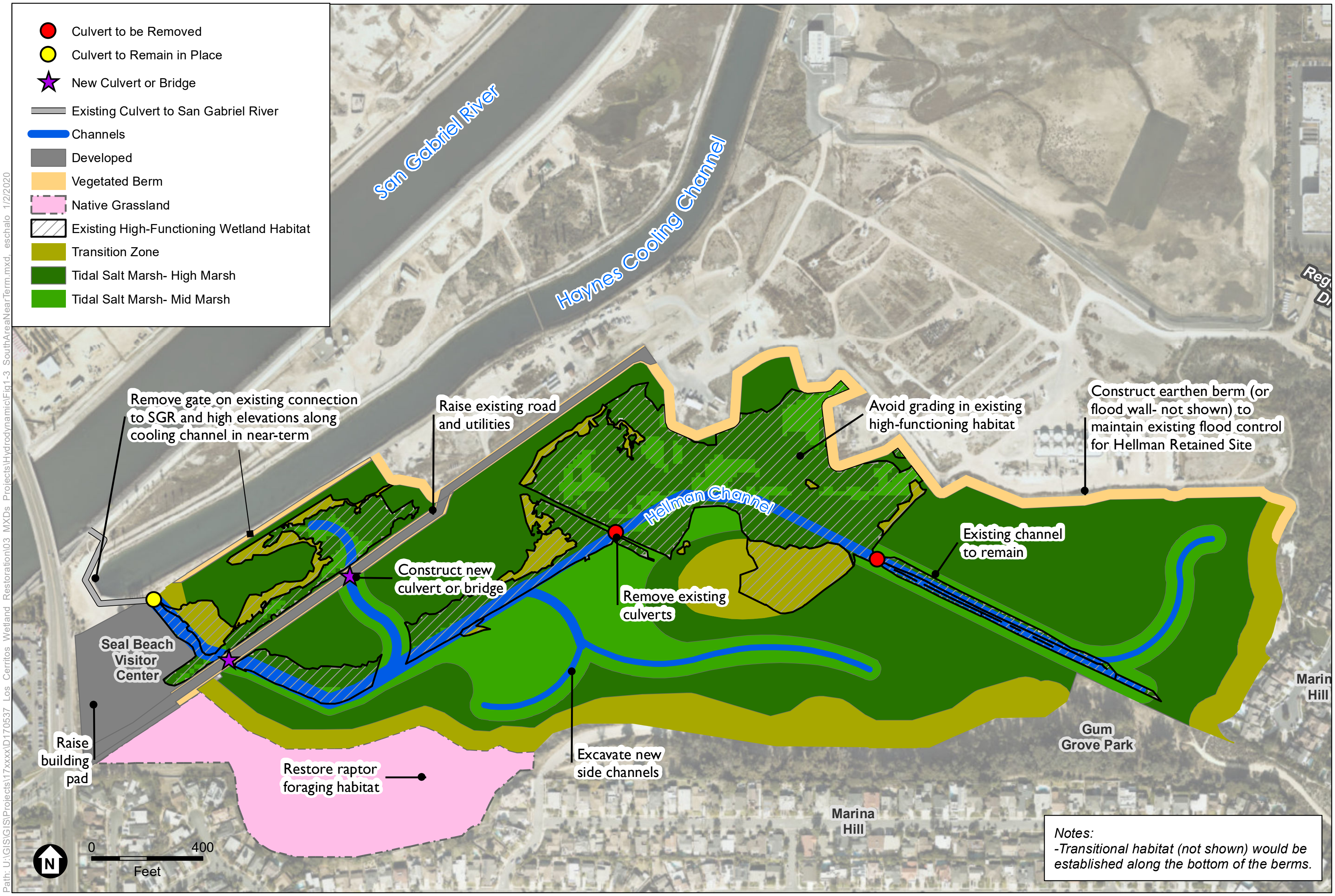
The proposed program would restore wetland, transition, and upland habitats throughout the program area. This would involve remediation of contaminated soil and groundwater, grading, revegetation, construction of new public access opportunities (including trails, visitor centers, parking lots, and viewpoints), construction of flood management facilities (including earthen levees and berms, and flood 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, Proposed South Area Near-Term Restoration):

- 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 Retained site 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;



SOURCE: ESRI,LCWA

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Figure 1-3
Proposed South Area Near-Term Restoration

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- 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.

Mid-term activities would include (Figure 1-4, Proposed South Area Mid-Term Restoration):

- 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 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

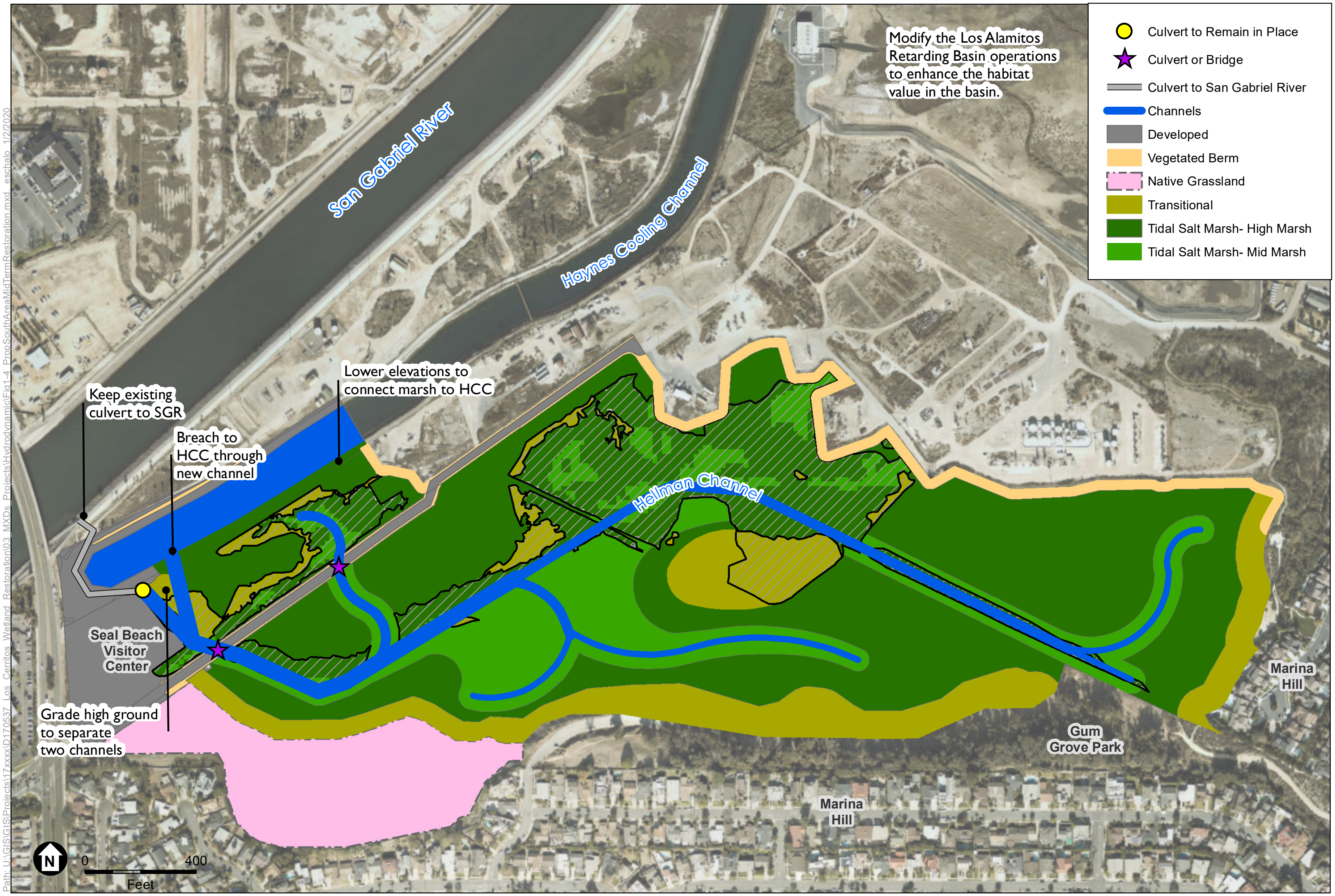
In the near-term, the proposed program would extend the restoration currently present on the Zedler Marsh site north into the Isthmus Bryant site and the portion of the DWP site west of the gas access road that connects to 2nd Street by improving the two existing culverts under the access road (Figure 1-5, Proposed Isthmus Area Restoration). 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 and the existing oil operations on the Central LCWA site operated by Signal Hill Petroleum, Inc. would be protected in place by raising the wells out of the floodplain. 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, Proposed Central Area Near-Term Restoration). Near-term activities would include:

- Relocating or modifying oil infrastructure and remediation of soils on the Central LCWA site;



SOURCE: ESRI,LCWA

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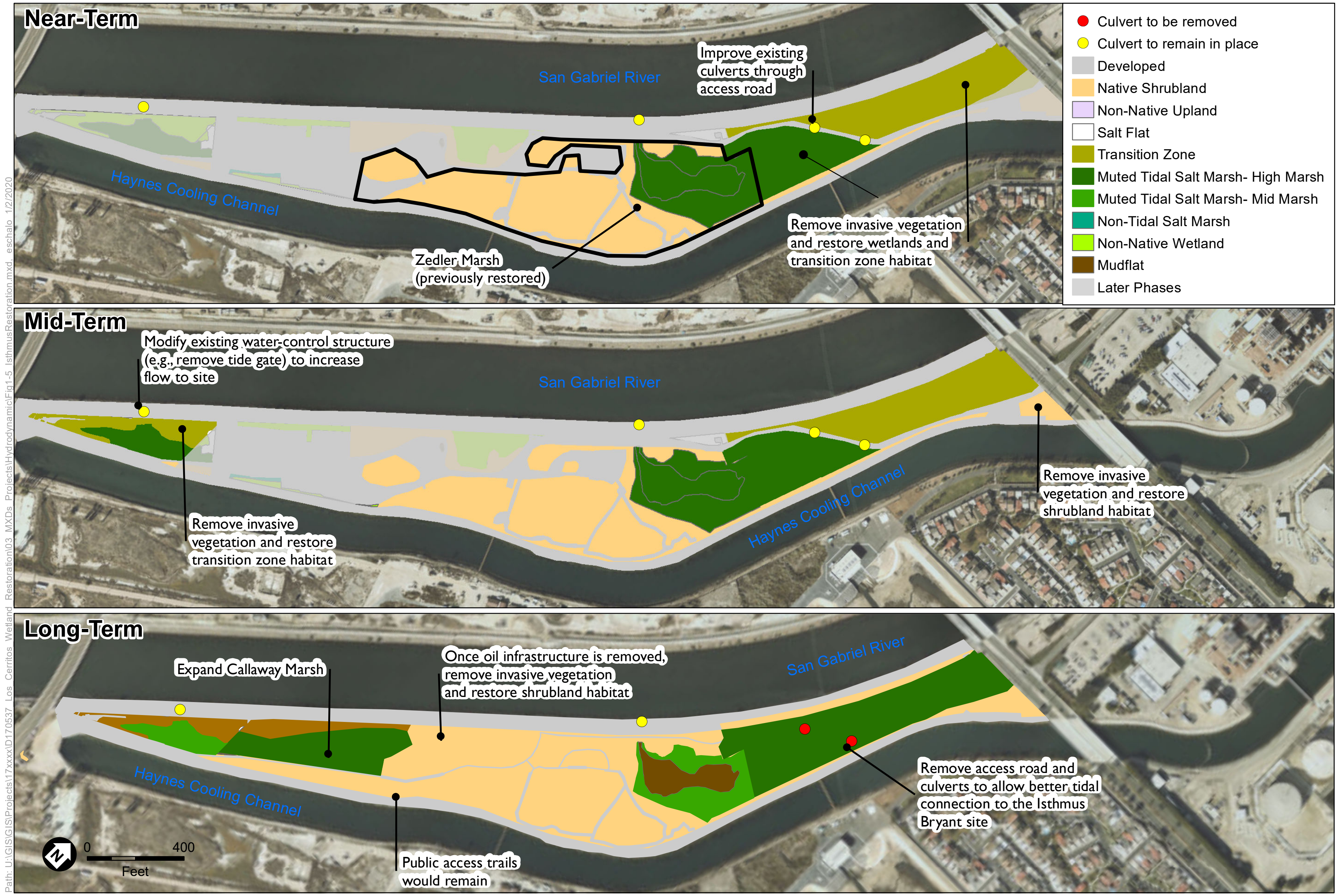
Figure 1-4
Proposed South Area Mid-Term Restoration

ESA



SOURCE: Mapbox, LCWA, NOAA, ESA

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Figure 1-5
Proposed Isthmus Area Restoration

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- 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;
- 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.

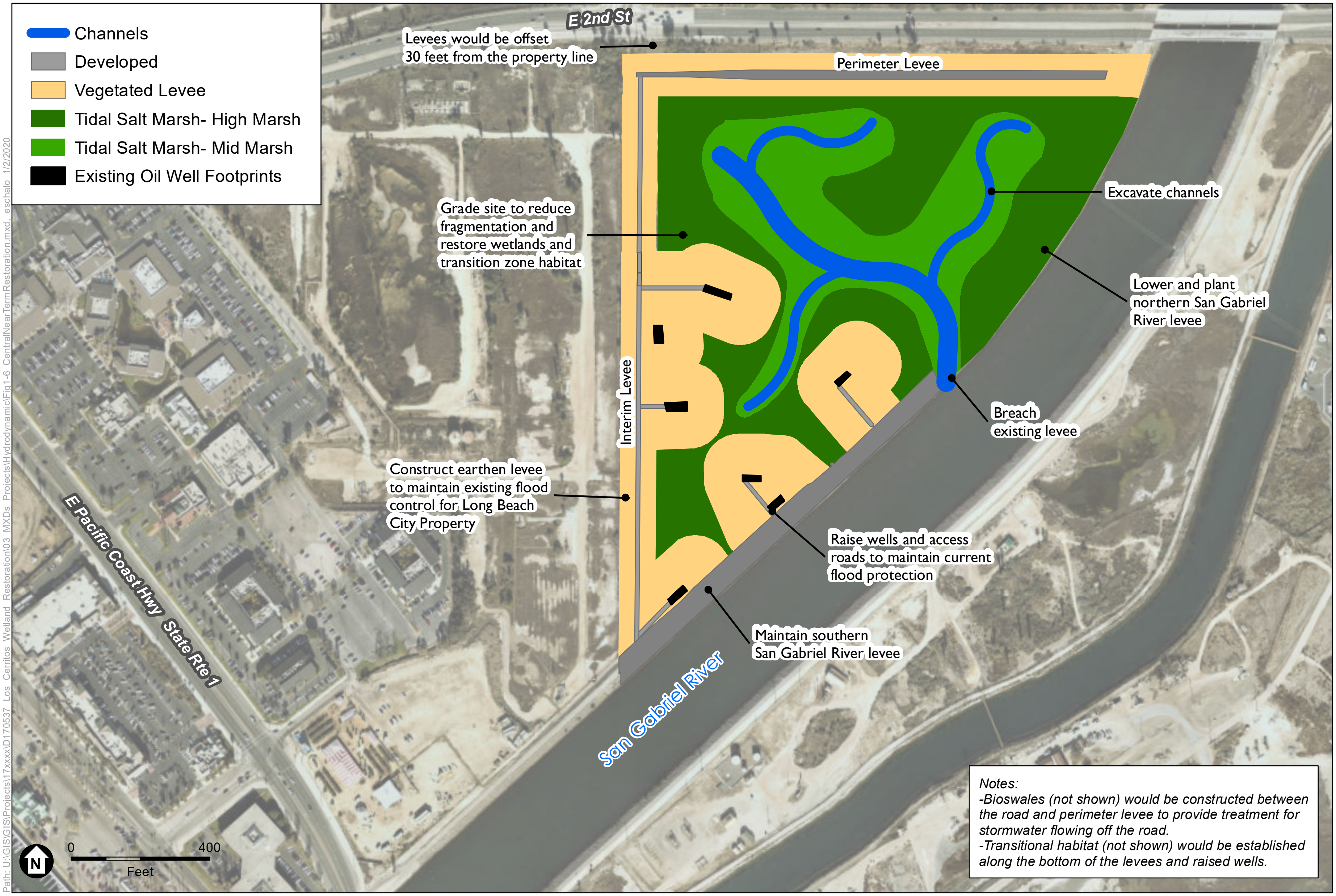
In the long-term, the Long Beach City Property site and the Pumpkin Patch site would be restored to tidal salt marsh, including (Figure 1-7, Proposed Central Area Long-Term Restoration):

- 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.

1.5 Modeling Goals

The goals of the hydrodynamic modeling for this project are two-fold:

1. Evaluate potential flood impacts to inform the restoration design, the CEQA analysis, and permitting.
2. Evaluate restored wetland hydrology and inform the habitat elevations for the restoration design for post-restoration and future conditions with sea-level rise.



SOURCE: NOAA, ESA, LCWA

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Figure 1-6
Proposed Central Area Near-Term Restoration

ESA

SOURCE: NOAA, ESA, LCWA

Figure 1-7
Proposed Central Area Long-Term Restoration

ESA

SECTION 2
Model Setup

ESA developed a two-dimensional (2D) hydrodynamic model of Los Cerritos Wetlands Restoration program using the USACE's HEC-RAS software package (v 5.0.7). This approach simulates 2D overbank flows across the floodplain where complex flow patterns are expected to occur. The model boundary includes the Central Area, the San Gabriel River, the Isthmus Area, the Haynes Cooling Channel, and the South Area (except for the Los Alamitos Pump Station and Los Alamitos Retarding Basin), as well as a small portion of Alamitos Bay Marina, where the Haynes Cooling Channel culverts connect to the bay. Four model geometries were analyzed:

- Existing Conditions: this scenario includes the existing topography, bathymetry, and culvert connections without the program. It is also referred to as the no program scenario.
- South Area, Near-Term Conditions: this scenario is focused on the South Area in the near-term (as described in Section 1.4.1), once the new earthen berm or flood wall is constructed, 1st Street is raised, the gate on the existing culvert connecting the South LCWA site to the San Gabriel River is removed, and the culverts under the former access roads are removed.
- Full Breach Conditions: this scenario includes the long-term Central Area restoration (Section 1.4.3) with a full breach connection to the San Gabriel River and new levees along the perimeter of the site. It also includes the mid-term Isthmus (Section 1.4.2) and South Area restorations (Section 1.4.1) once the South Area is connected to the Haynes Cooling Channel.
- Central Area, Culvert Conditions: this scenario is focused on the Central Area and considers an alternative to the full breach connection to the San Gabriel River. The San Gabriel River levee along the Central Area would be left in place, and a culvert or series of culverts would be installed through the levee to allow flows to enter the site. This scenario is otherwise identical to the Full Breach Conditions scenario.

Figure 2-1 shows the model extent used for the existing conditions, South Area, near-term conditions, full breach conditions and Central Area, culvert conditions.

Sections 2.1 through 2.4 describe the development of the four model scenarios including:

- Topography/Bathymetry – land and underwater surface elevations controlling where water flows.
- Structures – bridges and culverts that influence the hydraulics of the site.
- Hydraulic Roughness – a property of different land covers that imposes a resistance to flow (e.g., grasses or open dirt areas have lower hydraulic roughness and provide a lower resistance to flow while areas with dense salt marsh have higher hydraulic roughness and provide a higher resistance to flow).

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SOURCE: ESRI,LCWA

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Figure 2-1
Model Extent

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Sections 2.4 and 2.5 describe the different hydrology and tidal boundary conditions used for the different modeling runs:

- Hydrology – inflows along the San Gabriel River from upstream in the watershed and the two power plants.
- Tidal Boundary Conditions – downstream water surface elevations driven by the tides in the ocean.

2.1 Existing Conditions

The existing conditions model represents the pre-program conditions as they exist at the time of this report, prior to the construction of the program and other planned restoration projects.

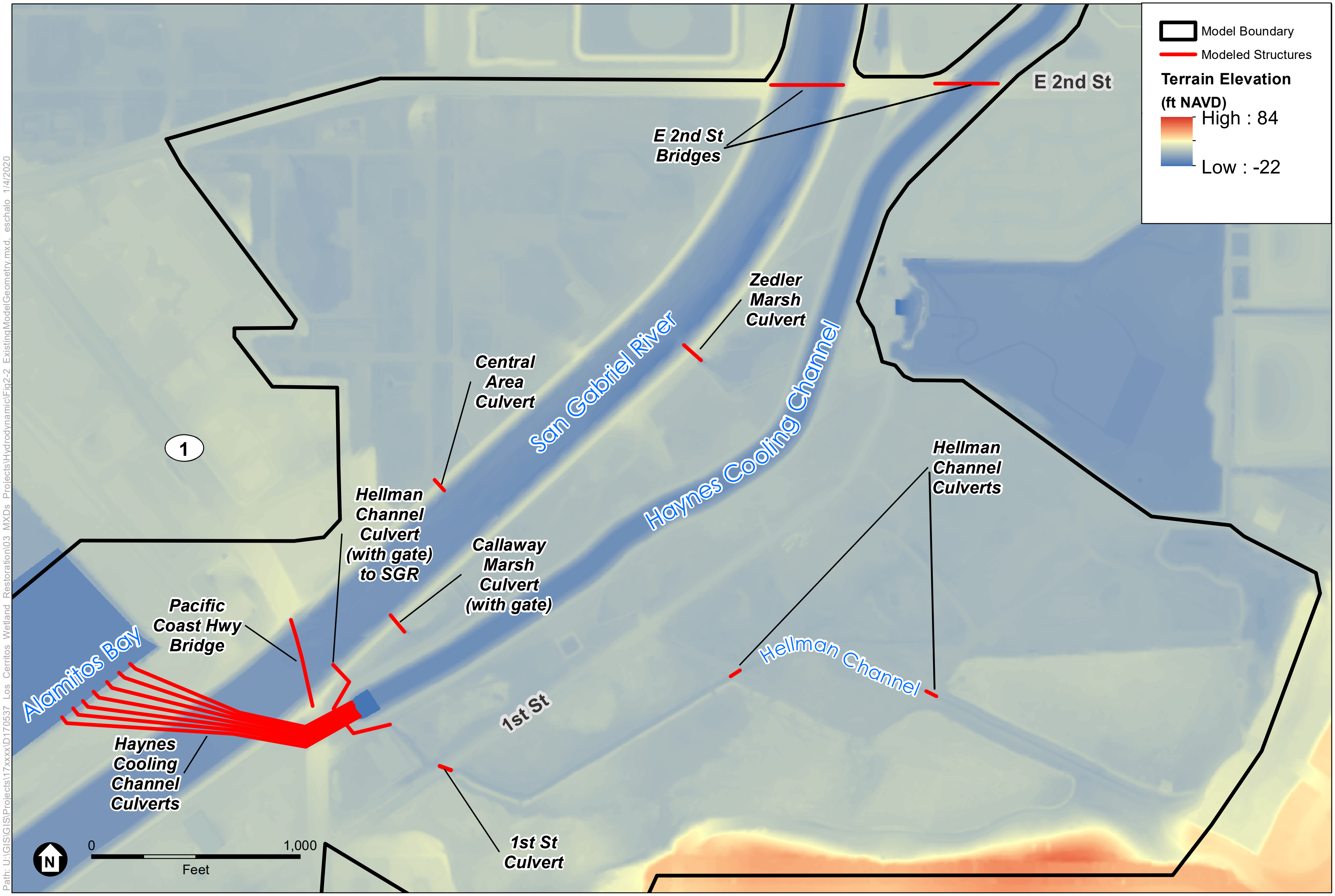
2.1.1 Topography

The Existing Conditions model topography was developed from five datasets, combined to achieve full coverage of the model extent. The San Gabriel River channel bathymetry was based on two sources: (1) a sonar-based bathymetric survey conducted by Cinquino & Passarino Inc. in 2019 as part of this project ranging between 2nd St and the Pacific Coast Highway; and (2) the USACE as-builts. The Haynes Cooling Channel bathymetry was developed from a channel cross section provided in the CRP Hydrologic and Hydraulic Baseline Report (2011). The 2009-2011 Coastal California TopoBathy Merged Project Digital Elevation Model (DEM) and 2010 LiDAR DEM by NOAA, were used to attain coverage of the remaining model extent. Figure 2-2 shows the model geometry for Existing Conditions.

2.1.2 Structures

In the South Area, a 4-foot culvert with an invert elevation of 0 feet NAVD connects the San Gabriel River to the Hellman Channel in the South LCWA site. This culvert runs around the southern edge of Haynes Cooling Channel, above and perpendicular to the 7 culverts that connect the Haynes Cooling Channel to the Alamitos Bay Marina (Figure 2-3). The culvert has a flap gate on it that is stuck open and allows some leakage into the site (Figure 2-4). The blockage depth modeled was determined by an iterative modeling calibration explained in Section 3.1 below. The South LCWA site has an additional 3 culverts along the Hellman Channel that allow the channel to pass under 1st Street and the remnant dirt roads.

There are seven 8-foot diameter culverts that connect the Alamitos Bay Marina to the Haynes Cooling Channel underneath the San Gabriel River with invert elevations of -9.2 feet NAVD. These culverts allow tidal waters into the channel and bring pumped water to the Haynes Generating Station to use for once-through cooling. These seven culverts sizes and inverts were gathered from the CRP Hydrologic and Hydraulic Baseline Report (2011). All other culvert dimensions were taken from the ESA field survey in fall 2019.



SOURCE: ESRI,LCWA

Figure 2-2
Existing Model Geometry

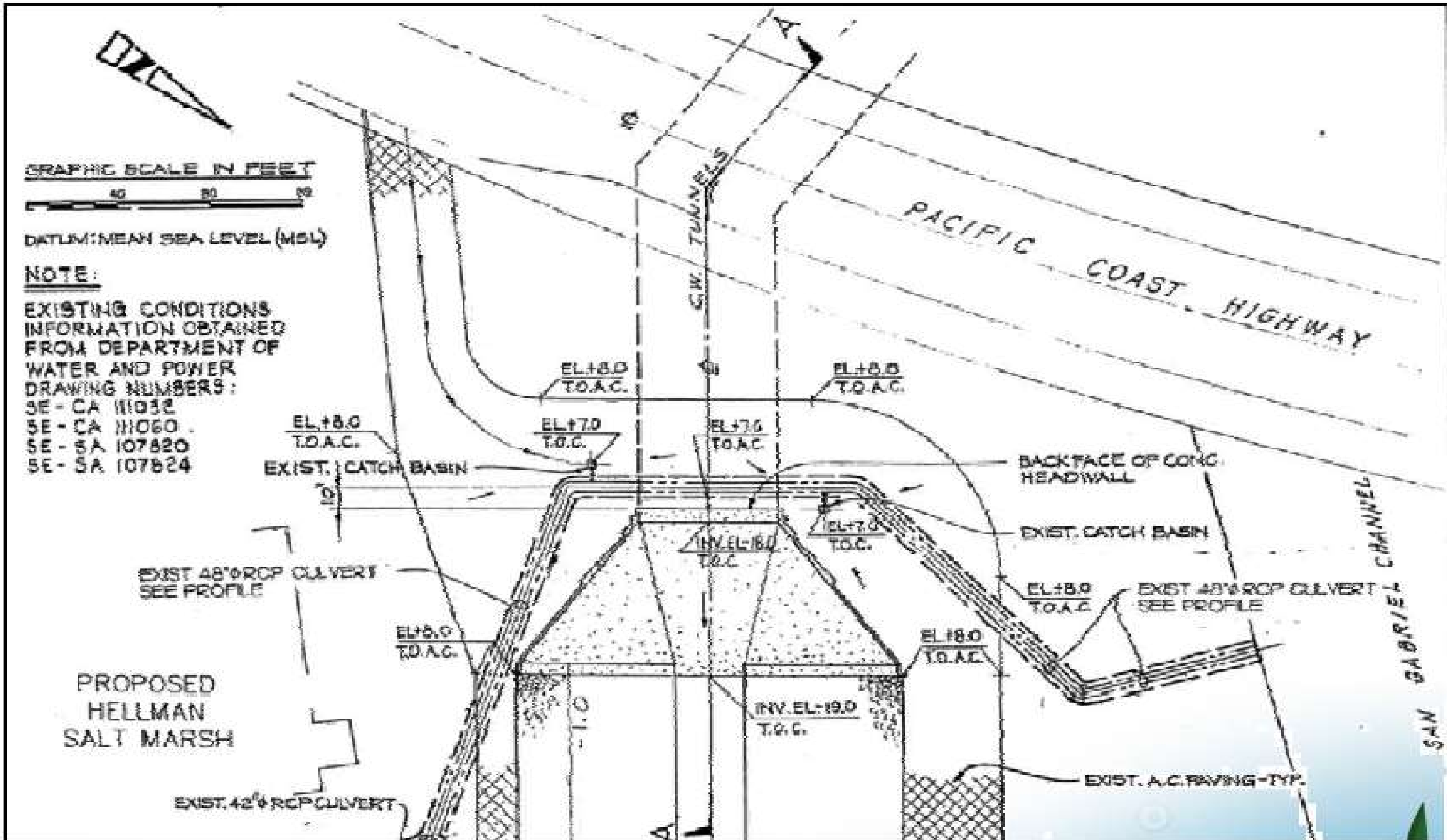


Figure 4-6. Plan View of Hellman Channel in the Vicinity of the Haynes Channel and San Gabriel River
(M&N 1996)

SOURCE: Moffatt & Nichol

Figure 2-3

Location of Culvert Connecting the San Gabriel River to the South LCWA Site

SOURCE: Tidal Influence, LLC

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Figure 2-4

Culvert Connecting the San Gabriel River to the South LCWA Site Gate Photos

Along the left bank (southeast bank) of the San Gabriel River at the Isthmus Area, a 3-foot culvert with an invert elevation of 0.3 feet NAVD on the river side and 2.3 feet NAVD on the marsh side connects to the Zedler Marsh site. Further west, a 3-foot culvert with an invert elevation of 2.1 feet NAVD connects the San Gabriel River to Callaway Marsh. The culvert to Callaway Marsh has a gate on it, which allows partial tidal influence. Figure 2-5 presents photos of the culvert and gate in its current conditions. The model used a blockage depth of 95% (i.e., 2.85 feet blocked of the 3-foot culvert) to achieve the muted tidal inundation seen in Callaway Marsh.

The Long Beach City Property in the Central Area is connected to the San Gabriel River through a 2-foot culvert with an invert of 5.2 feet NAVD.

TABLE 2-1
LCW CULVERT DIMENSIONS

	Number of Culverts	Gates	Diameter (feet)	Invert Elevation (feet NAVD)
South Area				
Culverts from Alamitos Bay Marina to Haynes Cooling Channel	7	No	8	-9.2
Culvert from SGR to South LCWA site	1	Yes, leaky flap gate (modeled as 45% closed)	4	0.0
Culvert under 1st Street	2	No	3	2.7
Culvert under remnant dirt roads (west)	2	No	1	3.6
Culvert under remnant dirt roads (east)	2	No	1	4.1
Isthmus Area				
Culvert from SGR to Zedler Marsh	1	No	3	0.3 (river side) 2.3 (marsh side)
Culvert from SGR to Callaway Marsh	1	Yes, leaky flap gate (modeled as 95% closed)	3	2.1
Central Area				
Culvert from SGR to Long Beach City Property site	1	No	2	5.2

SGR = San Gabriel River

The existing conditions model also includes three bridges over the San Gabriel River and one over the Haynes Cooling Channel. The southernmost bridge along the San Gabriel River is the Marina Drive bridge, with the Pacific Coast Highway bridge upstream along the western boundary of the Central and South Areas. The northernmost bridges included in the model are the 2nd Street bridges. 2nd Street crosses both the San Gabriel River and the Haynes Cooling Channel. The three bridges along the San Gabriel River are at elevations that are 3 to 7 feet above the modeled 500-year water level, so the decks of the bridges are not expected to influence flow. With this in mind, only the piers of the bridges were included in the model. The 2nd Street bridge across the Haynes Cooling Channel is 10.2 feet above mean higher high water (MHHW), which is above the 500-year tide level (see Section 2.5.2). (Note the Haynes Cooling 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). The geometry of the bridge piers was developed based on as-builts gathered from the County, field photos, and aerial imagery.

SOURCE: Tidal Influence, LLC

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Figure 2-5
Callaway Marsh Culvert Gate Photos

2.1.3 Hydraulic Roughness

The existing conditions hydraulic roughness across the model extent can be seen in Figure 2-6. The San Gabriel River, Haynes Cooling Channel, and Alamitos Bay were assigned a hydraulic roughness (manning's n) value of 0.03. Industrial, commercial, and residential areas were assigned as developed, medium density with a value of 0.080. Existing marsh areas were assigned a value of 0.05. The oil well fields and open land areas were assigned a value of 0.03.

2.2 South Area, Near-Term Conditions

The South Area, near-term conditions model is focused on the South Area in the near-term (as described in Section 1.4.1), once the new earthen berm or flood wall is constructed, 1st Street is raised, the gate on the existing culvert connecting the South LCWA site to the San Gabriel River is removed, and the culverts under the former access roads are removed.

2.2.1 Topography

The model topography was developed from one new dataset in addition to the five datasets used for existing conditions (Section 2.1.1): a conceptual-level, near-term South Area design terrain. The South Area, near-term conditions model geometry can be seen in Figure 2-7.

2.2.2 Structures

The culvert that connects the San Gabriel River to the Hellman Channel in the South LCWA site remains in place, but the gate is removed. The two culverts along the east end of the Hellman Channel are removed. The first culvert under 1st Street is removed and replaced with an open channel and a bridge. Initial model runs showed that replacing the existing two culverts (3-foot diameter) under 1st Street with either two 6-foot culverts or four 4-foot culverts still resulted in tides muted up to 0.5 feet south of the road. To provide a better tidal connection south of the road, the model was run with an open channel, assuming a bridge would be installed over the channel. This resulted in high tide muting of 0.06 feet south of the road. An additional bridge is added to 1st Street on the secondary channel.

The seven culverts that connect the Alamitos Bay Marina to the Haynes Cooling Channel underneath the San Gabriel River remain in place for the South Area, near-term conditions model.

2.2.3 Hydraulic Roughness

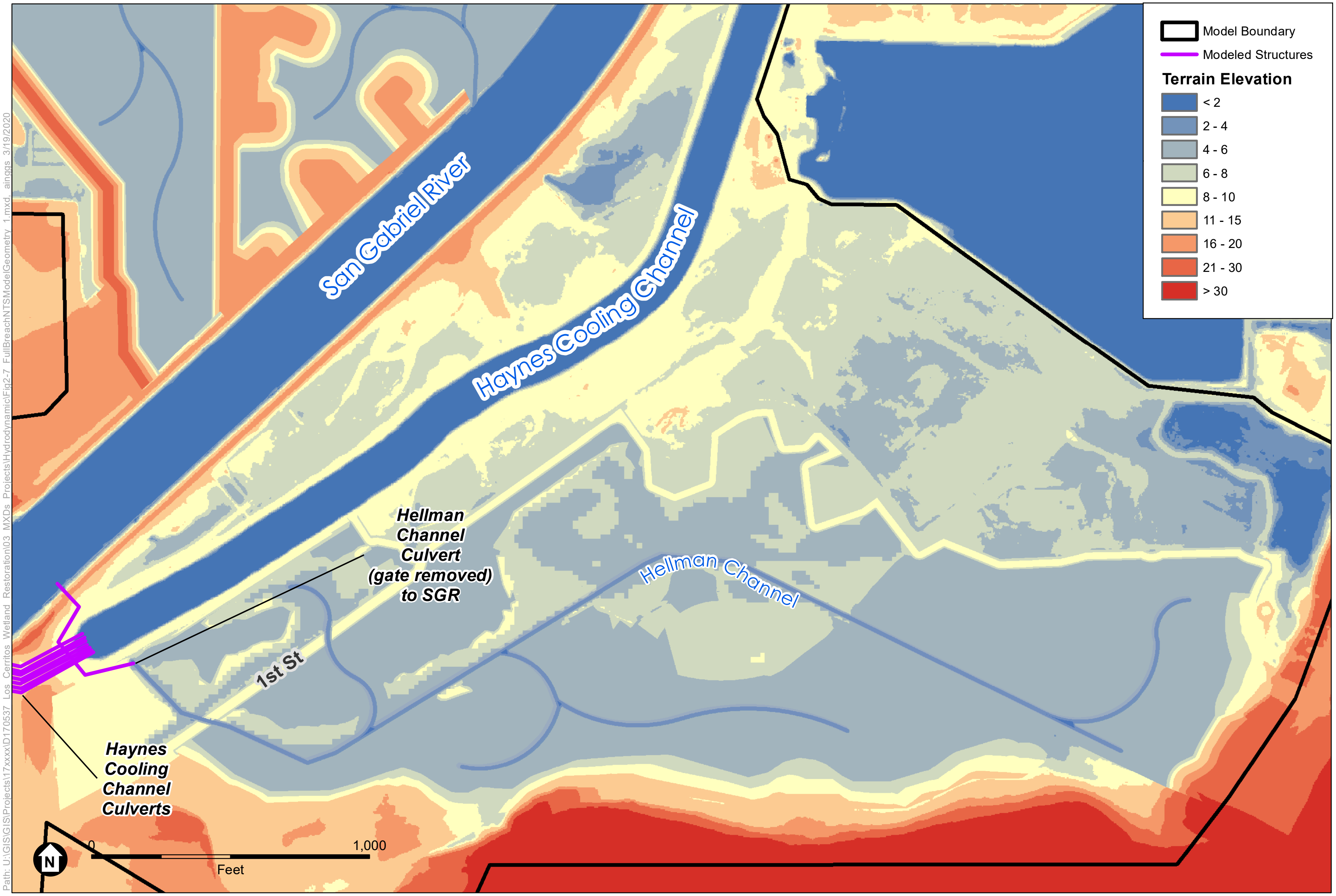
The South Area, near-term conditions hydraulic roughness values are the same as existing conditions in the South Area (Figure 2-8).

SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-6
Hydraulic Roughness for Existing Conditions

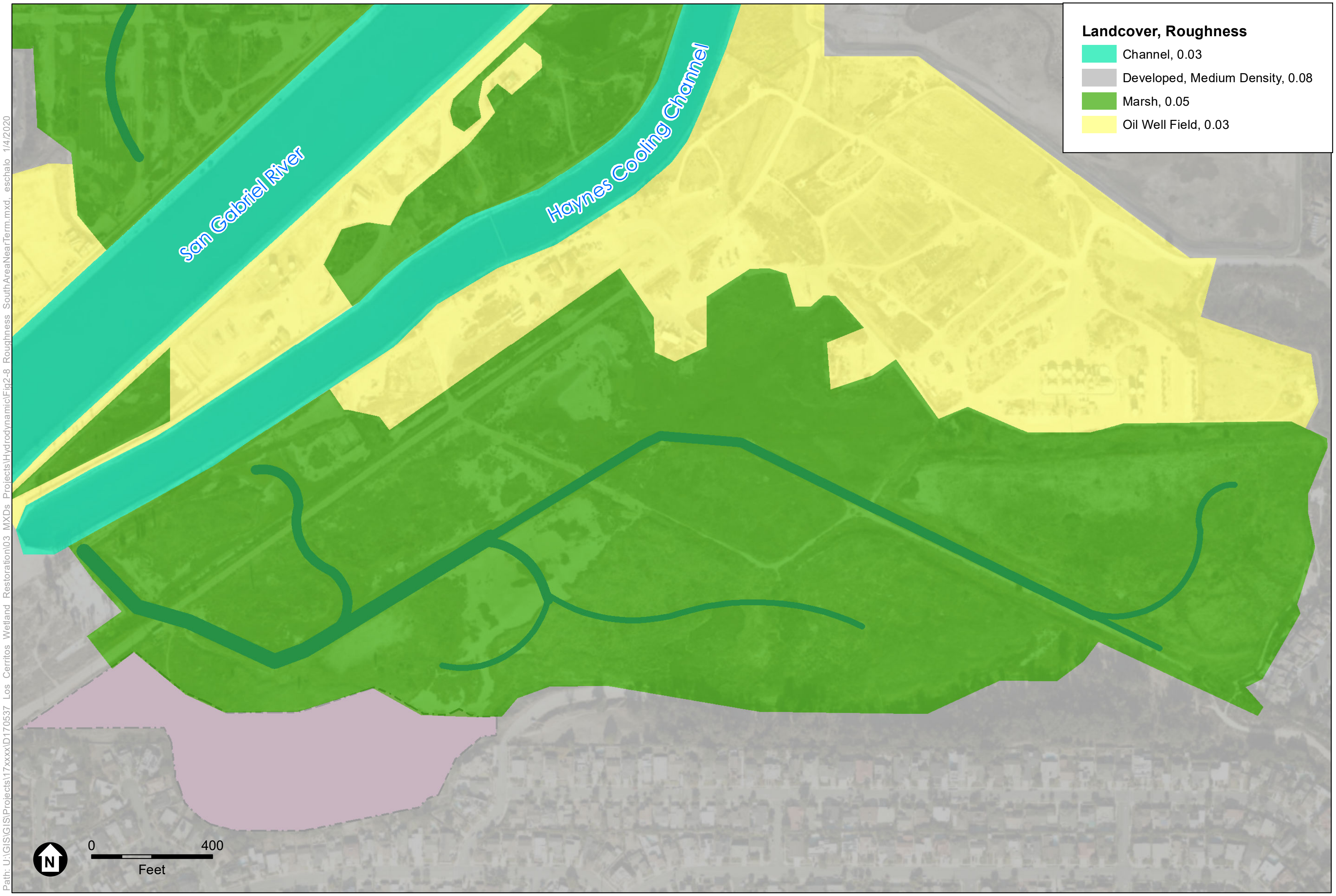
ESA



SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-7
South Area, Near-Term Model Geometry



Path: U:\GIS\GIS\Projects\17xxxx\D170537 Los Cerritos Wetland Restoration\03 MXDs Projects\Hydrodynamic\Fig2-8 Roughness SouthAreaNearTerm.mxd eschalo 1/4/2020

SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-8
Hydraulic Roughness for Full Breach, Near-Term Conditions

ESA

2.3 Full Breach Conditions

The full breach conditions model includes the long-term Central Area restoration (Section 1.4.3) with a full breach connection to the San Gabriel River and new levees along the perimeter of the site. It also includes the mid-term Isthmus (Section 1.4.2) and South Area restoration (Section 1.4.1) once the South Area is connected to the Haynes Cooling Channel.

2.3.1 Topography

The model topography was developed based on the five datasets used for existing conditions as well as two new additional datasets: (1) a conceptual-level, long-term Central Area design terrain; and (2) a conceptual-level, mid-term South Area design terrain. Figure 2-9 shows the model geometry for the full breach conditions.

In the South Area, the only difference between the South Area, near-term model geometry and the full breach model geometry is the new channel connecting the Haynes Cooling Channel to Hellman Channel and removal of the access road separating the Haynes Cooling Channel from the South LCWA site.

2.3.2 Structures

The full breach conditions structures have the same geometries as the South Area, near-term restoration structures in the South Area.

The seven culverts that connect the Alamitos Bay Marina to the Haynes Cooling Channel underneath the San Gabriel River remain in place. However, in the mid-term for the South Area, the Haynes Generating Station is expected to stop using the Haynes Cooling Channel for once-through cooling, so pumping activities that pull water into the channel under existing conditions would be stopped. The tidal flows in and out of the channel would continue.

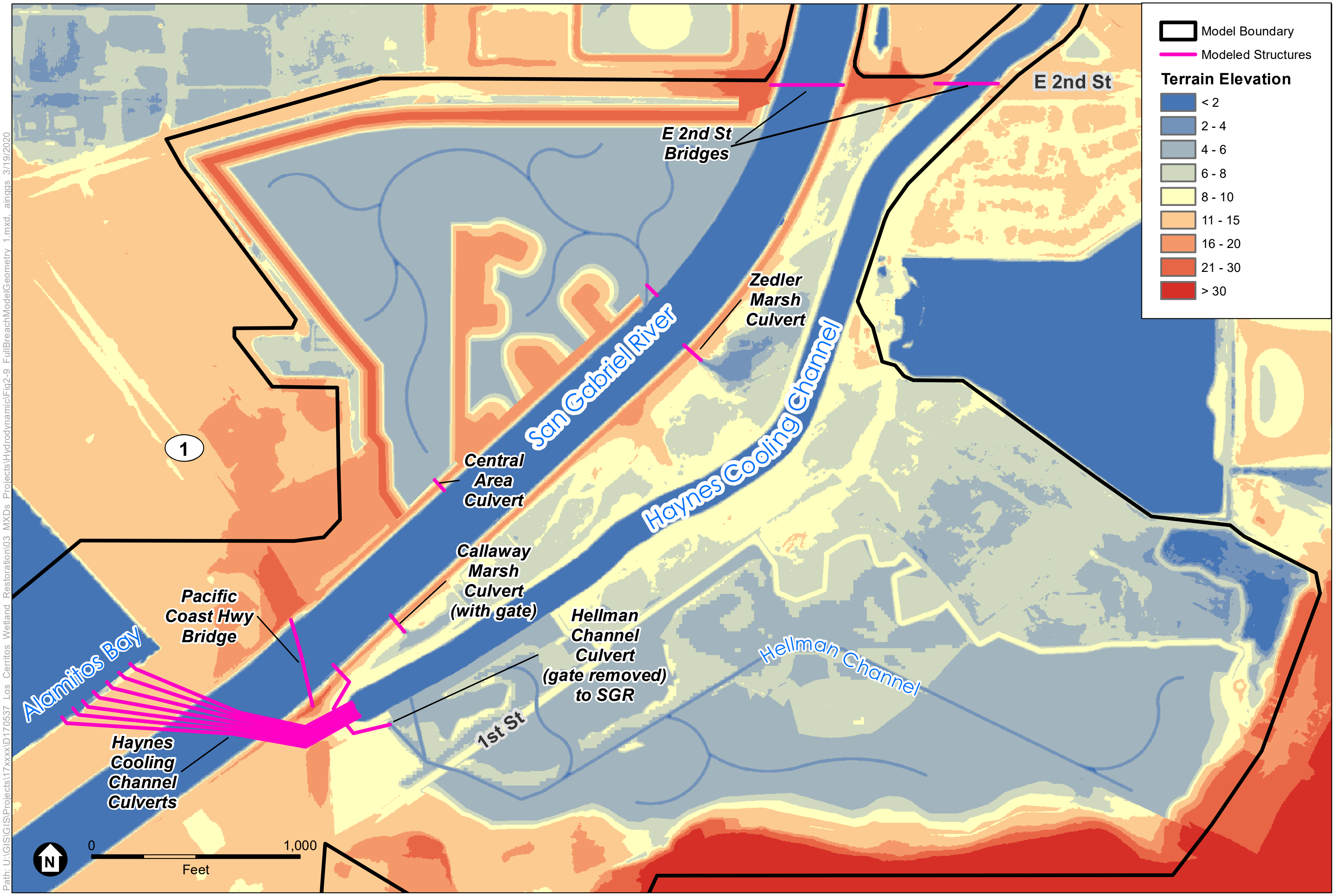
The culvert connecting the Long Beach City Property in the Central Area to the San Gabriel River remains in place under full breach conditions model, but the site is also connected to the river through a breach in the levee on the Central LCWA site.

The culvert connecting Zedler Marsh to the San Gabriel River remains in place under full breach conditions. Additionally, the culvert connecting the river to Callaway Marsh also remains in place, but the gate is removed.

The bridges in the full breach conditions are the same as under existing conditions.

2.3.3 Hydraulic Roughness

The full breach conditions hydraulic roughness values are the same as existing conditions except for the Central Area and Isthmus Bryant site, which were changed from roughness values of 0.03 to values of 0.05 to represent restoration or the marsh in these locations (Figure 2-10).

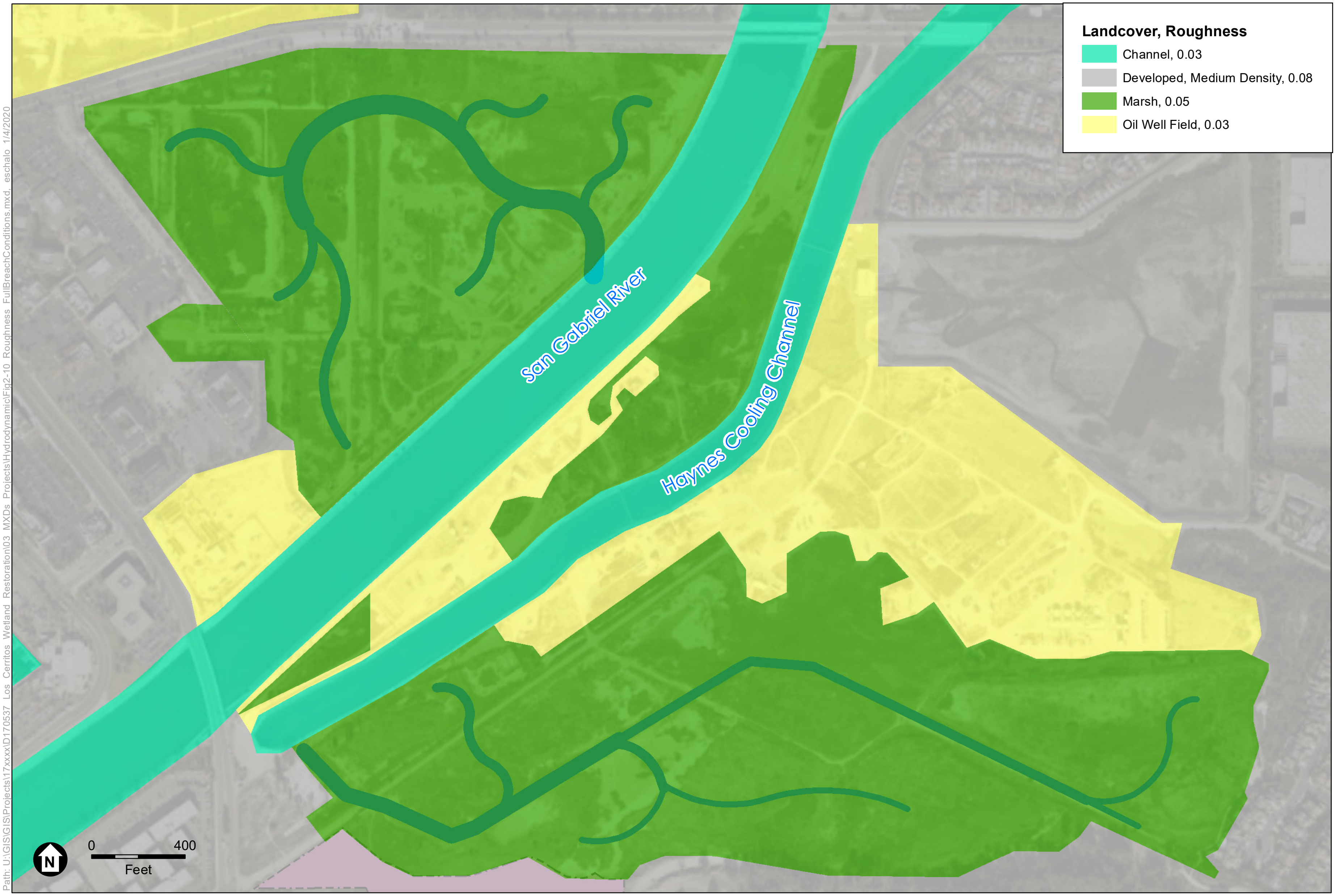


SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-9
Full Breach Model Geometry

ESA



SOURCE: ESRI,LCWA

Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-10

Hydraulic Roughness for Full Breach Conditions

ESA

2.4 Central Area, Culvert Conditions

The Central Area, culvert conditions scenario is focused on the Central Area and considers an alternative to the full breach connection to the San Gabriel River. The San Gabriel River levee along the Central Area would be left in place, and a culvert or series of culverts would be installed through the levee to allow flows to enter the site. This scenario is otherwise identical to the Full Breach Conditions scenario.

2.4.1 Topography

The model topography was developed based on the five datasets used for existing conditions as well as the conceptual-level, long-term Central Area design terrain, but without the breach in the existing San Gabriel River levee. Figure 2-11 shows the model geometry for the full breach conditions.

2.4.2 Structures

Multiple culvert configurations were modeled and analyzed as an alternative to the Full Breach Conditions in the Central Area. The goal of this analysis was to examine an alternative to the Full Breach Conditions design that could result in lower levees with a smaller footprint inside the site while maintaining a strong tidal connection. Ideally, the culverts would restrict flood flows into the site, but allow a full tide range.

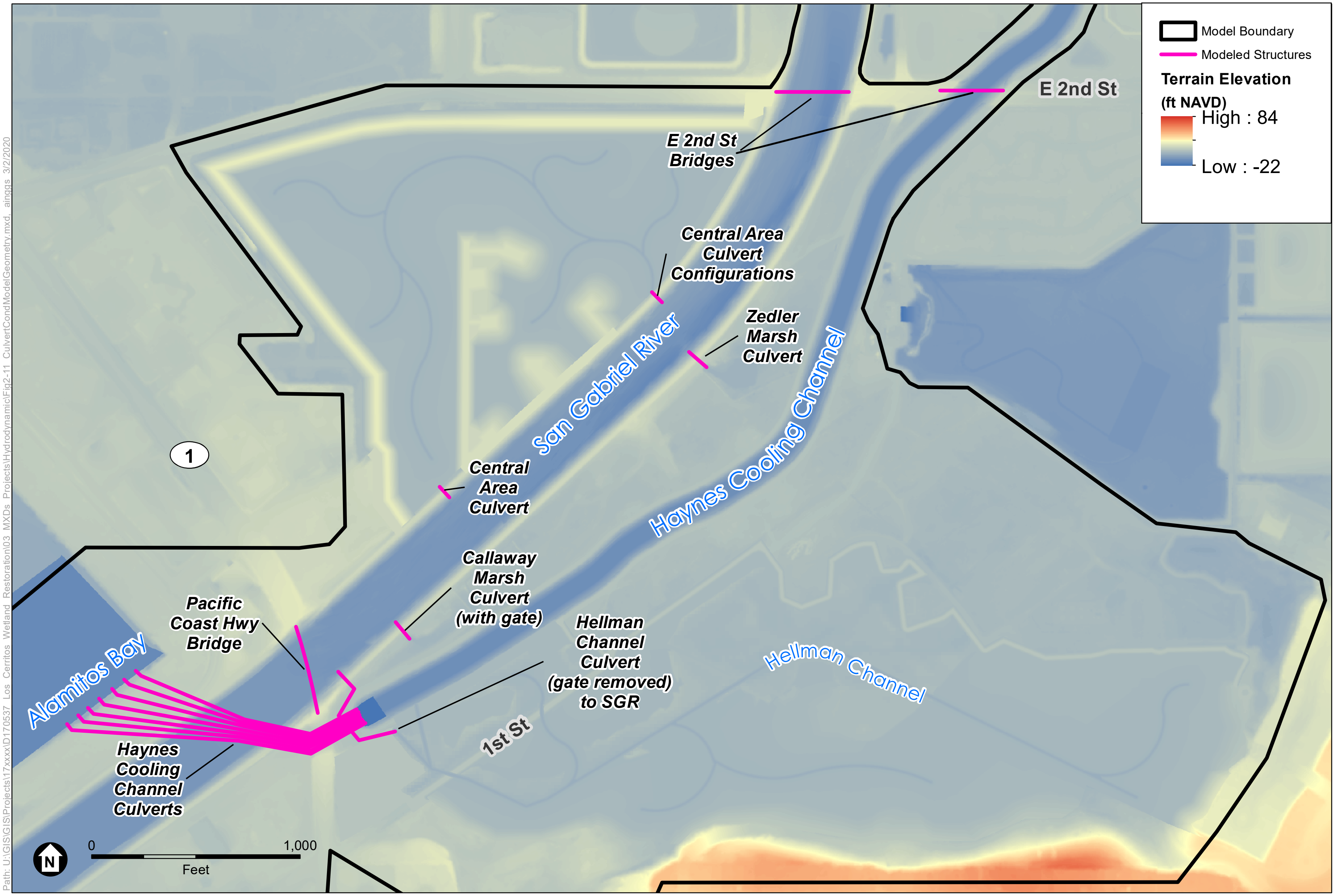
Circular culverts were modeled with diameters varying from 2 feet to 8 feet (Table 2-2). Individual culverts were modeled and banks of culverts including up to 9 culverts were assessed. Initial model runs were used to analyze culvert sizing. After reviewing these results, one 4-foot diameter culvert was chosen for further analysis (see Section 2.7 for model runs).

TABLE 2-2
CENTRAL AREA POTENTIAL CULVERT DIMENSIONS

No. of Culverts	Culvert Diameter	Invert Elevation
1	2 feet	2 feet NAVD
1	4 feet	2 feet NAVD
1	4 feet	0 feet NAVD
1	6 feet	2 feet NAVD
4	4 feet	2 feet NAVD
6	4 feet	2 feet NAVD
9	6 feet	2 feet NAVD
9	8 feet	2 feet NAVD

2.4.3 Hydraulic Roughness

The Central Area, culvert conditions hydraulic roughness values are the same as full breach conditions (Figure 2-10).



SOURCE: ESRI,LCWA

Figure 2-11
Central Area, Culvert Conditions Model Geometry

ESA

2.5 Hydrology

2.5.1 Power Plant Inflow

Under existing conditions, the two power plants along the San Gabriel River (the Haynes Generating Station on the southeast side and the AES Alamitos Energy Center on the northwest side) use once-through cooling in their processes. This involves pumping water into the facility from the Haynes Cooling Channel and Los Cerritos Channel and discharging the water into the San Gabriel River. This flow into the San Gabriel River was incorporated into the model.

In the 2007 Circulation Study Report (Section 1.3.1), discharges from the plants were measured during the period of January 1, 2006 to January 1, 2007. The Haynes Generating Station discharges varied from 600 to 1,500 cfs through the year, and the AES Alamitos Energy Center discharges varied from 0 to 2,000 cfs over the year.

The model incorporates discharge from three culverts from the Haynes Generating Station to the left bank of the river and one culvert from the AES Alamitos Energy Center to the right bank of the river (Figure 2-12). The model includes 1,500 cfs from the Haynes Generating Station (divided over the 3 culverts, so 500 cfs each) and 2,000 cfs from the AES Alamitos Energy Center for the storm event to represent a worst-case scenario. The combined discharge modeled for typical tides was 2,000 cfs.

SOURCE: ESA 2019 — Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-12
Power Plant Inflow Locations

In the mid-term restoration, once-through cooling would be discontinued at these plants, so the discharges into the river are not included in the model for the full breach conditions. The existing conditions and the South Area, near-term conditions models were run with both the outflows turned on (to evaluate existing and near-term water levels) and turned off (to compare against the program conditions). Since discontinuing once-through cooling is not part of the proposed program and just an expected condition when restoration occurs, the discussion comparing flood water levels under existing and program conditions relies on the model runs assuming no once-through cooling for either existing of program conditions.

2.5.2 Storm Conditions

The hydrographs for the 10-, 25-, 50-, 100-, and 500-year recurrence interval storm events (10%, 4%, 2%, 1%, and 0.2% annual chance storms, respectively) for the San Gabriel River were taken from Table 1 of the USACE Los Angeles County Drainage Area Review Final Feasibility Study Interim Report and Environmental Impact Statement from 1991. The hydrographs were developed for the San Gabriel River below Coyote Creek with a storm duration of 48 hours and discharge rates according to Table 2-3.

TABLE 2-3
DISCHARGE FREQUENCY (CFS)

	10-year	25-year	50-year	100-year	500-year
San Gabriel River below Coyote Creek	27,200	36,700	44,400	55,900	74,000

SOURCE: USACE 1991.

The hydrographs were applied as an inflow boundary condition at the most upstream portion of the San Gabriel River in the model, just downstream of 7th St (Figure 2-1).

2.6 Tidal Boundary Conditions

The San Gabriel River terminates in the Pacific Ocean, and the channel's hydraulics are influenced by the tidal input and water levels of the ocean. The nearest NOAA tide gauge is Station 9410660 located in the Port of Los Angeles at the end of Signal Street, approximately 9 miles west of the San Gabriel River mouth. ESA collected water level data in the San Gabriel River at the Zedler Marsh culvert from January 29 to April 18, 2019 to analyze how the tides propagate along the coast and into the channel and how the water levels at the site compare to the water levels at the NOAA tide gauge. Based on the results of this analysis (see Section 2.5.1), NOAA's tide gauge data was used to develop tidal boundary conditions for four downstream boundary conditions:

- 2-week typical tides time series, including a tide equal to the annual high tide – used for the tidal conditions scenarios.
- 2-week typical tides time series, including a tide equal to a typical spring high tide – used for the Central Area, culvert conditions.

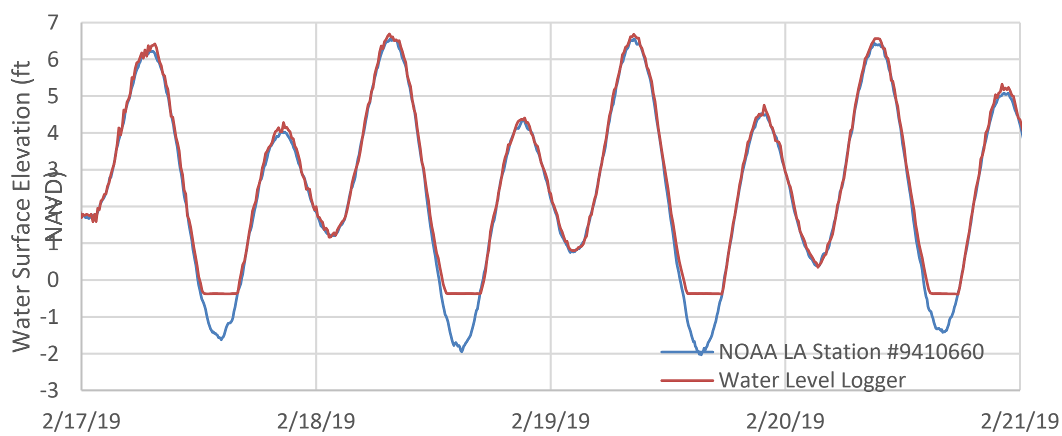
- 2-week typical tides time series, including a tide equal to MHHW – used for the Central Area, culvert conditions.
- 2-day annual high tide series – used for the storm conditions scenarios and timed so that the peak storm flow coincides with the annual high tide for worst-case water elevations.

Additionally, these tidal boundary conditions were increased to account for sea-level rise for the various sea-level rise scenarios. Downstream tidal boundary conditions are further discussed in the sections below.

2.6.1 ESA Water Level Data Collection

Since the elevations where different salt marsh species can occur are dependent on tidal water levels, and even a few inches can make a difference to the success of specific species, understanding water levels at a restoration site is essential. While the NOAA tide gauge provides a long-term dataset of water levels for Los Angeles (water levels have been collected there since 1960), there is often some amount of tidal amplification or muting that can make water levels vary throughout different parts of the coast or within a channel. ESA collected water level data in the San Gabriel River at the Zedler Marsh culvert to get a better understanding of how the water levels at the site compare to the more extensive NOAA tide data time series.

Data was gathered by installing a tide gauge and surveying it into NAVD. The tide gauge was located on the left bank of the San Gabriel River by the Zedler Marsh culvert headwall. Data was collected from January 29, 2019 until April 18, 2019. The water level data showed no amplification or muting of high tide levels compared to the NOAA gauge data (Figure 2-13), so the NOAA data was deemed sufficient to use for the tidal boundary input. Since the tide gauge was located along the side of the channel and not at the deepest part of the channel, the water levels dropped below the tide gauge around -0.5 feet NAVD.



SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-13
ESA Gauge Data Compared to NOAA Gauge Data

2.6.2 NOAA Tidal Data Analysis

Table 2-4 presents the tidal datums and extreme coastal water levels for the San Gabriel River based on the NOAA tide gauge data and FEMA extreme water level data.

TABLE 2-4
TIDAL DATUMS AT THE SAN GABRIEL RIVER

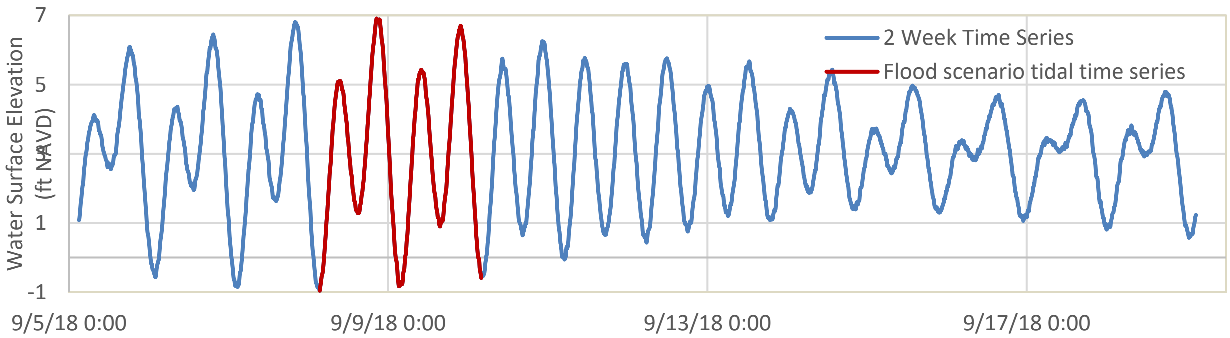
Tide	Water Level (feet NAVD)	Notes
500-year high tide in Alamitos Bay[1]	12.3	
100-year high tide in Alamitos Bay[1]	8.8	
50-year high tide in Alamitos Bay[1]	7.6	
HAT[2]	7.14	Occurred at 12/2/1990, 12:00
10-year high tide in Alamitos Bay[1]	7.0	
1-year high tide[2]	6.89	
MHHW[2]	5.29	
MHW[2]	4.55	
MTL[2]	2.64	
MSL[2]	2.62	
MLW[2]	0.74	
MLLW[2]	-0.20	
LAT[2]	-2.18	Occurred at 1/1/1987, 0:00

[1] Stillwater levels in Alamitos Bay based on FEMA 2018.
[2] Tidal datums from NOAA LA tide gauge.

2.6.2 Model Input

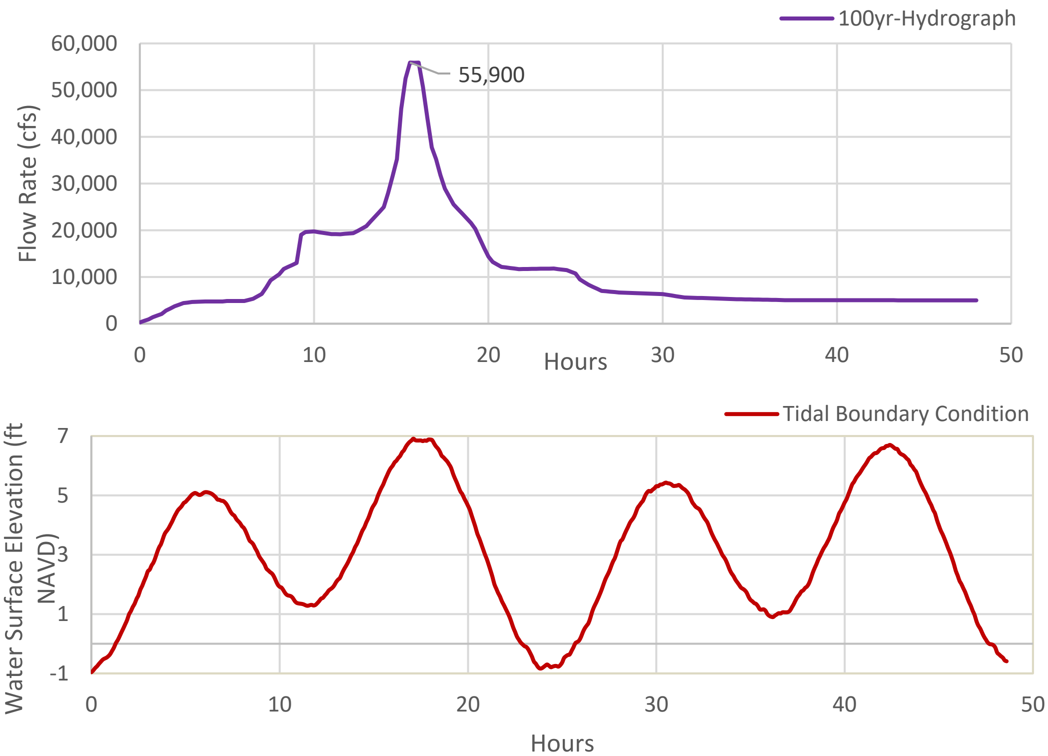
To evaluate flood risk, a conservative tidal boundary condition of the 1-year high tide was chosen. A representative 2-week tide cycle from September 5 to September 18, 2018, including an annual high tide of 6.9 feet NAVD, was used for the typical tides scenario (Figure 2-14).

For the flood scenarios, the tide cycle was shortened to a 48-hour period, including the 6.9 feet NAVD high tide, to reduce model times (Figures 2-14 and 2-15). The peak of the 100-year San Gabriel River flood discharge hydrograph was set to coincide with the 6.9 feet NAVD high tide as shown in Figure 2-15.



SOURCE: NOAA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-14
Tidal Boundary Conditions Model Input



SOURCE: NOAA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 2-15
Tidal Boundary Conditions Model Input For Storm Scenarios

To assess the capacity of the culverts in the Central Area, culvert conditions model runs, a MHHW and spring high tide cycle were analyzed. Similar to the typical tides scenario, the MHHW and spring high tides scenarios were 14-day tidal boundary conditions. The maximum water elevation for the MHHW tides was 5.3 feet NAVD88 and 6.0 feet NAVD88 for the spring high tide. A representative 2-week tide cycle from June 20 to July 4, 2019 was used for the MHHW conditions and a tide cycle from June 18 to July 2, 2019 was used for the spring high tide conditions.

2.6.3 Sea-Level Rise Model Input

State Guidance

Projections of global sea-level rise are well-documented and investigated, with recent research projecting sea-level rise on the order of 2 to 10 feet by 2100 in California (e.g., Cayan et al. 2008; Griggs et al. 2017). This research has been used to develop a series of policy guidance documents by the State of California that recommend including specific amount of sea-level rise in project planning and design, the most recent being the California Ocean Protection Council's (OPC) *State of California Sea-Level Rise Guidance* (OPC 2018). The OPC (2018) Guidance includes tables of projected relative sea-level rise at well-established tide gauges located along the coast of California through 2150 for a range of risk aversion scenarios, including low, medium-high, and extreme (e.g., H++). Table 2-5 shows the projections for Los Angeles. These projections were developed and summarized with the intention that local planning and design efforts would have a consistent and accepted basis for addressing future sea-level rise.

The California Coastal Commission (CCC) recently updated their *Sea-Level Rise Policy Guidance* in 2018 (CCC 2018). The CCC (2018) Guidance provides a basis for selecting the time horizon and the risk level of the project, which are used to define the appropriate sea-level rise amounts. The CCC (2018) Guidance recommends that project planning and design consider a range of scenarios in order to bracket the possible timing of a given amount of sea-level rise.

TABLE 2-5
PROJECTED SEA-LEVEL RISE (IN FEET) FOR LOS ANGELES

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					*H++ scenario (Sweet et al. 2017) *Single scenario*
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds…	*66% probability sea-level rise is between…*		*5% probability sea-level rise meets or exceeds…*	*0.5% probability sea-level rise meets or exceeds…*	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.3	0.2 -	0.5	0.6	0.7	1.0
	2040	0.5	0.4 -	0.7	0.9	1.2	1.7
	2050	0.7	0.5 -	1.0	1.2	1.8	2.6
Low emissions	2060	0.8	0.5 -	1.1	1.4	2.2	
High emissions	2060	1.0	0.7 -	1.3	1.7	2.5	3.7
Low emissions	2070	0.9	0.6 -	1.3	1.8	2.9	
High emissions	2070	1.2	0.8 -	1.7	2.2	3.3	5.0
Low emissions	2080	1.0	0.6 -	1.6	2.1	3.6	
High emissions	2080	1.5	1.0 -	2.2	2.8	4.3	6.4
Low emissions	2090	1.2	0.7 -	1.8	2.5	4.5	
High emissions	2090	1.8	1.2 -	2.7	3.4	5.3	8.0
Low emissions	2100	1.3	0.7 -	2.1	3.0	5.4	
High emissions	2100	2.2	1.3 -	3.2	4.1	6.7	9.9
Low emissions	2110*	1.4	0.9 -	2.2	3.1	6.0	
High emissions	2110*	2.3	1.6 -	3.3	4.3	7.1	11.5
Low emissions	2120	1.5	0.9 -	2.5	3.6	7.1	
High emissions	2120	2.7	1.8 -	3.8	5.0	8.3	13.8
Low emissions	2130	1.7	0.9 -	2.8	4.0	8.1	
High emissions	2130	3.0	2.0 -	4.3	5.7	9.7	16.1
Low emissions	2140	1.8	0.9 -	3.0	4.5	9.2	
High emissions	2140	3.3	2.2 -	4.9	6.5	11.1	18.7
Low emissions	2150	1.9	0.9 -	3.3	5.1	10.6	
High emissions	2150	3.7	2.4 -	5.4	7.3	12.7	21.5

SOURCE: OPC 2018

The OPC Guidance identifies three levels of risk to consider when planning for sea-level rise (blue boxes in Table 2-5):

- The low risk aversion scenario is appropriate for adaptive, lower consequence decisions (e.g., unpaved coastal trail), but is not adequate to address high impact, low probability events.
- The medium-high risk aversion scenario is appropriate as a precautionary projection that can be used for less adaptive, more vulnerable projects or populations that will experience medium to high consequences as a result of underestimating sea-level rise (e.g., coastal housing development).
- The extreme risk aversion scenario is appropriate for high consequence projects with little to no adaptive capacity and which could have considerable public health, public safety, or environmental impacts (e.g., coastal power plant, wastewater treatment plant, etc.).

For habitat restoration projects, the CCC (2018) Guidance recommends using multiple time horizons and sea-level rise projections (CCC 2018, pg. 102):

> *Determining an anticipated life for restoration activities or other related projects is somewhat more complex than for typical development projects because these activities are typically meant to exist in perpetuity. As such, assessing sea-level rise impacts may necessitate analyzing multiple different time frames, including the present, near future, and very long-term depending on the overall goals of the project. For restoration projects that are implemented as mitigation for development projects, an expected project life that is at least as long as the expected life of the corresponding development project should be considered.*

LCW Sea-Level Rise Scenarios

To inform the habitat design for the LCW, two sea-level rise amounts were selected to bracket the range of potential projections: 1.7 and 3.3 feet. According to OPC 2018, there is a 66% chance that sea-level rise will be between 1.7 and 3.3 feet of sea-level rise by 2110. There is a 0.5% chance that sea-level rise will reach or exceed 3.3 feet as soon as 2070.

To analyze potential flood impacts along the San Gabriel River, the medium-high risk aversion scenario is recommended per the OPC Guidance, since homes and other development in the area are at risk for flooding. Table 2-6 shows the model scenarios and the corresponding time frames (the first year in the range) under the medium-high risk aversion projection, for high emissions. To analyze habitat elevations, the low risk aversion project of sea-level rise, for high emissions (the third column in Table 2-5) can be used to understand the likely habitat acreages that will develop over time. Since habitat restoration requires a balance of creating wetland habitat post-restoration and providing space for future wetland habitat, the low risk aversion projection is used to assess habitat development with sea-level rise. (rather than the medium-high risk aversion). The model scenarios and the corresponding time frames under the low risk aversion projection (the second year in the range) are shown in Table 2-6.

TABLE 2-6
LOS CERRITOS WETLANDS SEA-LEVEL RISE PROJECTIONS (IN FEET)

	~2040–2070	~2070–2110
Amounts of sea-level rise	1.7	3.3

2.7 Run Catalog

Table 2-7 presents the run catalog for the different modeled scenarios with the varying model inputs.

TABLE 2-7
LOS CERRITOS WETLANDS HYDRODYNAMIC MODELING RUN CATALOG

	Run	Scenario/ Geometry	Hydrology	Downstream Boundary Conditions	Sea-Level Rise
Typical Tides	Calibration	Existing	Power plant inflow	Two weeks tides from gauge data	—
	1	Existing	Power plant inflow	Two weeks typical tides, w/ annual high tide	—
	2	Existing	No flow	Two weeks typical tides, w/ annual high tide	—
	3	South Area, Near-Term	Power plant inflow	Two weeks typical tides, w/ annual high tide	—
	4	South Area, Near-Term	No flow	Two weeks typical tides, w/ annual high tide	—
	5	Full Breach	No flow	Two weeks typical tides, w/ annual high tide	—
Flood Conditions	6	Existing	100-year event	Two days, w/ annual high tide	—
	7	South Area, Near-Term	100-year event	Two days, w/ annual high tide	—
	8	Full Breach	10-year event	Two days, w/ annual high tide	—
	9	Full Breach	25-year event	Two days, w/ annual high tide	—
	10	Full Breach	50-year event	Two days, w/ annual high tide	—
	11	Full Breach	100-year event	Two days, w/ annual high tide	—
	12	Full Breach	500-year event	Two days, w/ annual high tide	—
Sea-Level Rise	13	Existing	No flow	Two weeks typical tides, w/ annual high tide	1.7 feet
	14	Full Breach	No flow	Two weeks typical tides, w/ annual high tide	1.7 feet
	15	Existing	No flow	Two weeks typical tides, w/ annual high tide	3.3 feet
	16	Full Breach	No flow	Two weeks typical tides, w/ annual high tide	3.3 feet
Central Area Culvert Dimension Analysis	17	Culvert / 2ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	18	Culvert / 4ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	19	Culvert / 4ft diameter	100-year event	Two weeks typical tides, w/ annual high tide	—
	20	Culvert / 6ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	21	Culverts / four 4ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	22	Culverts / six 4ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	23	Culverts / six 4ft diameter	100-year event	Two weeks typical tides, w/ annual high tide	—

TABLE 2-7
LOS CERRITOS WETLANDS HYDRODYNAMIC MODELING RUN CATALOG

	Run	Scenario/ Geometry	Hydrology	Downstream Boundary Conditions	Sea-Level Rise
	24	Culverts / nine 6ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	25	Culverts / nine 6ft diameter	100-year event	Two weeks typical tides, w/ annual high tide	—
	26	Culverts / nine 8ft diameter	No flow	Two weeks typical tides, w/ annual high tide	—
	27	Culverts / nine 8ft diameter	100-year event	Two weeks typical tides, w/ annual high tide	—
Central Area Culvert Analysis Refinement	28	Culvert / 4ft diameter	No flow	Two weeks typical tides, w/ MHHW tide	—
	29	Culvert / 4ft diameter	No flow	Two weeks typical tides, w/ spring high tide	—
	30	Culvert / 4ft diameter / lower invert	No flow	Two weeks typical tides, w/ annual high tide	—
	31	Culvert / 4ft diameter / lower invert	100-year event	Two weeks typical tides, w/ annual high tide	—
	32	Culvert / 4ft diameter	No flow	Two weeks typical tides, w/ annual high tide	1.7 feet
	33	Culvert / 4ft diameter	No flow	Two weeks typical tides, w/ annual high tide	3.3 feet

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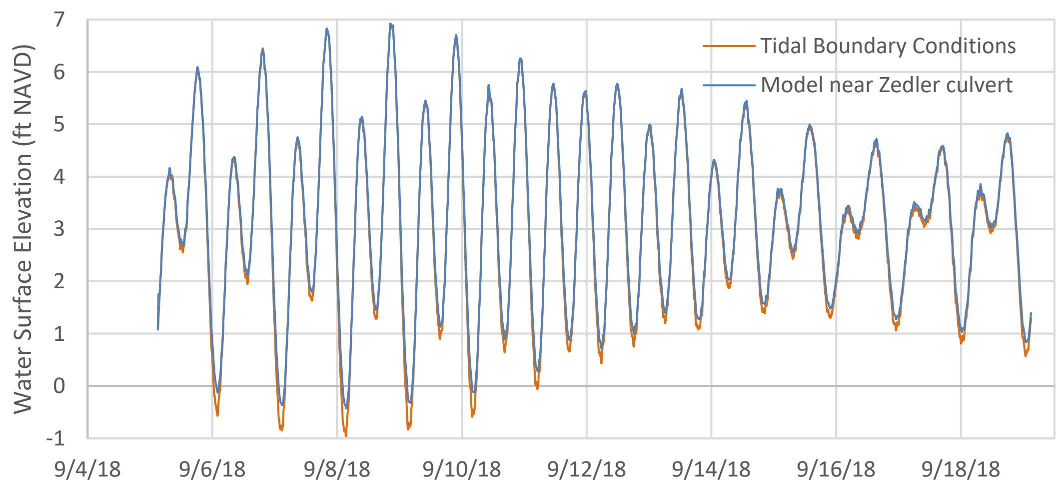
SECTION 3
Results and Discussion

3.1 Model Calibration

The model was calibrated using ESA's tide gauge data in the San Gabriel River (Section 2.5.1) and M&N's tide gauge data in the Hellman Channel (1.3.2). Additionally, Tidal Influence LLC surveyed the high tide water level extent in Zedler Marsh on November 26, 2019 during a high tide of 7.1 feet NAVD.

3.1.1 San Gabriel River Water Levels

As explained in Section 2.5.1, ESA collected tide gauge data at the Zedler Marsh culvert in the San Gabriel River. The tide data in front of Zedler Marsh matched closely to the NOAA tide data (Figure 2-13). The model also shows that the water levels in the river in front of Zedler Marsh match closely with the input NOAA tide data (Figure 3-1).



SOURCE: ESA 2019

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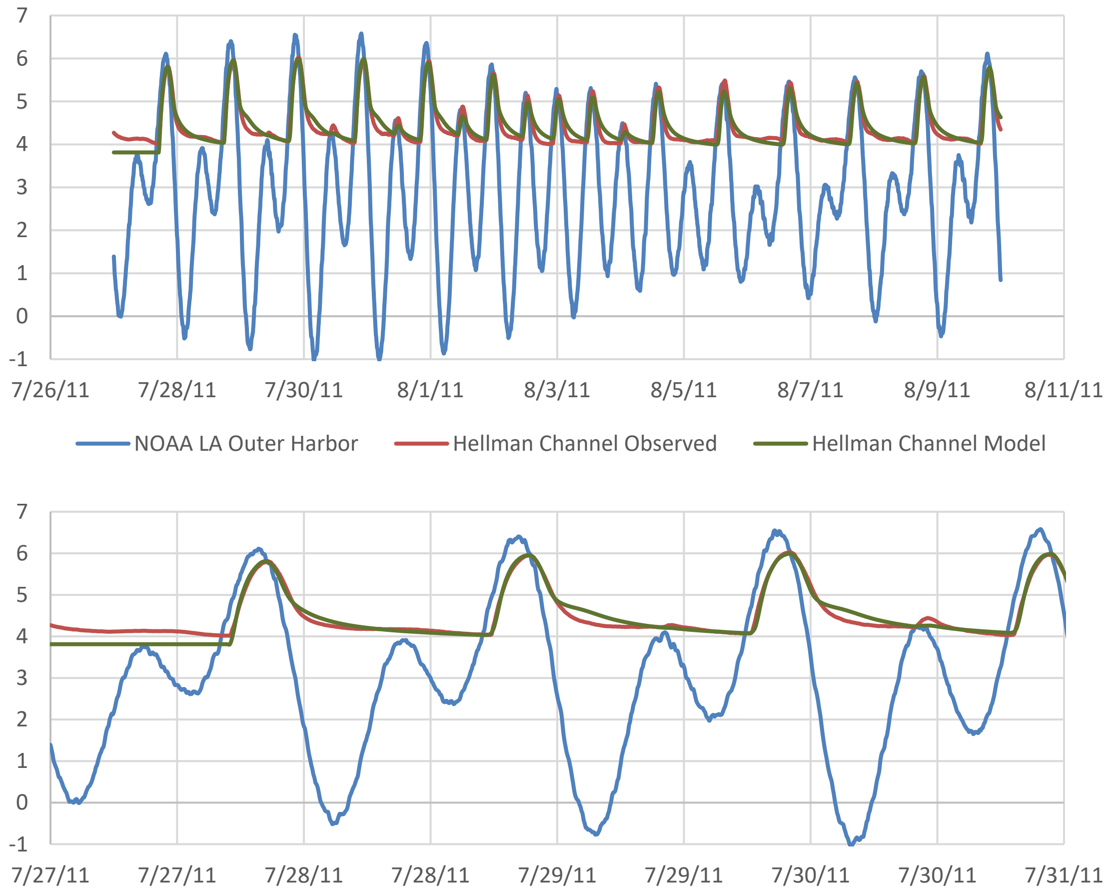
Figure 3-1
Water Levels in SGR near Zedler Marsh Compared to the Model Input Data

3.1.2 Hellman Channel Water Level Calibration

The M&N tide gauge data in Hellman Channel was used to estimate the leakage on the culvert gate between the San Gabriel River and the South LCWA site. As a first pass and based on photos of the culvert and gate (Figure 2-5) the culvert was modeled at 90% blocked (i.e., only 10% of the culvert is open to allow flow into the site). A number of iterations were made in the culvert geometry and connection data to determine the optimal configuration to most closely match the M&N tide gauge data in the channel. The culvert configuration that led to the closest relationship between the modeled and measured water levels was the culvert blocked to 45% (i.e., a 1.8-foot opening to the 4-foot culvert). The results of this calibration can be seen below in Figure 3-2 below.



SOURCE: ESA 2019

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Figure 3-2
Model Calibration for Water Levels in the Hellman Channel

Figure 3-2 shows that the measured water levels in the Hellman Channel are muted (i.e., the high tides are lower) compared to the water levels in the San Gabriel River (i.e., tidal boundary condition). The measured water levels bottom out at around 4 feet NAVD, which is the elevation of the bottom of the channel in the location of the tide gauge. In other words, when the water levels drop below 4 feet NAVD, the channel in this location is dry. Figure 3-2 also shows the high tides and bottom elevation for the measured and modeled water levels are almost identical. Water levels take a longer time to drain in the model compared to the measured data. However, the model results were deemed sufficiently representative of the measured water level data when the culvert gate is blocked to 45%.

3.1.3 Zedler Marsh Flooding Extent

The flooding extent in Zedler Marsh under existing conditions was compared to data collected by Tidal Influence during a 7.1 feet NAVD high tide. Figure 3-3 shows the extent of the flooding as measure by Tidal Influence and the results of the existing conditions model during a similar tide. The model extents showed slightly more flooding in the south of the site and up towards the Isthmus Bryant site, but were generally similar to the observed extents. This means the model is likely to provide slightly more conservatively high water levels than actual conditions.

3.2 Current Sea Level Model Results

3.2.1 Typical Tides

South Area

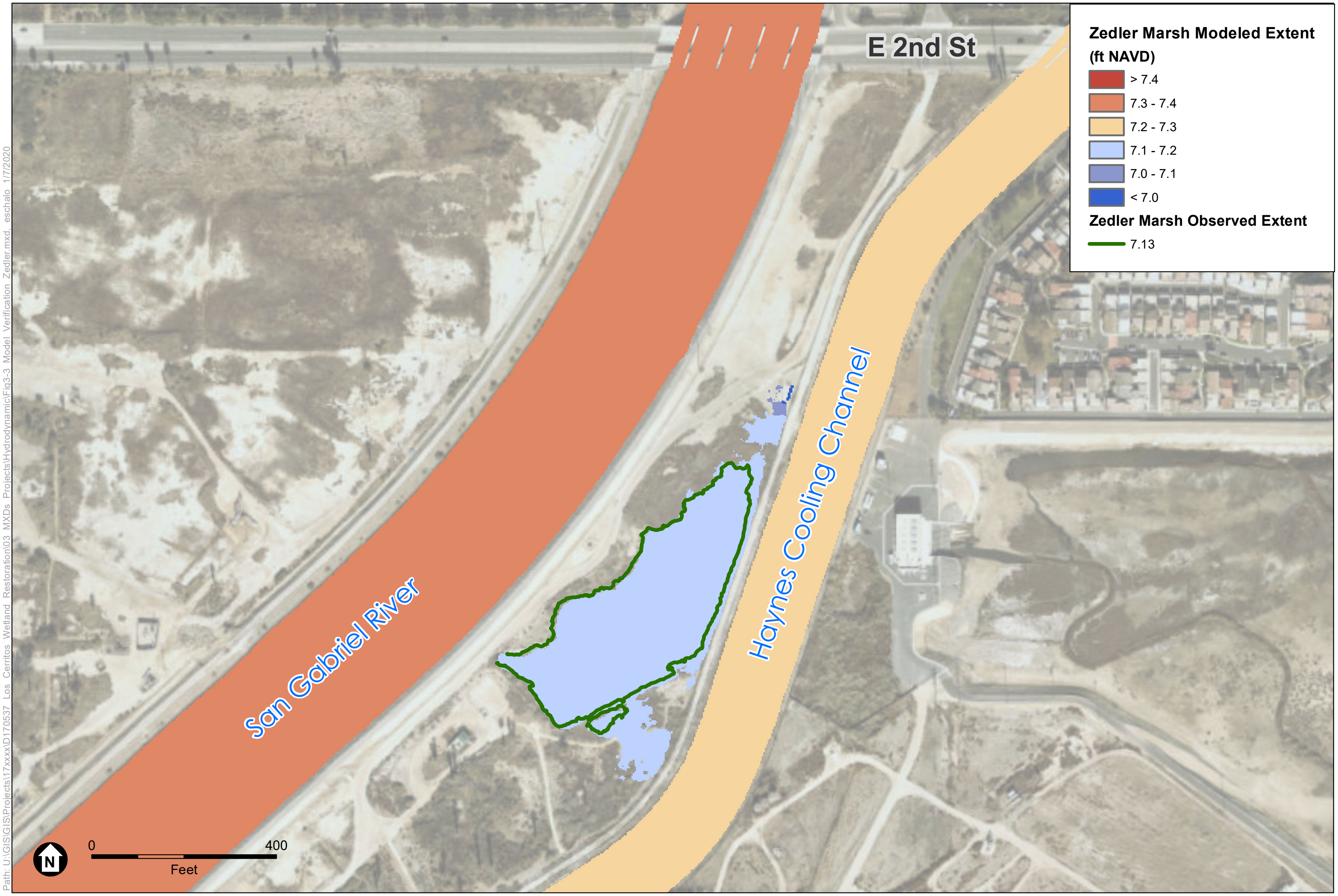
Inundation Extent and Water Levels

Under existing conditions, the model results show that tidal waters inundate the Hellman Channel and the lowest lying areas in the marsh (top panel of Figure 3-4). Most of the inundation is in the vicinity of the Hellman Channel and the tides at the back of the marsh are limited by the series of culverts along the channel, resulting in lower water levels. As shown in Table 3-1, the model shows the annual high tide water level at the mouth of the Hellman Channel as 6.2 feet NAVD, while the water level at the back of the marsh is 5.4 feet NAVD. The model shows the tide waters do not extend to the Hellman Retained site under the highest annual tide.

TABLE 3-1
MODELED WATER LEVELS IN THE SOUTH AREA UNDER TYPICAL TIDES

	Water Levels in Hellman Channel (feet NAVD)				
Scenario	**Haynes Cooling Channel**	**Mouth**	**South of 1st Street**	**Middle of Marsh (between marsh culverts)**	**Back of Marsh**
Existing Conditions	6.8	6.2	6.2	5.5	5.4
South Area, Near-Term Conditions	6.8	5.8	5.8	5.7	5.7
Full Breach Conditions	6.7	6.7	6.6	6.3	6.2

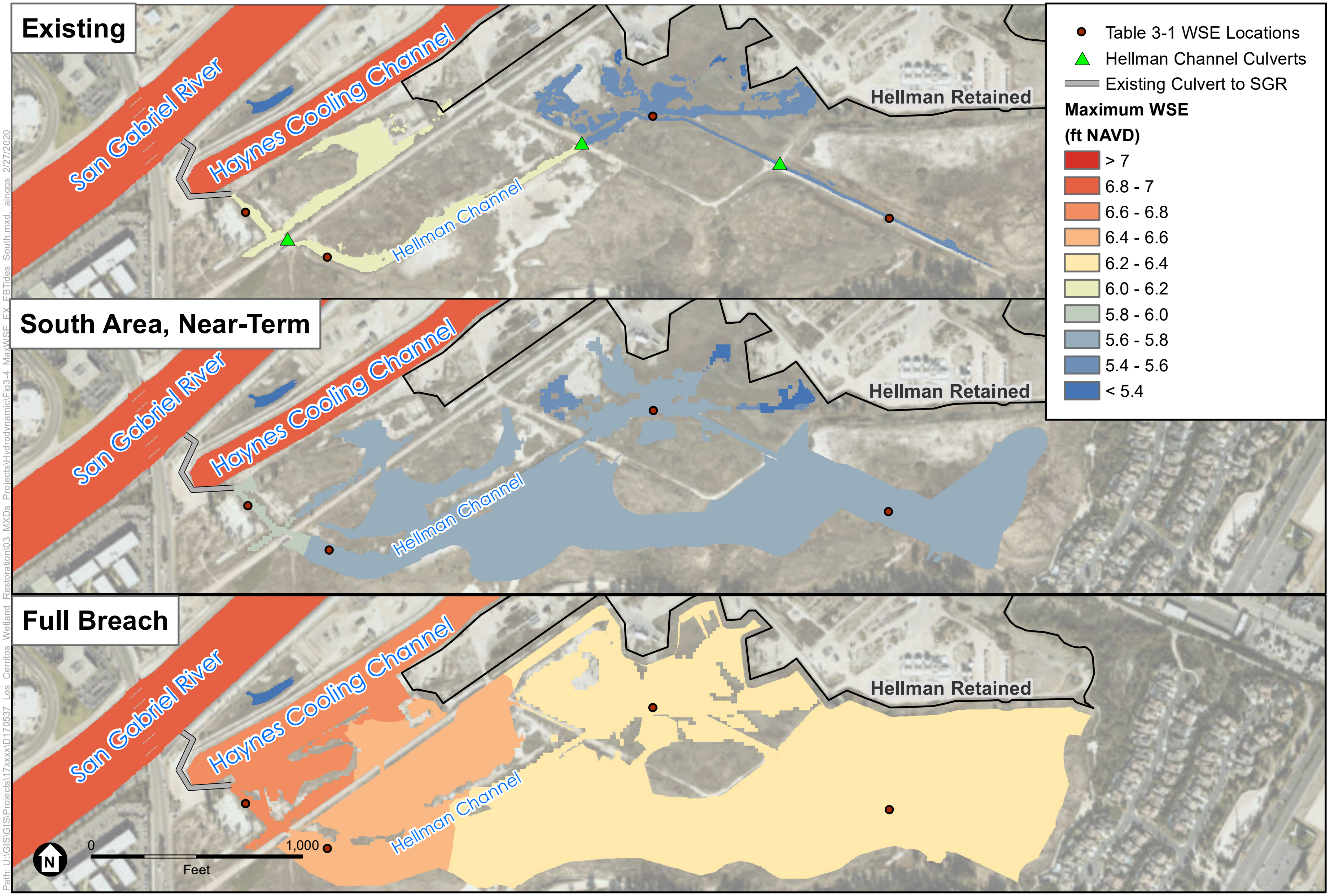
Figure 3-4 shows the locations for each column of the table.



SOURCE: ESRI,LCWA

Figure 3-3
Model Verification at Zedler Marsh

ESA



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

ESA

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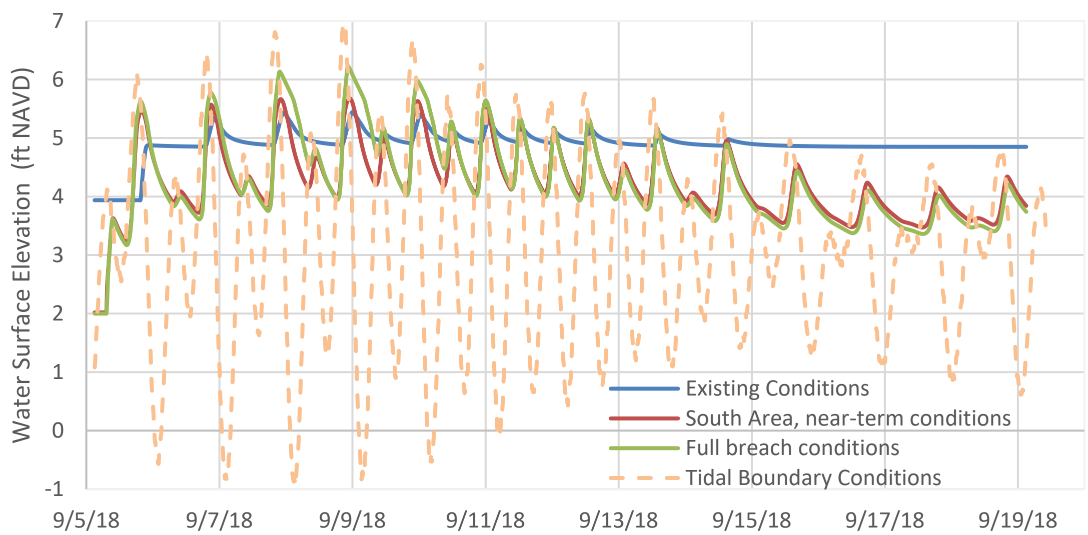
Figure 3-4
Modeled Extent of Inundation during an Annual High Tide in the South Area

Under the South Area, near-term conditions, the model shows that more of the marsh is inundated annually due to the restoration grading because the grading would lower ground elevations (middle panel of Figure 3-4). In the South Area, near-term conditions, the culverts within the marsh that constrain the water levels at the back of the marsh under existing conditions are removed. As a result, the model shows water levels are more similar across the marsh (i.e., less muting) and the annual high tide water level at the back of the marsh (Figure 3-5) is only 0.1 feet lower than the water level at the mouth of the Hellman Channel (Table 3-1).

The water levels at the mouth of the Hellman Channel are 0.4 feet lower than in existing conditions, based on the model results. This is because the grading of the site under the near-term restoration creates a much larger space for water to flow, but the culvert to the San Gabriel River still limits the amount of water that can enter the site. With the removal of the culverts within the marsh, the available water spreads more evenly across the site and water levels at the back of the site are higher than existing conditions, but the water levels near the mouth of the Hellman Channel are lower.



SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 3-5
Model Water Levels at the Back of the Marsh in the South LCWA site

The full breach conditions model results show that mid-term restoration (including connecting the site to the Haynes Cooling Channel) would further increase the extent of inundation (bottom panel of Figure 3-4). During the annual high tide, the majority of the site in inundated. The channel under 1st Street acts as a minor constriction, and the model results show water levels at the back of the marsh are up to 0.5 feet lower than water levels at the mouth of the Hellman Channel. Low tides at the back of the marsh are damped by between a few tenths of a foot up to 5 feet after higher tides compared to tides in Alamitos Bay.

The model results for the full breach conditions show that the water levels at the mouth of Hellman Channel reach an elevation of 6.7 feet NAVD, 0.5 feet higher than under existing conditions, which is due to a greater volume of water entering the marsh from the connection to the Haynes Cooling Channel. However, this is still slightly muted from the annual high tide elevation used for the tidal boundary conditions (Figure 3-5). Water levels in the Haynes Cooling Channel show a drop from South Area, near-term conditions to full breach conditions (Table 3-1), indicating that the culverts connecting the Haynes Cooling Channel to the Alamitos Bay Marina are slightly constricting flow into the site.

Tide Range and Wetland Area

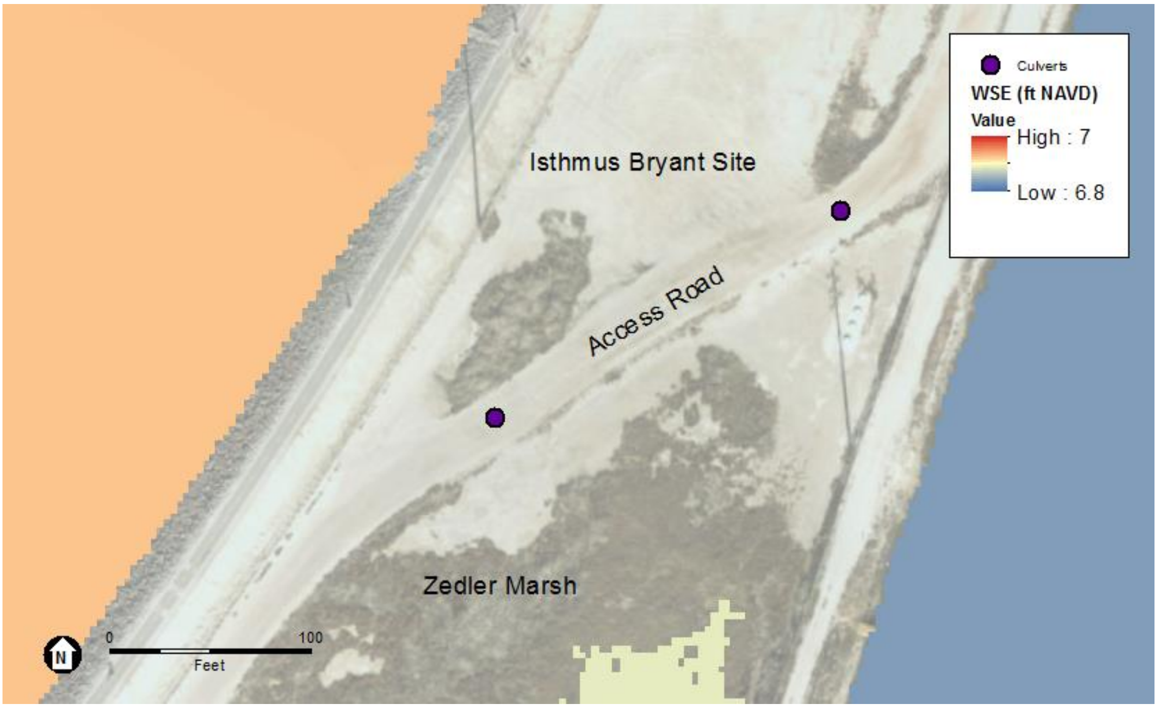
Figure 3-5 illustrates how the restoration in the South Area would increase the tidal range at the site. At the back of the site, the tide range under existing conditions is 1.4 feet (from the bottom of the channel [4.0 feet NAVD] up to the annual high tide in the site [5.4 feet NAVD]). With the restoration, the channel is excavated to 2 feet NAVD and the tide range under the South Area, near-term conditions increases to 3.7 feet, and the tide range under the full breach conditions increases to 4.2 feet, since the annual high tide also increases with restoration. The model shows the program is expected to increase the tide range by 2.3 feet in the near-term and an additional 0.5 feet in the mid-term (full breach conditions), but is damped compared to the tide range in Alamitos Bay.

The area inundated by the annual high tide would also increase, from 7.6 acres under existing conditions to 32.8 acres under the South Area, near-term conditions based on the model results. The full breach conditions model results show that mid-term restoration (including connecting the site to the Haynes Cooling Channel) would further increase the inundated marsh to 65.8 acres, 58.2 acres more than existing conditions and 33 acres more than the South Area, near-term conditions.

Isthmus Area

In Callaway Marsh, the model shows tidal waters extend only into the low-lying areas near the culvert and reach an elevation of 5.3 feet NAVD under existing conditions during the annual high tide. Under the full breach conditions (removal of the gate on the Callaway Marsh culvert), the model results for the storm event show that opening the culvert could result in increased flooding to the LCWA Isthmus Area property during the 100-year storm event (see discussion in Section 3.2.2). Since this property is currently used for oil operations, the gate on the culvert would need to stay in place until oil operations cease, and the hydrodynamics at Callaway Marsh would not be expected to change from existing conditions. Alternatively, a berm could be built around Callaway Marsh to allow for higher water levels within the site.

At Zedler Marsh, the model shows the tides reach an elevation of 6.9 feet NAVD during an annual high tide (6.9 feet NAVD) under existing conditions, indicating no tidal muting up to the annual high tide. The model shows the waters do not extend all the way north to the culverts under the access road (Figure 3-6). Therefore, under the full breach conditions, the water levels and extent would stay the same even if the culverts under the access road were improved.



SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

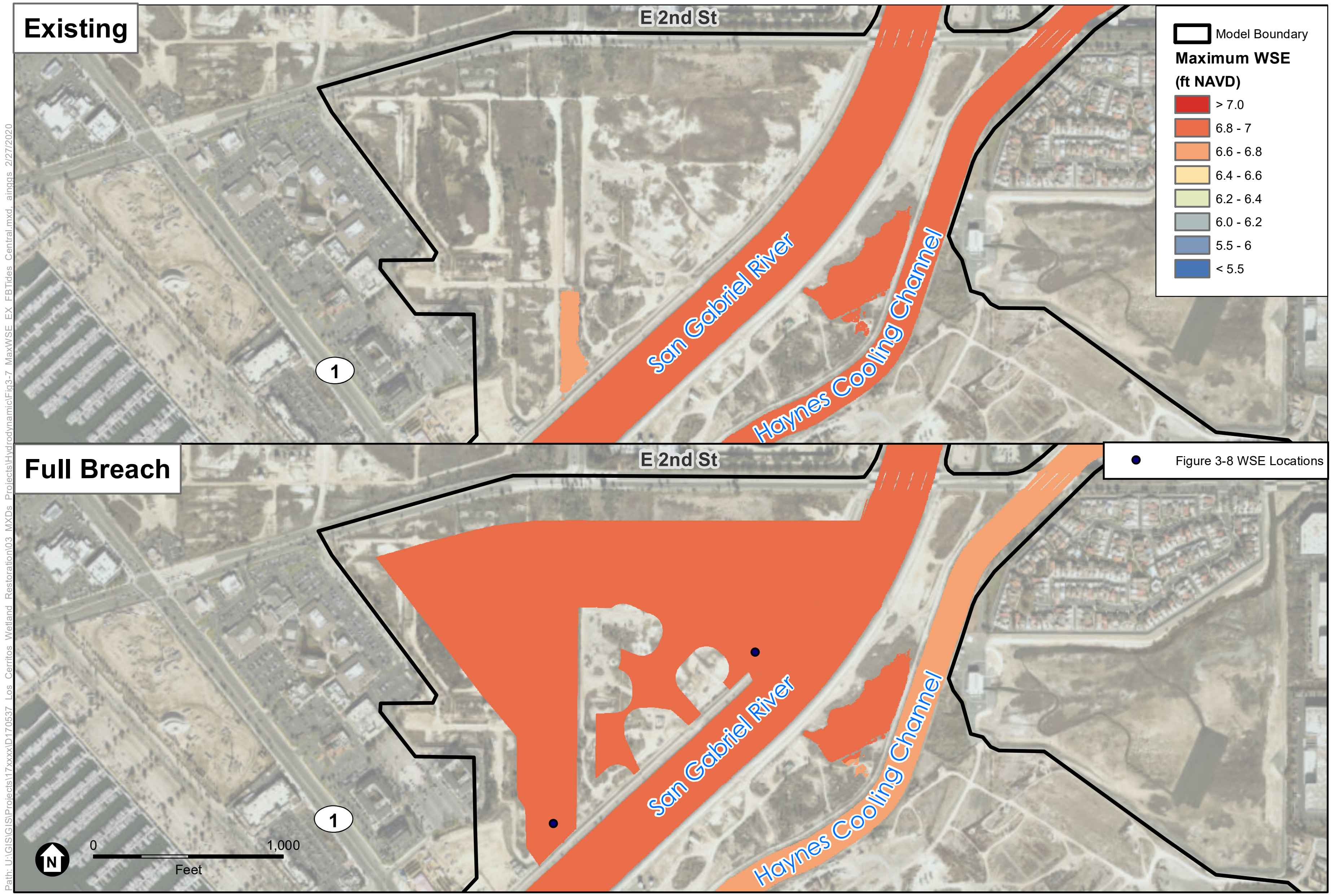
Figure 3-6
Existing Conditions Typical Tides, Maximum Water Surface Elevation in Zedler Marsh

Central Area

Existing and Full Breach Conditions

Under existing conditions, the model results show that the Central Area experiences minimal inundation, since it is limited by one perched hydraulic connection to the San Gabriel River (top panel of Figure 3-7). The maximum water surface elevation in the Central Area during the annual high tide (6.9 feet NAVD) is approximately 6.6 feet, near the culvert.

With the restoration program, the Central Area would be graded down and the existing San Gabriel River levee would be breached to provide a full tidal connection. The model results show that under the full breach conditions, the entire marsh is fully inundated (bottom panel of Figure 3-7). There is a minor time lag for high tide to reach the back of the site, but the water levels in the back of the site are within 0.1 to 0.2 feet of the water levels at the breach (Figure 3-8). The maximum water surface elevation during the annual high tide matches the tidal boundary condition. These results indicate that, with a full breach, the tides in the Central Area would function as a fully tidal marsh.



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

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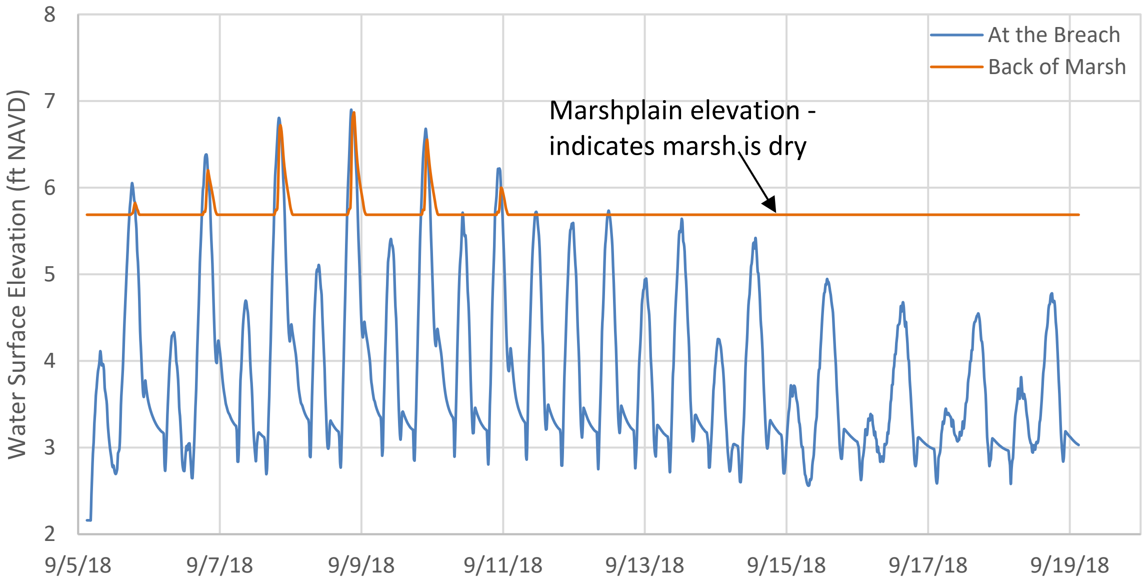
Figure 3-7

Modeled Extent of Inundation during an Annual High Tide in the Central Area

ESA



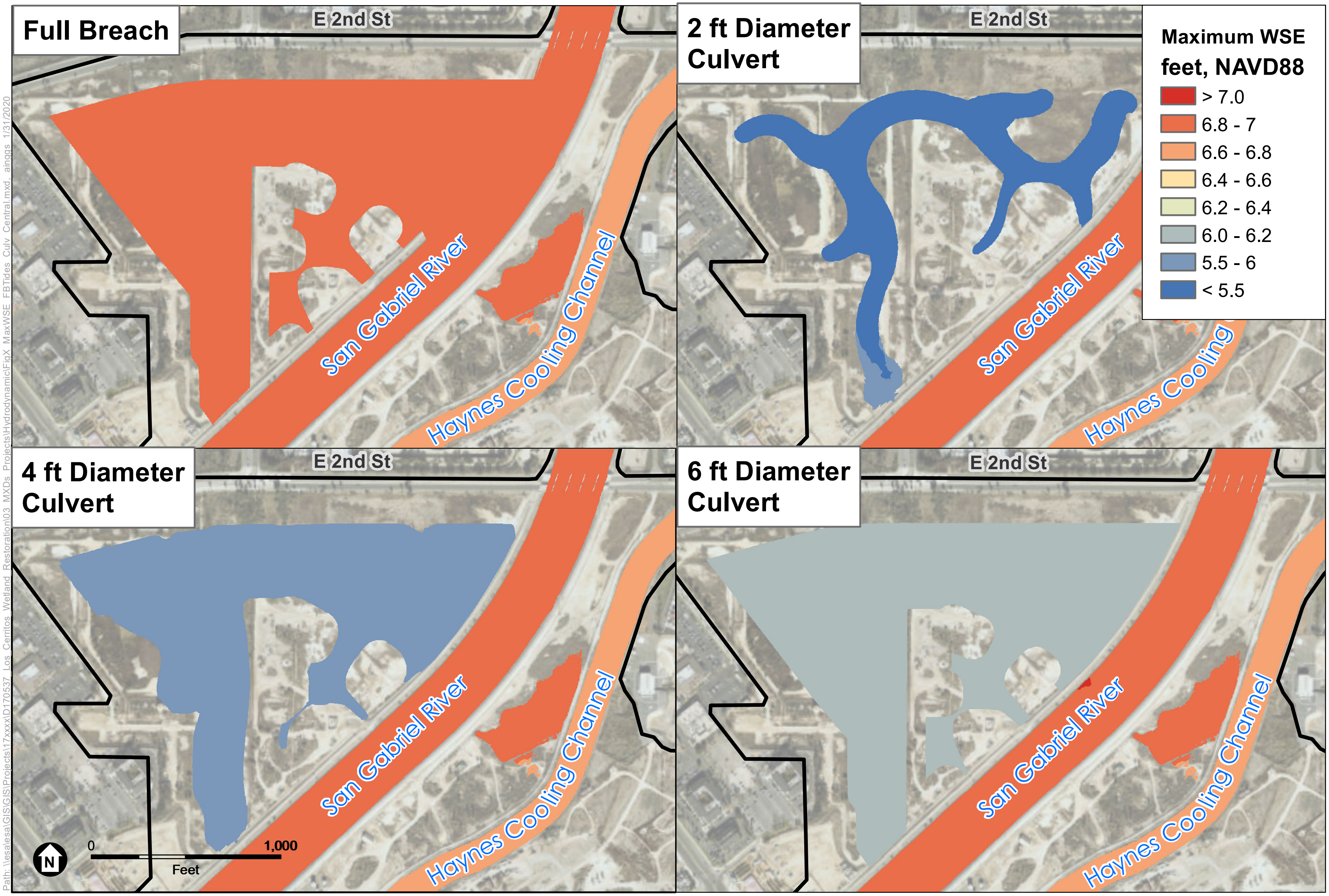
SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 3-8
Modeled Water Levels in the Central Area

Central Area, Culvert Conditions

Under the Central Area, culvert conditions the water levels in the site are constrained by the culvert or culverts in the different scenarios. Figure 3-9 shows the modeled inundation extents for the full breach compared to the 2-foot, 4-foot, and 6-foot diameter culvert scenarios. Note that the full breach and culvert scenarios assume the same restoration grading. The marsh inundation is limited to along the channels for the 2-foot diameter culvert, while the flood extents with the 6-foot culvert are similar to the full breach conditions, although the model shows that the maximum water level during the annual high tide is almost a foot lower. Adding additional culverts at larger diameters than the 6-foot diameter culvert scenario show only minor change in the inundation extents, though the tidal range and water level continue to rise.

Table 3-2 presents the modeled minimum and maximum water levels for the different culvert configurations. The maximum water level in the Central Area marsh increases with additional and larger culverts, though the differences in water levels becomes increasing smaller, as shown in Figure 3-10. However, the maximum water surface elevation during the annual high tide does not match the water level under the full breach conditions, meaning the site is not fully tidal with a culvert configuration of nine 8-foot-diameter culverts.



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

ESA

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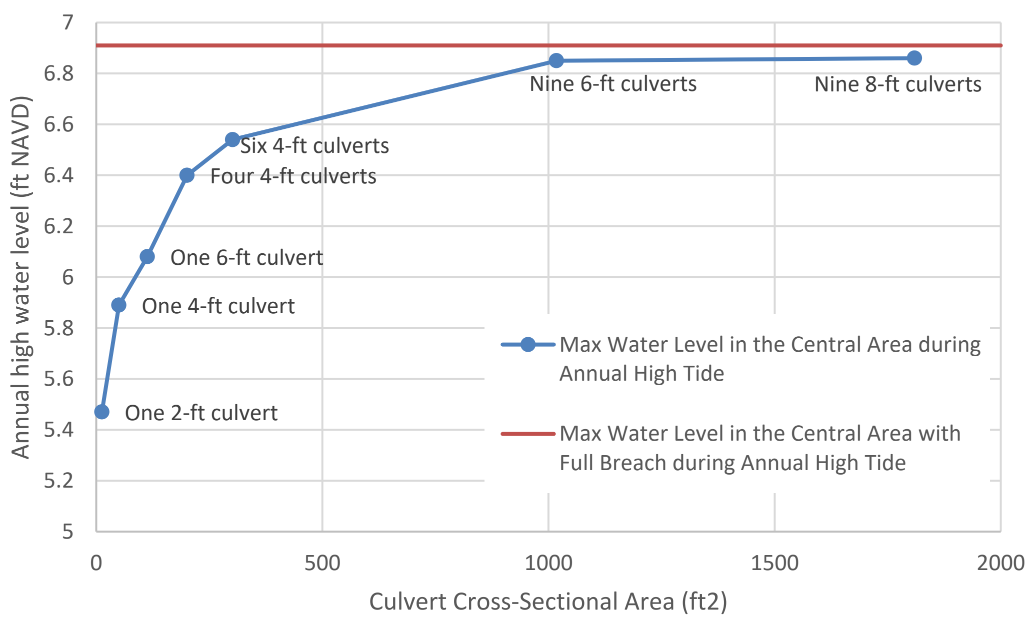
Figure 3-9
Modeled Extent of Inundation during an Extreme High Tide in the Central Area

TABLE 3-2
CENTRAL AREA, CULVERT CONDITIONS RESULTS

Culvert quantity and size	XSA (ft2)	Min tide level (feet NAVD)	Max tide level (feet NAVD)	Tidal muting of 1-year high tide (feet)	Annual tide range (feet)
Full breach (invert at 2 feet NAVD)(for reference)	—	***2.9***	***6.9***	—	***4.0***
One 2-foot culvert @ 2 feet NAVD	13	3.4	5.5	1.4	2.1
One 4-foot culvert @ 2 feet NAVD	50	3.5	5.9	1.0	2.4
One 6-foot culvert @ 2 feet NAVD	113	3.4	6.1	0.8	2.7
Four 4-foot culverts @ 2 feet NAVD	201	3.4	6.4	0.5	3.0
Six 4-foot culverts @ 2 feet NAVD	302	3.4	6.5	0.4	3.1
Nine 6-foot culverts @ 2 feet NAVD	1018	3.4	6.9	0.06	3.5
Nine 8-foot culverts @ 2 feet NAVD	1810	3.4	6.9	0.05	3.5
One 4-foot culvert @ 0 feet NAVD	50	0.9	5.9	1.0	5.0



SOURCE: ESA 2019

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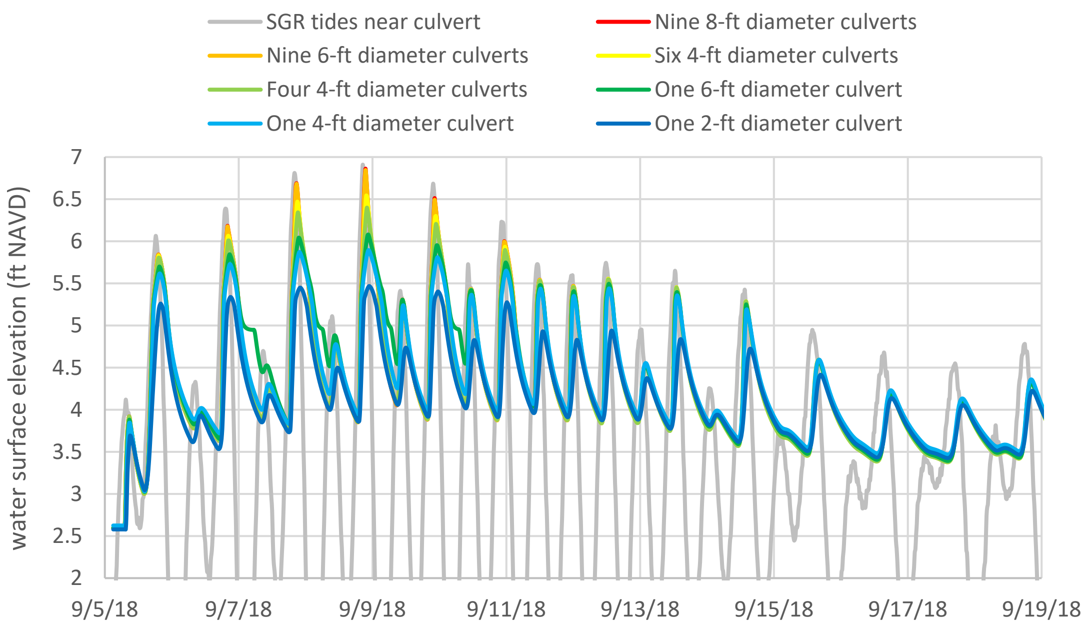
Figure 3-10
Modeled Water Levels in the Central Area Under Different Culvert Configurations

The tidal range was assessed for all culvert configurations, and is presented in Table 3-2. The invert elevation of the culverts limits how low water levels can drain within the site. The initial culvert dimensions’ analysis assumed all of the culverts would have an invert elevation of 2 feet NAVD, to match the designed channel invert. An annual tidal range of 2.1 to 3.5 feet was calculated for all configurations with the 2-foot-NAVD invert. Figure 3-11 shows time series plots of the modeled water levels in the proposed channel mouth inside the Central Area for all configurations with the 2-foot-NAVD invert.



SOURCE: ESA 2019

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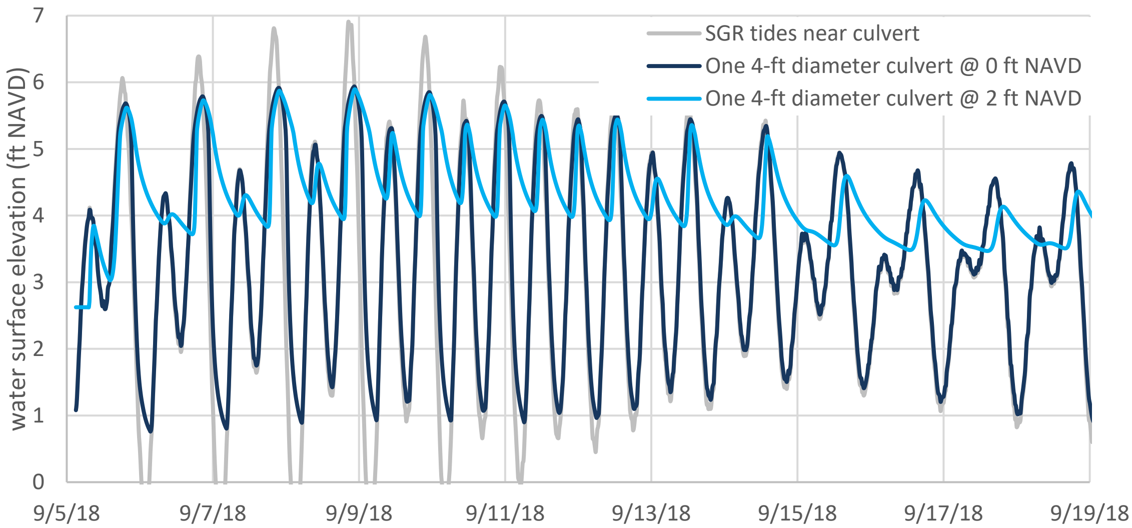
Figure 3-11
Modeled Water Levels in the Central Area with Different Culvert Configurations

Since the 2-foot-NAVD invert was limiting the low tide drainage in the site, an additional scenario was run with a 4-foot-diameter culvert at an invert elevation of 0 feet NAVD. The topography of the site in the vicinity of the culvert had to be adjusted for this lower elevation, but otherwise, the scenario matched the other culvert scenarios. Lowering the 4-foot culvert invert to 0 feet NAVD yielded an annual tidal range of 5.0 feet, which was 2.6 feet greater than the tide range for the 2 foot NAVD invert scenario (Figure 3-12). The tide range increases by more than the difference in the invert elevation, which indicates that the hydraulic head drives additional drainage in the lower invert scenario. Hydraulic head is the pressure of water, so when water levels are high within the Central Area and low within the San Gabriel River (e.g., when the tide is falling), the head drives water through the culvert towards the lower water levels in the river. When the culvert invert is set lower in the tide frame, there is more time when the culvert is full of water compared to the higher invert elevation culvert, so more volume of water can flow out. However, having a culvert set in a sump (i.e., a low spot relative to the surrounding areas) has the potential to lead to increased sediment accumulation and maintenance needs.



SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report

Figure 3-12
Modeled Water Levels in the Central Area with Different Culvert Invert Elevations

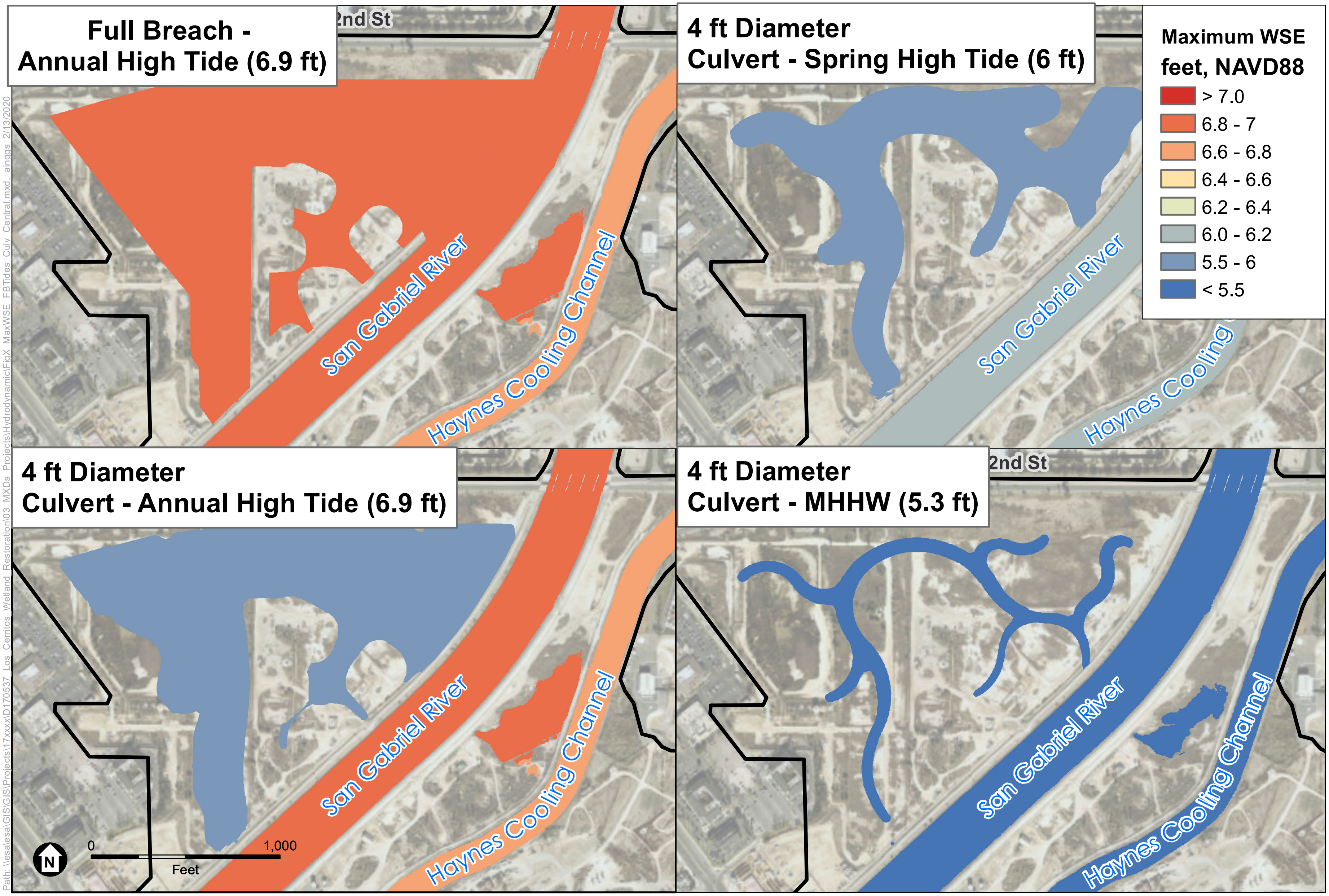
Additional analysis was conducted for the 4-foot diameter culvert scenario (with invert at 2 feet NAVD) to better understand how the scenario would function under different tidal conditions. Figure 3-13 shows the modeled inundation extent for the 4-foot diameter culvert during the annual high tide, a typical spring high tide, and at MHHW. The modeled inundation extent during the annual high tide is comparable to the full breach conditions (7.6 acres less, some of which is due to removal of the existing San Gabriel River levee), but the inundation during the spring high tide and MHHW tide show that inundation is limited to around the channel. This means that much of the site would not experience inundation except for a few times a year during more extreme tides, based on the currently proposed grading plan. However, areas that are inundated rarely, such as high marsh and transition zone habitat, are also valuable habitats.

3.2.2 100-Year Storm Event

South Area

Flooding Extent and Water Levels

During the 100-year storm event under existing conditions, water flows from the San Gabriel River through the leaky culvert, covers most of the South LCWA site, and flows into the Hellman Retained site (top panel of Figure 3-14). Due to the high elevations of the site, much of the area remains dry. The model shows water levels under the 100-year storm are approximately 1 foot above the tide levels (Table 3-1 compared to Table 3-3).



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

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Figure 3-13

Modeled Extent of Inundation during High Tide in the Central Area

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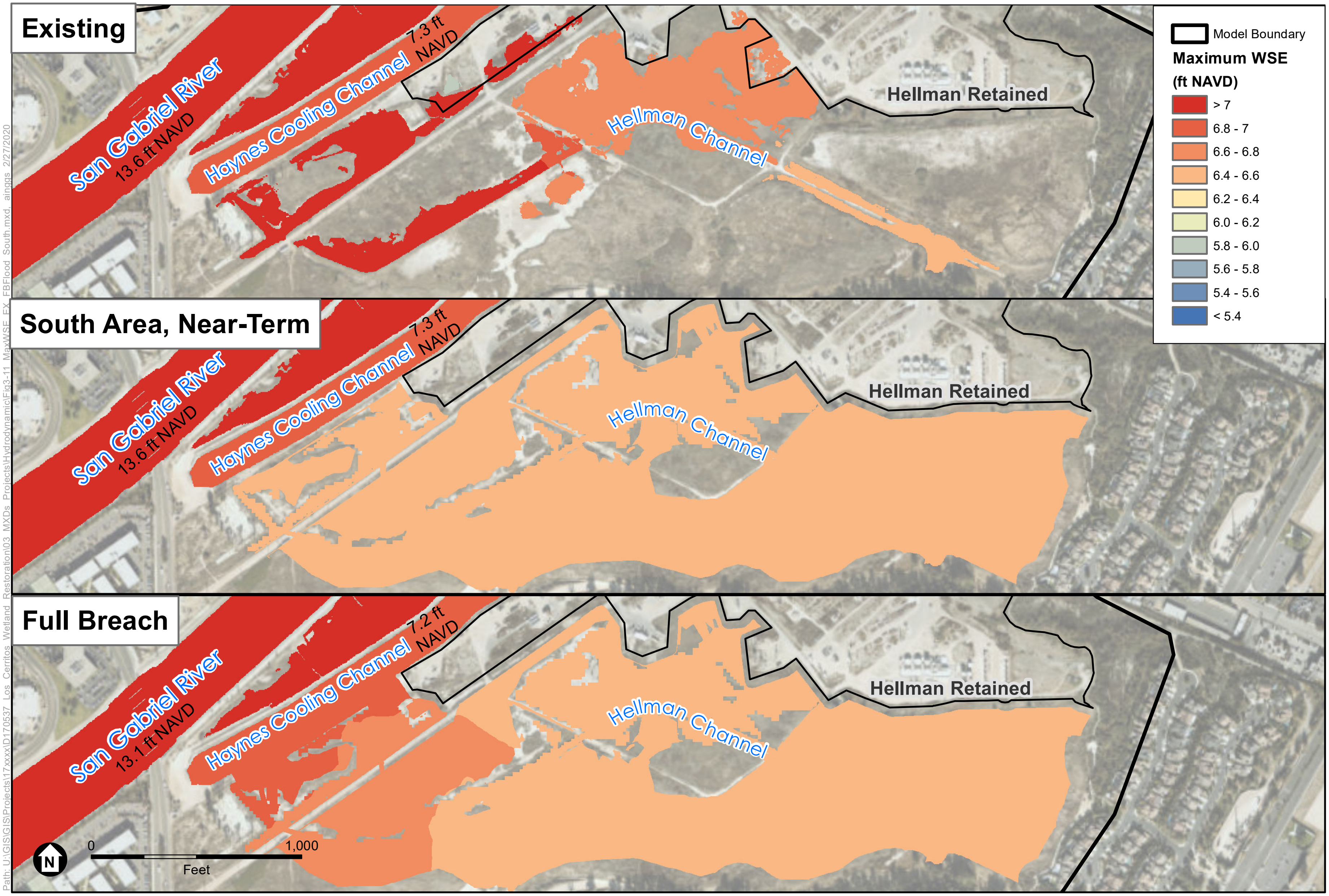

SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

ESA

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Figure 3-14

Modeled Water Levels during a 100-Year Storm Event in the South Area

Under the South Area, near-term conditions, the water levels in the site during the 100-year storm show a similar pattern to the tidal model results. Flooding is driven by the culvert connecting the South LCWA site to the San Gabriel River. With removal of the culverts in the middle of the marsh, the water levels across the site flatten out and there is less muting at the back of the marsh. However, since the culvert from the San Gabriel River still limits flow into the site, the model shows that water levels near the mouth of the Hellman Channel are lower under the South Area, near-term conditions than existing conditions, and the water level at the back of the marsh is the same as at the Hellman Channel mouth (Table 3-3). The model shows the flood extent in the South Area, near-term conditions decreases on the Hellman site due to the construction of the berm along the Hellman Retained site (Figure 3-14). However, the flood extent increases throughout the South LCWA site as intended by the design. The model shows water levels under the 100-year storm are approximately 0.7-0.8 feet above the tide levels.

TABLE 3-3
MODELED WATER LEVELS IN THE SOUTH AREA DURING THE 100-YEAR STORM EVENT

	Water Levels in Hellman Channel (feet NAVD)			
Scenario	**Mouth**	**South of 1st Street**	**Middle of Marsh**	**Back of Marsh**
Existing Conditions	7.3	7.0	6.6	6.5
South Area, Near-Term Conditions	6.5	6.5	6.5	6.5
Full Breach Conditions	6.8	6.7	6.5	6.4
Full Breach Conditions (coastal 100-year event)	8.6	8.6	8.6	8.6

Under the full breach conditions, the model results show that water levels near the mouth of the Hellman Channel are lower than under existing conditions, since the water is able to expand back into the marsh without the marsh culvert constrictions. Water levels under the full breach condition are approximately 0.2 feet higher than under the South Area, near-term conditions and are driven by the tides in the Haynes Cooling Channel (Table 3-2). This is because the tidal water levels in the Haynes Cooling Channel are still higher than the water levels in the site, so additional water flows from the channel and raises the water levels.

The model indicates that flooding in the full breach conditions is driven by coastal water levels (from Alamitos Bay and the Haynes Cooling Channel) rather than from riverine water levels from the San Gabriel River. As a result, the South Area was analyzed for a 100-year coastal water level event, because water levels would be higher under this condition (last row of Table 3-2). The model results showed that water levels would reach 8.6 feet in the site, which is 1.3 to 2.1 feet above the existing conditions water levels for the 100-year coastal water level event.

Hellman Berm Freeboard

Under existing conditions, flood waters flow onto the Hellman Retained site.

Under the South Area, near-term conditions and full breach conditions, flood levels along the Hellman Berm reach 6.5 feet NAVD (Table 3-4). This leaves 3.5 feet of freeboard to the berm crest (10 feet NAVD). During a 100-year coastal event, water levels in the South Area rise to 8.6 feet NAVD, which leaves 1.4 feet of freeboard on the berm.

TABLE 3-4
BERM FREEBOARD LEVELS IN THE SOUTH AREA DURING THE 100-YEAR EVENT

Scenario	Water level along the berm (feet NAVD)	Freeboard (feet)
Existing Conditions	—	—
South Area, Near-Term Conditions	6.5	3.5
Full Breach Conditions	6.5	3.5
Full Breach Conditions (coastal 100-year event)	8.6	1.4

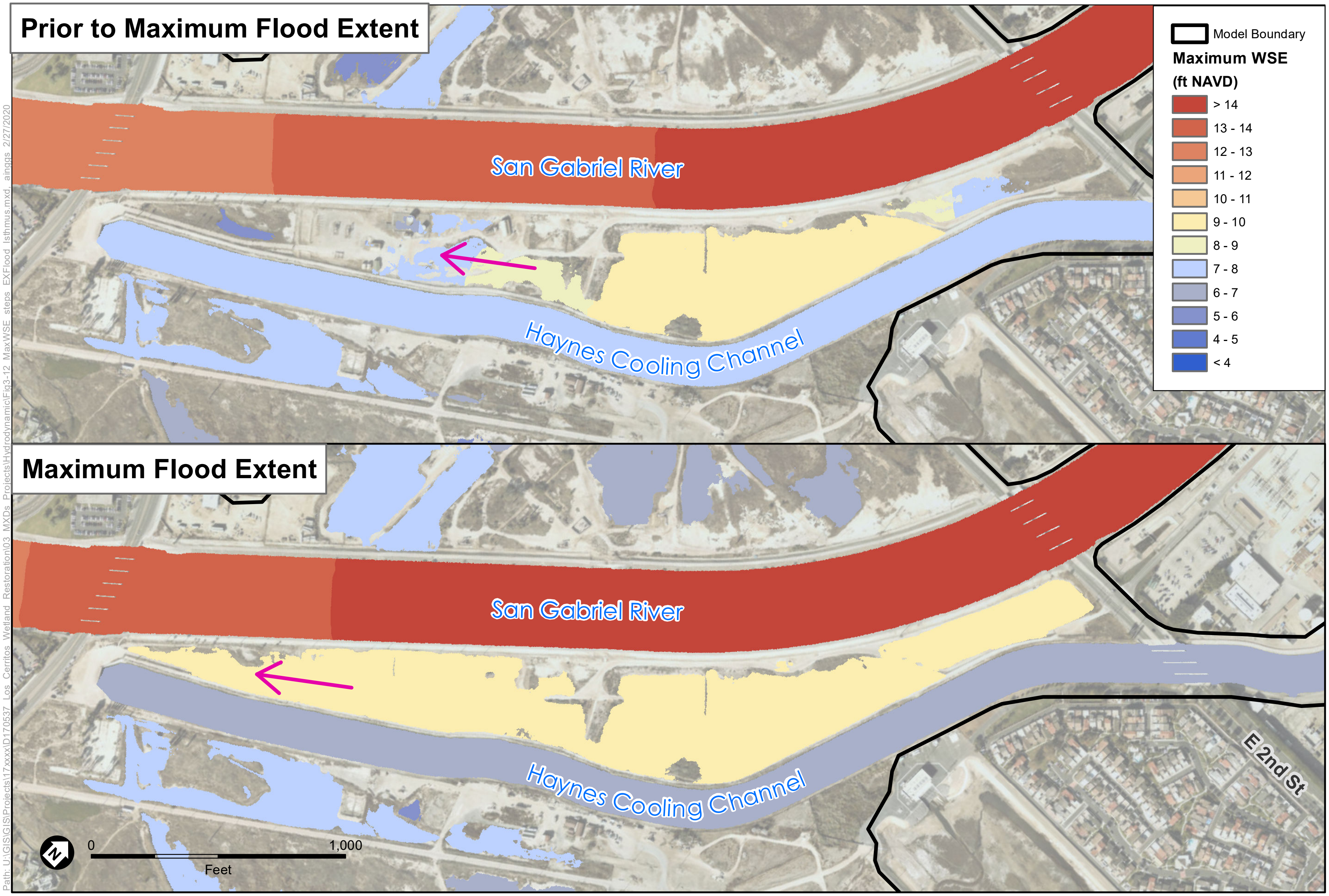
Isthmus Area

During the 100-year storm under existing conditions, the Zedler Marsh culvert allows in enough water to flood the majority of the Isthmus Area, except the DWP site (bottom panel of Figure 3-15). Flooding from the Callaway Marsh culvert does not extend beyond the Callaway Marsh site before waters from the Zedler Marsh reach the Callaway Marsh site (i.e., the Zedler Marsh culvert controls flooding of the Isthmus Area under existing conditions) (top panel of Figure 3-15). The maximum water level modeled during the 100-year storm was 9.3 feet NAVD across the site.

Under the full breach conditions, the model was initially run with the Callaway Marsh culvert gate removed. However, with no additional grading at the site, this resulted in flooding of the Isthmus LCWA property before waters from the Zedler Marsh culvert reached the Callaway Marsh site. The maximum water level modeled during the 100-year storm was 9.2 feet NAVD across the site (0.2 feet higher than existing conditions). This indicates that removing the Callaway Marsh culvert gate without additional grading could worsen flooding during smaller storm events during which the Zedler Marsh culvert does not flood the full site.

The model was rerun for the full breach scenario with the Callaway Marsh culvert gate in place. This resulted in no changes to the flooding in the Isthmus Area compared to existing conditions.

The Callaway Marsh culvert gate should not be completely removed. Further analysis and modeling would be required to develop a plan and design for modifying the culvert (e.g., the extent to which the culvert can be opened) and/or constructing a berm or other flood management measure around Callaway Marsh to avoid increasing flood levels.



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

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Figure 3-15

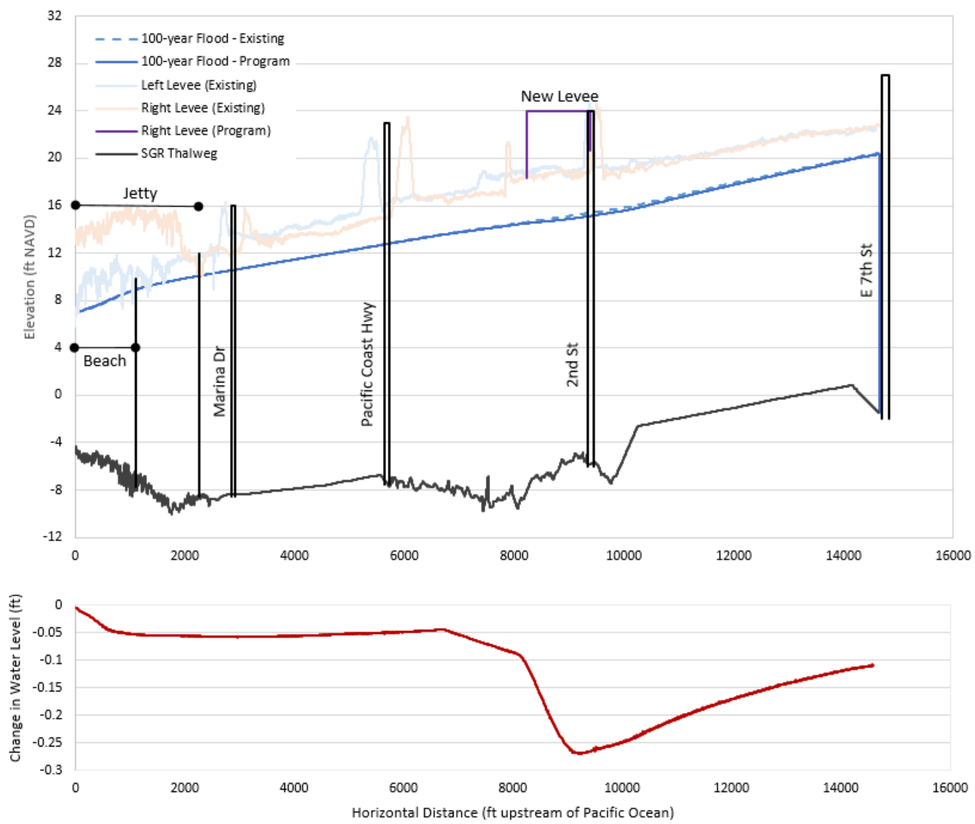
Modeled Water Levels during a 100-Year Storm Event in the Isthmus Area, Existing Conditions

ESA

San Gabriel River

During the 100-year storm event under existing conditions, flood levels are contained within the San Gabriel River channel with an average freeboard of 2-3 feet along the levees in the vicinity of the Central Area (Figure 3-16, Table 3-5). Flood levels do not reach the bridge decks during the 100-year storm. Downstream of Marina Drive but before the beach, the existing conditions model results show flood overtopping of the levee on the left bank levee (southeast side). Additionally, the model shows flood levels overtop the jetty that separates the San Gabriel River from Alamitos Bay under existing conditions. The model was also run without the inflow from the power plants upstream of 2nd Street. This reduced water levels slightly.

Under the full breach conditions, the model shows that water levels in the San Gabriel River upstream of the Central Area are reduced by up to 0.3 feet compared to existing conditions without inflow from the power plants during a 100-year flow event (Figure 3-16). In the vicinity of the Central Area, the model shows that water levels are reduced by 0.3 feet compared to existing conditions. Downstream of the Central and South Areas, the water levels in the channel are reduced by up to 0.2 feet compared to existing conditions. The reduction in water levels is likely due to the additional storage provided by the Central and South Areas.



SOURCE: ESA 2019

NOTE: SGR = San Gabriel River

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Figure 3-16
Modeled Water Levels during a 100-Year Storm Event along the San Gabriel River

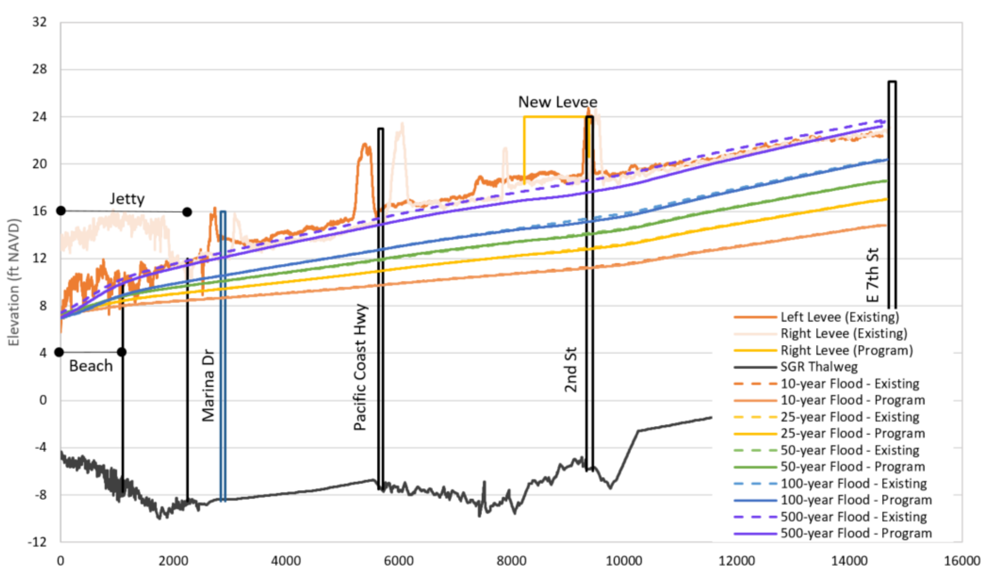
In addition to lowering water levels in the river, the restoration would also increase the levee height in the Central Area. The existing levee elevation is around 19 feet NAVD, and the conceptual design proposes constructing the new levees to 24 feet NAVD. The model results show this results in a levee freeboard of 9.4 feet in the Central Area. The height of the levee and the resulting freeboard is expected to be refined as part of future design phases.

TABLE 3-5
LEVEE FREEBOARD DURING THE 100-YEAR STORM EVENT

	Levee Freeboard in the Vicinity of the Central Area (feet)
Existing Conditions[1]	2 – 3
Program[2]	9.4

[1] Freeboard to existing levee
[2] Freeboard to proposed Perimeter Levee

Figure 3-17 shows the water surface profile model results for a range of peak flows representing the 10-, 25-, 50-, 100-, and 500-year events. These results show the sensitivity of the water surface profile to discharge rates as well as the consistent trend of slightly lower water levels under the program conditions. The results show that the program's effect on the water surface profile increase relative to existing conditions as discharge increases. For example, the model results show that the program reduces the 10-, 25-, and 50-year flood levels by up to 0.1 feet, but the 100-year flood level is reduced by up to 0.3 feet and the 500-year flood level is reduced by up to 1 foot. The 1-foot modeled reduction during the 500-year event is likely a significant benefit of the program. Further analysis could be performed to assess the potential reduction in flooding upstream and downstream of the program.



SOURCE: ESA 2019 Los Cerritos Wetlands Restoration Plan Program EIR Hydrodynamic Technical Report
NOTE: SGR = San Gabriel River

Figure 3-17
Modeled Water Levels during Varying Storm Event along the San Gabriel River

Central Area

Existing and Full Breach Conditions

The top panel of Figure 3-18 shows the modeled maximum water levels during the 100-year storm event in the Central Area for existing conditions. The water levels are muted by the perched culvert connection to the San Gabriel River, so flooding is minimal, although more extensive than under tidal conditions (top panel of Figure 3-7). Waters extend up towards 2nd Street near the intersection with Studebaker Road, but water levels are about 2 feet below the road elevation. The maximum water level during the 100-year storm in the Central Area is approximately 7.5 feet NAVD.

Under full breach conditions, the model shows the Central Area marsh floods to the edge of the proposed levee to a maximum flood elevation of 14.6 feet (bottom panel of Figure 3-18). This is roughly 7 feet higher than under existing conditions. However, construction of the Perimeter Levee as part of the restoration would provide increased flood protection for 2nd Street and Shopkeeper Road. As opposed to the 2 feet of freeboard from the flood waters to 2nd Street under existing conditions, the model shows the full breach conditions would provide approximately 9.4 feet of freeboard, a 7-foot increase above existing conditions (Table 3-6).

TABLE 3-6
FREEBOARD TO 2ND STREET DURING THE 100-YEAR STORM EVENT

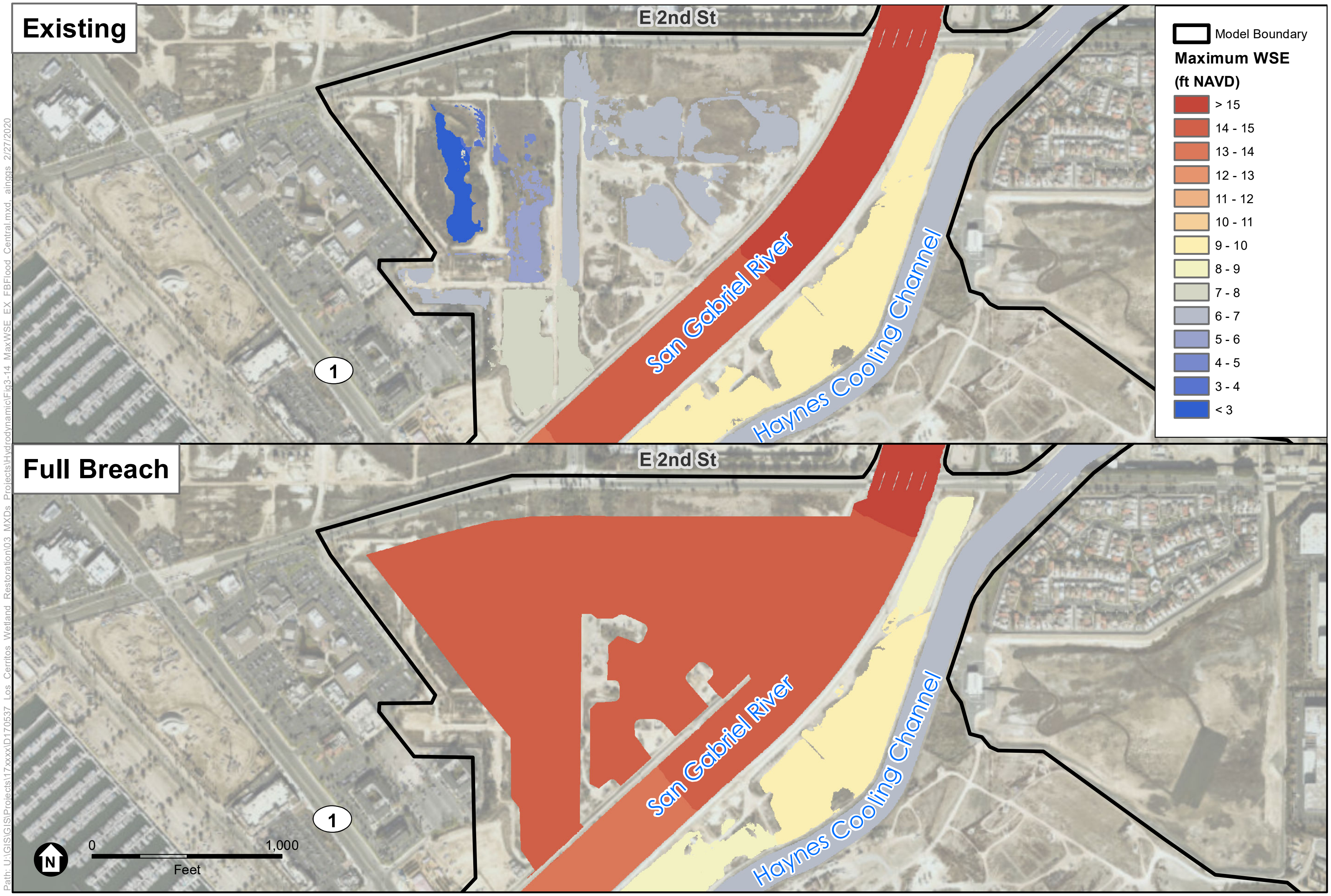
	Freeboard to 2nd Street (feet)
Existing Conditions[1]	2
Program[2]	9

[1] Freeboard to 2nd Street
[2] Freeboard to proposed Perimeter Levee

Under existing conditions, the Central Area provides flood storage for surrounding areas. With restoration, the new levee would limit drainage to the Central Area. The proposed design includes bioswales and a new freshwater marsh area to accommodate the offsite drainage. These features would be sized in the next phase of design and are not analyzed in this report.

Central Area, Culvert Conditions

Under Central Area, culvert conditions, the maximum water levels in the Central Area are muted by the culvert connections to the San Gabriel River. The maximum water level varies according to the culvert size and number of culverts, as shown in Table 3-7. With a 4-foot diameter culvert, the modeled maximum water level is 7.7 feet NAVD, providing approximately 16.3 feet of freeboard to the proposed Perimeter Levee. The model results show that increasing the size and number of culverts decreases the amount of freeboard to the proposed Perimeter Levee as seen below (Table 3-7).



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

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Figure 3-18

Modeled Water Levels during a 100-Year Storm Event in the Central Area

ESA

TABLE 3-7
FREEBOARD TO 2ND STREET DURING THE 100-YEAR STORM EVENT

	Maximum 100-year stormwater level (feet NAVD)	Freeboard to 2nd Street (feet)
Full Breach (for reference)	***14.4***	***9***
One 4-foot culvert[1]	7.7	16
Six 4-foot culverts	11.0	12
Nine 6-foot culverts	13.6	10
Nine 8-foot culverts	14.3	9

[1] For both culvert with invert of 2 feet and 0 feet NAVD

The culvert option to the full breach was analyzed to evaluate whether a culvert connection could provide a full tidal connection while limiting flood flows in the site. If the culvert option could provide lower flood levels, then the levee design could be refined to reduce the levee height and footprint. To maintain the same level of freeboard as the full breach scenario, the one 4-foot culvert scenario could reduce the proposed levees along 2nd Street and Shopkeeper Road by 7 feet. This would result in a reduction in the levee footprint based on the proposed design of up to 2.6 acres.

3.3 Future Conditions with Sea-Level Rise

3.3.1 South Area

The South Area, mid-term scenario is expected to be constructed in 10 – 20 years, or by 2040. The LCW sea-level rise scenarios assume 1.7 feet of sea-level rise occurs between 2040 and 2070. Therefore, the South Area, near-term scenario was not modeled for sea-level rise conditions, since it would occur before 2040, when sea-level rise is still less than 1.7 feet (based on the LCW sea-level rise scenarios).

Inundation Extent and Water Levels

Under existing conditions (i.e., no program scenario) with 1.7 feet of sea-level rise, the model shows water levels in the South LCWA site increase by roughly 0.5 feet compared to tidal conditions with no sea-level rise (Table 3-8). The annual water level in the South Area with 1.7 feet of sea-level rise is 6.6 feet NAVD around the mouth of Hellman Channel. The culvert from the San Gabriel River limits how much water can enter the site, so the water levels in the South LCWA site do not increase linearly with sea-level rise (i.e., water levels in the site are not 1.7 feet higher than under no sea-level rise) and do not inundate much of the marsh (middle panel of Figure 3-19).

With 3.3 feet of sea-level rise, the Hellman Retained site begins to inundate directly from the Haynes Cooling Channel and inundation from the South LCWA site increases and extends to the State Lands Parcel site (bottom panel of Figure 3-19). The annual water level in the South Area with 3.3 feet of sea-level rise is 8.8 feet NAVD (Table 3-8). Under an extreme tide level with 3.3 feet of sea-level rise, 1st Street would overtop and the entire South Area would be inundated.

Under the full breach conditions with 1.7 feet of sea-level rise, the model shows water levels in the South LCWA show about a foot of tidal muting from the front and back of the marsh (Table 3-8). The maximum water level in the South Area with 1.7 feet of sea-level rise is 8.2 feet NAVD around the mouth of Hellman Channel.

With 3.3 feet of sea-level rise, the model shows the Hellman Retained site begins to inundate directly from the Haynes Cooling Channel. However, the Hellman Berm continues to prevent water from the South LCWA site from flowing into the Hellman site. The annual water level in the South Area with 3.3 feet of sea-level rise is 9.6 feet NAVD (Table 3-8). The restoration includes raising the building pad on the State Lands Parcel site, so tidal inundation does not occur on this site under restored conditions.

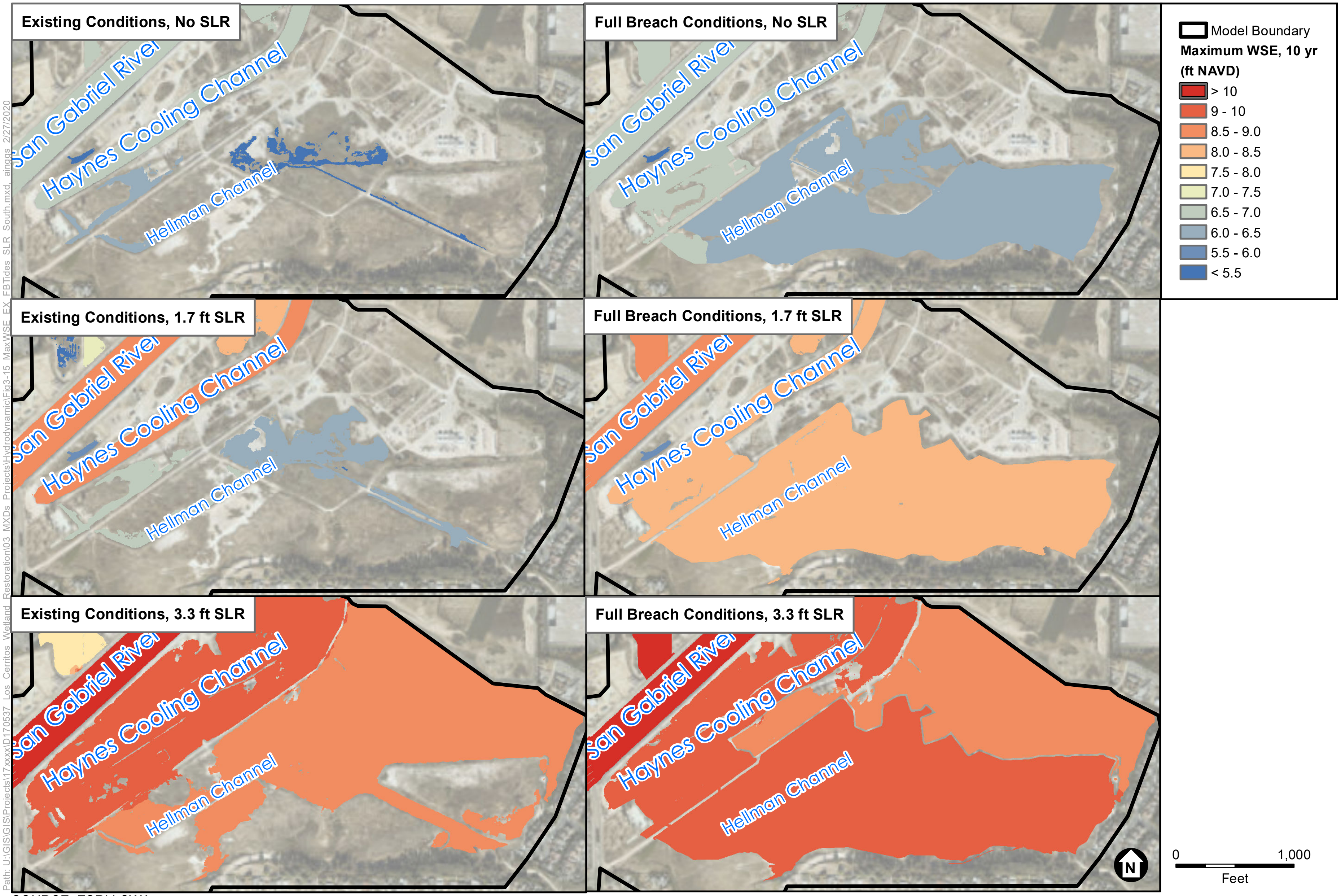
The model shows water levels in the Haynes Cooling Channel do not increase linearly with sea-level rise (Table 3-8). This indicates that the culverts from the Alamitos Bay Marina continue constraining the flow into the channel. With 3.3 feet of sea-level rise under program conditions, the water levels are about 0.5 feet below those in the San Gabriel River and open ocean.

TABLE 3-8
MODELED WATER LEVELS IN THE SOUTH AREA UNDER TYPICAL TIDES

	Water Levels in Hellman Channel (feet NAVD)				
Scenario	**Haynes Cooling Channel**	**Mouth**	**South of 1st Street**	**Middle of Marsh (between marsh culverts)**	**Back of Marsh**
Existing Conditions, no sea-level rise	6.8	6.2	6.2	5.5	5.4
Existing Conditions, 1.7 feet of sea-level rise	8.6	6.6	6.6	6.0	6.0
Existing Conditions, 3.3 feet of sea-level rise	9.8	9.6	8.8	8.8	8.8
Full Breach Conditions, no sea-level rise	6.7	6.7	6.6	6.3	6.2
Full Breach Conditions, 1.7 feet of sea-level rise	8.3	8.2	8.2	8.2	8.2
Full Breach Conditions, 3.3 feet of sea-level rise	9.7	9.7	9.6	9.6	9.6

Tide Range

At the back of the site, the model results show that the tide range with 1.7 feet of sea-level rise under existing conditions is 2.0 feet (from the bottom of the channel [4.0 feet NAVD] up to the annual high tide in the site [6.0 feet NAVD]). This is a 0.9-foot increase in tide range from the no sea-level rise scenario. The tide range under the full breach conditions is 6.2 feet, since the annual high tide increases with restoration and the bottom of the channel in program conditions is 2 feet NAVD. The model shows the program is expected to increase the tide range by 4.2 feet compared to existing conditions with 1.7 feet of sea-level rise.



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

SLR = Sea-Level Rise

ESA

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Figure 3-19

Modeled Extent of Inundation during an Annual High Tide in the South Area, with SLR

In the same analysis location, the model results show that the tide range with 3.3 feet of sea-level rise under existing conditions is 2.6 feet and the tide range under the full breach conditions is 7.7 feet.

3.3.2 Isthmus Area

Under existing conditions and project conditions, the model shows that the maximum tidal water level in Zedler Marsh with 1.7 feet of sea-level rise is 8.2 feet NAVD and the extents are confined to Zedler Marsh and Calloway Marsh within the Isthmus Area. With 1.7 feet of sea-level rise, water will reach the culverts under the access road and likely flow into the Isthmus Bryant site. However, data on these culverts was not included in the model.

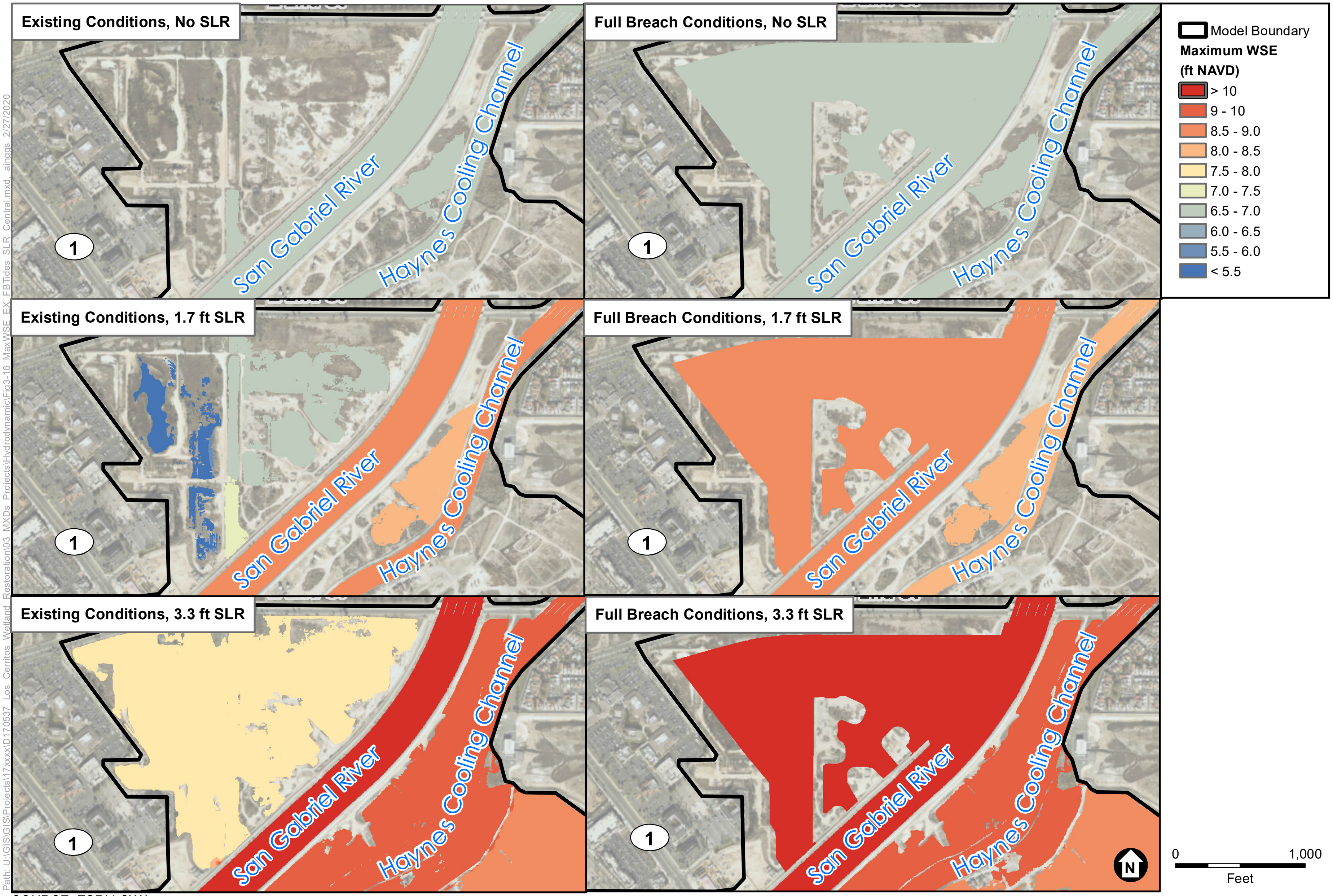
Under 3.3 feet of sea-level rise, Haynes Cooling Channel overtops its banks (9.5 feet NAVD on the Isthmus Area side) during the annual high tide and higher water levels (Figure 3-19). The model shows the maximum tide level is 9.8 feet NAVD under the no program conditions, which inundates the entire Isthmus Area (including the DWP site). The model shows the maximum tidal water level is 9.6 feet under the full breach conditions, since the restoration in the South Area lowers the water level in the Haynes Cooling Channel.

3.3.3 Central Area

Existing and Full Breach Conditions

The model results for existing conditions (i.e., no program conditions) show that the maximum water surface elevation in the Central Area with 1.7 feet of sea-level rise is approximately 7.4 feet and it increases to 7.8 feet with 3.3 feet of sea-level rise. As the water levels rise, the perched culvert becomes less perched, and water can flow into the site more frequently and for longer portions of the tidal cycle (Figure 3-20). Water levels in the site do not increase linearly with sea-level rise, due to the constraint of the culvert on flow to the site.

The model results for full breach conditions show that the maximum water surface elevation in the Central Area with 1.7 feet of sea-level rise is approximately 8.6 feet, and it increases to 10.2 feet with 3.3 feet of sea-level rise. This indicates that water levels in the Central Area are expected to increase linearly with sea-level rise (i.e., the increase in tidal water levels at the site is expected to be the same as the increase in sea-level rise).



SOURCE: ESRI,LCWA

NOTE: WSE = Water Surface Elevation

SLR = Sea-Level Rise

ESA

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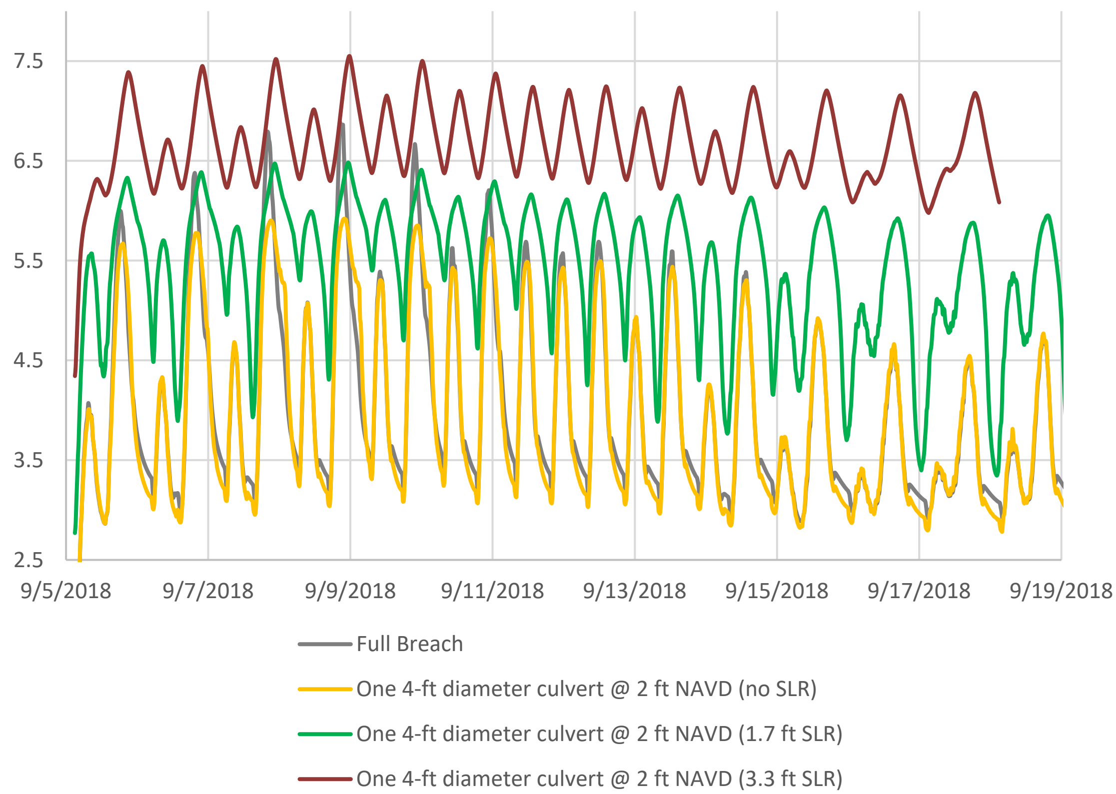
Figure 3-20

Modeled Extent of Inundation during an Annual High Tide in the Central Area, with SLR

Central Area, Culvert Conditions

The two sea-level rise scenarios were run for the 4-foot-diameter culvert configuration. The tidal range in the site narrows with sea-level rise, as the culvert limits drainage and the site stays ponded (Figure 3-21). With 1.7 feet of sea-level rise, the tide range drop to approximately 2 feet and with 3.3 feet of sea-level rise, it drops to 1 foot. With 3.3 feet of sea-level rise, the model results show that the marshplain is permanently inundated and does not drain at low tide.

It is expected that with the culvert set to a 0-feet-NAVD invert, rather than the 2-feet-NAVD invert modeled and presented in Figure 3-21, the low tides may drain lower with 1.7 feet of sea-level rise. However, as the tides continue to rise in the river to 3.3 feet of sea-level rise, it is expected that the tide range would be similar for the two culvert invert elevations, because the full culvert would be inundated for the majority of the time.



SOURCE: ESA 2019
NOTE: SLR = Sea-level rise

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Figure 3-21
Modeled Water Levels during a 100-Year Storm Event along the San Gabriel River

3.3.4 100-Year Storm Event with Sea-Level Rise

In the South Area, the 100-year coastal storm event with 3.3 feet of sea-level rise would reach 12.1 feet NAVD. This would overtop the berm along the Hellman Retained site, but the Hellman Retained site would flood from the Haynes Cooling Channel well before this point. Additional flood protection for the Hellman Retained site would be needed before 3.3 feet of sea-level rise occurs; if the oil operations are still present at this time and berm along the Haynes Cooling Channel is raised to increase flood protection, the berm along the property line between the South LCWA and Hellman Retained site could be raised as well.

In the Isthmus Area, flooding would be driven by the tides from the Haynes Cooling Channel with 3.3 feet of sea-level rise, which would inundate the full Isthmus Area. Water levels across the site would reach 10.0 feet NAVD.

In the Central Area, water levels under 3.3 feet of sea-level rise and with a 100-year storm would be greater for the program conditions compared to existing conditions due to the breach. The model shows water levels reach 15.7 feet NAVD during the storm. This still leaves 8.3 feet of freeboard along the Perimeter Levee. Note that the height of the levee and the resulting freeboard is expected to be refined as part of future phases of the design.

SECTION 4
Habitat Elevations

The salt marsh habitat zones can be defined for different areas based on the elevation of the area relative to tidal datums (i.e., as a surrogate for the frequency of tidal inundation). ESA calculated estimated habitat elevation ranges at LCW based on vegetation-inundation relationships measured at other reference sites and field measurements at Steam Shovel Slough, Zedler Marsh, and Hellman Retained site.

4.1 Existing Conditions and Verification

Inundation frequencies were determined for each habitat zone based on the CRP and literature values (ESA PWA 2015, James and Zedler 2000, Josselyn and Welchel 1999, Myers et. al 2017, Ward, Callaway, and Zedler 2003, Zedler 1982, and Zedler 2000). Table 4-1 presents the percent inundations and the corresponding elevations based on the NOAA Los Angeles gauge for fully tidal conditions, for reference. The M&N tide data in the Hellman Channel only measured water levels down to around 4 feet NAVD, which means lower water levels were missed. Instead of using this data to estimate the inundation frequency for the South Area, the existing conditions modeling results at the front of the marsh were used, since the results captured lower water levels. Since the model was calibrated to the M&N data, the results are representative of conditions on site.

The habitat elevations in Table 4-1 were compared to elevations of pickleweed and cordgrass at LCW taken during two survey dates in March and April 2018 for verification. At Steamshovel Slough, the average cordgrass elevation was 4.1 feet NAVD (with measurements ranging from 3.1 to 6.0 feet NAVD), which falls at the upper end of the low marsh category for fully tidal marsh. Drainage at Steamshovel Slough is muted, so the low marsh at Steamshovel Slough would be expected to be perched above the fully tidal low marsh habitat band. Average pickleweed elevation was measured to be 5.2 feet NAVD (with measurements ranging from 3.7 to 7.0 feet NAVD), which falls into the mid-marsh category.

At the Zedler and LCWA South properties, the average pickleweed elevations were 6.9 feet NAVD (6.0 to 8.6 feet NAVD range) and 7.5 feet NAVD (6.0 to 8.4 feet NAVD range), respectively, which are higher than the 10-year tidal water level. As a result, the upland and transition zone categories in Table 4-1 were shifted higher than would be indicated based on tidal inundation frequency alone to capture actual site conditions.

TABLE 4-1
ELEVATION BANDS AND INUNDATION FREQUENCIES OF DIFFERENT HABITAT TYPES UNDER EXISTING CONDITIONS FOR THE SOUTH AREA

	Fully Tidal (reference)		Muted Tidal (South Area)		
Habitat Type	**Elevation Bands (feet NAVD)**	**Inundation Frequency (% time)**	**Front of the Marsh Elevation Bands (feet NAVD)**	**Back of the Marsh Elevation Bands (feet NAVD)**	**Notes**
Upland	> 9.0	Based on field observations	> 8.5	> 8.5	Based on existing vegetation; 100-yr tidal inundation is approx. 7.0 feet NAVD at the front of the marsh and 6.5 feet NAVD at the back of the marsh
Transition Zone	7.1 to 9.0	0.05% to 10-yr inundation	6.9 to 8.5	6.1 to 8.5	Based on existing vegetation to 0.05% inundation frequency
High Marsh	5.7 to 7.1	0.05% to 4%	5.9 to 6.9	5.4 to 6.1	0.05% to 4% inundation frequency
Mid Marsh	4.3 to 5.7	4% to 20%	4.5 to 5.9	4.9 to 5.4	4% to 20% inundation frequency
Low Marsh	2.9 to 4.3	20% to 50%	3.1 to 4.5	4.85 to 4.93	20% to 50% inundation frequency
Mudflat	-1.8 to 2.9	50% to 99.99%	0 to 3.1	4.1 to 4.9	50% inundation frequency to culvert elevation
Subtidal	< -1.8	> 99.99%	< 0	< 4.1	culvert elevation

Additional field data collection at the site and at reference sites will be needed to further refine these habitat elevation estimates. Some additional factors to consider for the next phase of the design, include:

- Transition zone lower and upper elevation limits vary between systems and are dependent on topography (e.g., slope), tidal muting, and fluvial flooding frequency and depth.
- High marsh upper elevation limit can be highly variable and depends on topography (e.g., slope) and tidal muting.
- Mid marsh elevation limits are likely more consistent between natural marshes with different tidal connections/muting.
- Low marsh elevation limits are especially sensitive to distortions of low tides (e.g., invert elevations of culvert connections, distance from tidal connections, etc.). The low marsh elevation range is wider and extends lower where low tides are fully expressed (e.g., San Diego Bay, Anaheim Bay, Upper Newport Bay) and narrower where low tides are distorted (e.g., Carpinteria marsh, Tijuana estuary).
- Mudflat elevation limits are also sensitive to distortion of low tides (e.g., invert elevations of culvert connections, distance from tidal connections, etc.).
- Subtidal upper elevation limit is controlled by the invert elevation of the tidal connection (e.g., culvert invert or sill height). In a perfectly drained site, the invert elevation equals the subtidal upper elevation limit, but more likely, the elevation limit is up to a foot or higher than the invert elevation.

4.2 Program Conditions

To determine the habitat elevations for the post-restoration tidal conditions, water levels from the modeling analysis were used (Section 3). Table 4-2 shows the habitat elevation bands for the different restoration scenarios.

TABLE 4-2
ELEVATION BANDS AND INUNDATION FREQUENCIES OF DIFFERENT HABITAT TYPES UNDER PROGRAM CONDITIONS

Habitat Type	Central Area Full Breach Elevation Bands (feet NAVD)	South Area, Near-Term Elevation Bands (feet NAVD)	South Area, Full Breach Elevation Bands (feet NAVD)
Upland	> 9.0	> 8.5	> 8.5
Transition Zone	7.1 to 9.0	6.5 to 8.5	7.6 to 8.5
High Marsh	5.7 to 7.1	5.7 to 6.5	6.1 to 7.6
Mid Marsh	4.3 to 5.7	4.5 to 5.7	4.6 to 6.1
Low Marsh	2.9 to 4.3	3.8 to 4.5	3.7 to 4.6
Mudflat	-1.8 to 2.9	0 to 3.8	-0.2 to 3.7
Subtidal	< -1.8	< 0	< -0.2

As discussed in Section 3.2.1, the tide range in the South Area increases with restoration. This means that the habitat bands expand to a wider range of values. After restoration, the South Area continues to be perched above a fully tidal system due to muting of low tide drainage due to the channel system and the Haynes Cooling Channel culverts. The restored Central Area is expected to be a fully tidal system.

4.3 Sea-Level Rise Conditions

Future habitat elevations were estimated for 1.7 and 3.3 feet of sea-level rise. To determine the future habitat elevations for the Central Area, sea-level rise was applied to the habitat elevations shown in Table 4-2 (Tables 4-3 and 4-4), since the modeling results showed that water levels in the Central Area increased linearly with sea-level rise. For the future habitat elevations for the South Area, the sea-level rise modeling results were used to determine habitat elevations under muted conditions based on inundation frequency. The full breach scenario was used rather than the South Area, near-term scenario, based on the assumption that the mid-term restoration would be completed before 1.7 feet of sea-level rise has occurred.

TABLE 4-3
ELEVATION BANDS AND INUNDATION FREQUENCIES OF DIFFERENT HABITAT TYPES UNDER 1.7 FEET OF SEA-LEVEL RISE

Habitat Type	Central Area Full Breach Elevation Bands (feet NAVD)	South Area, Full Breach Elevation Bands (feet NAVD)
Upland	> 10.7	>10.2
Transition Zone	8.8 to 10.7	9.2 to 10.2
High Marsh	7.4 to 8.8	7.6 to 9.2
Mid Marsh	6.0 to 7.4	6.1 to 7.6
Low Marsh	4.6 to 6.0	5.6 to 6.1
Mudflat	-0.1 to 4.6	-1.5 to 5.6
Subtidal	< -0.1	< 1.5

TABLE 4-4
ELEVATION BANDS AND INUNDATION FREQUENCIES OF DIFFERENT HABITAT TYPES UNDER 3.3 FEET OF SEA- LEVEL RISE

Habitat Type	Central Area Full Breach Elevation Bands (feet NAVD)	South Area, Full Breach Elevation Bands (feet NAVD)
Upland	> 12.3	>11.8
Transition Zone	10.4 to 12.3	10.4 to 11.8
High Marsh	9.0 to 10.4	9.1 to 10.4
Mid Marsh	7.6 to 9.0	7.5 to 9.1
Low Marsh	6.2 to 7.6	6.5 to 7.5
Mudflat	1.5 to 6.2	3.1 to 6.5
Subtidal	< 1.5	< 3.1

With 1.7 feet of sea-level rise, the habitats in the South Area are still perched, but the existing habitats would be inundated more frequently than under no sea-level rise conditions. With 3.3 feet of sea-level rise, only the lower habitats are perched (low marsh and mid marsh) and high marsh and transition zone habitat are at elevations similar to fully tidal areas.

These habitat elevation bands will inform the next phase of design work, which is expected to include a more detailed grading plan.

SECTION 5
Conclusions

The goals of the hydrodynamic modeling for this project are two-fold:

1. Evaluate potential flood impacts to inform the restoration design, the CEQA analysis, and permitting.
2. Evaluate restored wetland hydrology and inform the habitat elevations for the restoration design for post-restoration and future conditions with sea-level rise.

The following discussion summarizes the modeling results as they apply to the study goals.

5.1 Potential Flood Impacts

Table 5-1 graphically summarizes the differences between existing conditions and program conditions by area and scenario. The modeling results show the program could potentially result in two environmental impacts without mitigation.

The first potential impact is that the model results show that the water levels in the South LCWA site during the near-term restoration would be 0.1 feet lower than under existing conditions in the west side of the marsh during an annual tide and up to 0.5 feet lower during more extreme tides. This could impact existing habitats by reducing the tidal inundation to areas of established vegetation. However, during the more frequent tides, this difference in water levels would be negligible and it is likely that existing vegetation would be able to accommodate the difference.

The second potential impact is that the model results show that removing the gate on the Callaway Marsh culvert would result in increased flooding of the Isthmus LCWA site during storm and sea-level rise conditions (see Section 3.3.2 for further discussion). Since the Isthmus LCWA site is an active oil field, increased flooding would impact operations at the site. This potential impact could be addressed by building a berm along the edge of Callaway Marsh, leaving the gate in place, or replacing the gate with new gate that would enhance tidal inundation, but avoid increased flooding.

Further design of the program areas can address both of these potential flood impacts.

TABLE 5-1
LCW RESTORATION IMPACTS ON WATER LEVELS COMPARED TO EXISTING CONDITIONS

		South Area			Isthmus Area					San Gabriel River	Central Area
		State Lands Parcel	South LCWA	Hellman Retained	Callaway Marsh	Isthmus LCWA	Zedler Marsh	Isthmus Bryant	DWP	All	All
Extreme High Tide	South Area, Near-Term	○	⬆ (green) ⬇ (red)	○	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
	Full Breach	○	⬆ (green)	○	⬆ (green)	○	◒	○	○	◒	⬆ (green)
100-Year Storm Event	South Area, Near-Term	○	⬇ (green)	⬇ (green)	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
	Full Breach	○	⬆ (green)	⬇ (green)	⬆ (green)	⬆ (red)	◒	◒	○	⬇ (green)	⬆ (green)
Extreme High Tide with 1.7 ft of Sea-Level Rise	Full Breach	○	⬆ (green)	⬇ (green)	⬆ (green)	⬆ (red)	◒	○	○	◒	⬆ (green)
Extreme High Tide with 3.3 ft of Sea-Level Rise	Full Breach	⬇ (green)	⬇ (green)	⬇ (green)	⬆ (green)	⬆ (red)	⬇ (green)	⬇ (green)	⬇ (green)	◒	⬆ (green)
100-Year Storm Event with 3.3 ft of Sea-Level Rise	Full Breach	⬇ (green)	⬇ (green)	⬇ (green)	⬆ (green)	⬆ (red)	⬇ (green)	⬇ (green)	⬇ (green)	⬇ (green)	⬆ (green)

○ No flooding under existing or program conditions

◒ No changes between existing and program conditions

⬆ (green) Water levels increase with the program, no impacts

⬇ (green) Water levels decrease with the program, no impacts

⬆ (red) Water levels increase with the program, and could result in impacts

⬇ (red) Water levels decrease with the program, and could result in impacts

5.2 Restoration Design

The modeling results provide insight for future iterations of the design. Future phases of the design should consider the following, in addition to the items identified in Section 5.1:

- **A refined design for the Hellman Channel under 1st Street in the South Area.** The model results showed that increasing the existing two 3-foot culverts to two 6-foot culverts or four 4-foot culverts still resulted in tides muted up to 0.5 feet south of the road. With an open channel, (assuming a bridge would be installed over the channel), the model showed that high tide would be muted by around 0.1 feet south of the road. The design of the open channel should be refined using hydraulic geometry relationships and/or modeling to size the channel to appropriately convey the tidal prism through the site.
- **The limitations of the Haynes Cooling Channel culverts.** The model results showed that the restoration in the South Area creates a large enough tidal prism to result in muted tides through Haynes Cooling Channel culverts. Water levels in the Haynes Cooling Channel were muted by 0.1 feet under current conditions (i.e., no sea-level rise) and up to 0.3 feet with 3.3 feet of sea-level rise.
- **The limitations of the culvert option for the Central Area.** The model results show that a culvert option in the Central Area could not achieve both a fully tidal system and a reduced flood level during the 100-year event. The culvert configurations that were closest to achieving a full tide range during an annual high tide were also big enough that water levels in the site during a 100-year storm were nearly identical to the water levels under the full breach scenario. Smaller culvert configurations, such as one 4-foot-diameter culvert, could allow for a smaller levee system (7 feet lower than the levee needed for the full breach condition), but would result in less regular inundation across the marshplain and substantially less resilience with sea-level rise. An intermediate culvert configuration with six 4-foot-diameter culverts reduces 100-year storm water levels by about 3 feet and result in a 3-foot tide range, compared to a 4-foot tide range modeled for a full breach.

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