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Avila Beach

Sea-Level Rise Vulnerability Assessment

PORT SAN LUIS HARBOR DISTRICT

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Glossary

ASCE	American Society of Civil Engineers
CSLC	California State Lands Commission
GHG	Greenhouse Gas {emissions}
M&N	Moffatt & Nichol
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OCOF	Our Coast Our Future
OPC	Ocean Protection Council
ROM	Rough Order of Magnitude
SAFRR	Science Application for Risk Reduction
SLO	San Luis Obispo
SLR	Sea-Level Rise
USACE	United Stated Army Corps of Engineers
USGS	United Stated Geological Survey

Executive Summary

The purpose of this study is to meet the requirements of AB 691 which requires trustees of granted state lands to assess impacts from Sea Level Rise (SLR) to their facilities. As trustee, the mission of the Port San Luis Harbor District (District) is to develop a harbor that meets the needs of the people of California. The study was performed in accordance with best available science as set forth by the Ocean Protection Council (OPC 2018) considering the Medium-High Risk Aversion (1 in 200 chance of exceedance) that projects up to 6.7 ft of SLR by 2100. In conjunction with SLR, effects due to storm events (wind, wave and runoff) and tsunami waves were studied and results summarized below.

Presently the District shoreline, and adjacent areas, are subject to fluvial (creek runoff) and coastal (wave and storm surge) flooding during large ("100 year") storm events. Flooding from San Luis Obispo Creek has potential impacts to the community of Avila Beach. Coastal flooding affects the entire shoreline during storms with high tides. This flooding will increase with SLR.

The District shoreline could be significantly impacted by tsunami hazards in worst-case scenarios (CalEMA "1,000 year" planning scenario) that could produce wave run-up to elevation 42 to 49 feet NAVD88. In such a scenario, all public beach areas would be inundated as would District facilities and Harford Pier and Avila Pier. Run-up would flow into San Luis Obispo Creek, flood portions of low-lying valleys at the coast, primarily Wild Cherry Canyon and Harford Canyon, impact Avila Beach Drive and have limited impact to Diablo Canyon Road The duration of inundation is estimated to be on the order of 20 to 30 minutes each wave cycle (about every hour) and last for up to 24 hours during which the area would be evacuated. The estimated warning time is 5 hours during which tsunami alerts would be issued and evacuation procedures initiated. SLR will increase tsunami run-up elevations by the amount of SLR, but not ameliorate nor exacerbate the run-up.

Key Findings:

1. SLR will impact District beaches:
   - Olde Port Beach by 2050.
   - Avila Beach and Fisherman's Beach by 2100.
   - Sea-Level Rise and storm wave damage estimated at $5.5M by 2100.
   - Aggregate non-market losses are estimated at $39M to $43M by 2100.
   - Potential mitigation involves utilizing dredged material from the harbor.

2. Limited habitat on the lower San Luis Obispo Creek could be impacted by sea-level rise.
   - Aggregate non-market losses are estimated as $254k by 2100.
3. District upland facilities are at low risk of being impacted by SLR.
   - Shoreline parking at Harford Pier may have overtopping and shallow flooding.
4. The primary recommended adaption and mitigation measures are:
   - Design new facilities to be resilient to sea-level rise.
   - Follow existing, or develop new standards requiring floodproof materials in new construction and repair of existing infrastructure.
   - Identify public assets at risk of flooding that serve transit dependent users.

1. Introduction

The Port San Luis Harbor District (District), located on the Central California Coast in San Luis Obispo County, is a major center for commercial, recreational and industrial activities.

The coast of which 8,400 acres of State tidelands is under the control of the District, represents a fascinating interaction between land, water, and human enterprise.

1.1. Historical Background

1.1.1. Formation of the Harbor District

Since the Port's development in the late 1800s, the harbor has served a critical function in the economy and in the identity of San Luis Obispo County.

The importance of the harbor was recognized by the local community in 1953 by voting for the formation of the District. At that time, the District served purely commercial harbor functions, which were enterprise in nature. Commercial fishing, agricultural exports and a marine oil terminal were the primary cargoes transferred at the harbor. At the time, these functions provided much of the funding required for the District to operate through the collection of wharfage and rental income. Uses of the harbor included: (3) commercial piers, commercial fishing, recreational boating, marine repairs, and the wholesale processing of fresh fish, including abalone processing.

The State Legislature gave impetus to the development of the harbor in 1954 by approving the local vote and formation of the District and in 1955 by granting to the District those state-owned tidelands encompassing San Luis Obispo Bay.

Harbor Districts are formed to improve and develop the harbor including dredging, ship ways, berths, anchorage and turning basins, the construction of jetties, breakwaters, bulkheads, seawalls, wharves, ferry slips, warehouses, roads and spurs tracks or shortline railroads.

1.2. State of California Granted Lands

1.2.1. Use of the Tidelands

The tidelands granted in 1955 (and amended in 1957) to the District by the State of California, were mandated "to be used for harbor, aviation, wharves, docks, piers, slips, quays, and other structures." The land was also "to be used for establishment of public buildings, parks, playgrounds, public recreation, public fishing, and public access and public navigation".

The State tidelands grant mandates specific functions that the District must guarantee for public use. The grant mandates that the District provide "facilities and appliances necessary or convenient for the promotion and accommodation of commerce and commercial as well as recreational navigation by air and by water". It also mandates that "the State of California shall have at all times the right to use, without charge, all wharves, docks, piers, slips, quays or any other improvements and facilities constructed on said lands".

1.2.1.1. Original Purpose

The original intent of the District to obtain the State Tidelands Grant was to develop a public harbor to meet the needs of the people of the state. The tidelands grant was based on this objective and mandated that the District also provide recreational and visitor-serving uses within the granted lands. The Harbor District, while complying with the State Lands Commission's directive, has recognized the need to provide additional non-enterprise services to ensure the enjoyment, safety, and access of the State granted lands.

1.2.1.2. Current Function

Since the formation of the District, Port San Luis has taken on additional functions beyond harbor enterprise (oil industry and commercial fishing) functions. As a result of the California Coastal Act of 1976, the District has been required to provide non-enterprise coastal-dependent visitor-serving and recreational uses. The Coastal Act Section 30701 also declares that the Ports of the State of California constitutes one of the State's primary economic and coastal resources and are an essential element of the national maritime (including recreational) industries.

Recreational activities include public beaches, public piers, swimming, fishing, the historic coastal lighthouse, hiking, recreational vehicle camping, and special events.

District facilities offered for coastal use and boating include parking areas, a small craft harbor, a mooring field with approximately 162 moorings, a boat haul out and repair yard, boat and gear storage, a water taxi service, marine diesel and ice facility, small boat launch and skiff racks, bait and tackle, and bilge pump out.

Commercial activities hosted by the District include: three restaurants, charter boat services, surf instruction, paddleboard and kayak rentals, beach equipment rentals, fresh and live fish markets, and commercial fishing.

1.2.2. Avila State Beach & Pier

In 1984, the State and County gave the Avila State Beach and Pier properties to the Harbor District. Avila Beach is the most popular beach in San Luis Obispo County, and contains many amenities and services that the Harbor District provides to the public. These include public restrooms, maintenance of beach/buildings, maintenance of the 1,630-foot Avila Pier, utility costs, lifeguard and security services.

1.2.3. Harford Pier

Harford Pier is the working pier of Port San Luis and is 1,424-feet in length. It hosts various businesses and is the main hub of commercial fishing for the port. As there are no slips or docks in the port, it is the only facility where fishermen can load and offload goods and materials. Originally built in 1873, it has been identified as eligible for national historic structure status by the California State Historic Preservation Office. As a result, it has required the Harbor District to preserve and maintain the pier, which serves a major commercial and recreational fishing function. It is the only pier in the County which can be driven on by the public.

1.2.4. Cal Poly Pier

The Cal Poly Pier is a 3rd pier located in the harbor and within the Tidelands. The Harbor District does not own this facility but leases the footprint to Cal Poly and has permitting jurisdiction.

1.2.5. Mooring Field

The area of San Luis Obispo Bay west of the Harford Pier and between the Harford Pier and the Cal Poly Pier is utilized as a mooring field for recreational boaters. The mooring field encompasses approximately 162 moorings for commercial vessels, sportfishing, power boats, sailboats, and visiting vessels. The mooring field and anchorages can accommodate vessels up to 55 feet in length, and with a vessel-dedicated anchorage boats over 55 feet. A portion of the mooring field along Fisherman's Beach and the Olde Port Beach is dedicated to seasonal rentals from April 1st through October 31st for boats up to 35 feet.

1.2.6. Coastal Access

The District provides coastal access facilities within the Avila Beach and Port San Luis areas by making improvements to piers, boat launching facilities, public restrooms, and handicap access facilities. The District has also assisted in providing public access to the Pecho Coast and historic Point San Luis Lighthouse. The Harbor District has recently undertaken the development of the Harbor Terrace site to greatly expand camping opportunities.

The District wishes to continue to provide coastal access in compliance with California Coastal Act Section 30212. Tax revenues for the Harbor District fund many non-enterprise public programs. These tax-funded improvements are essential in maintaining and enhancing the community's use of the public facilities at Port San Luis.

1.2.7. Current District Functions

Although Port San Luis once performed pure harbor enterprise functions, it now has expanded to provide many public-serving (non-enterprise) activities. Current uses of the Harbor now include:

- Public fishing
- Unrestricted navigation
- Public beaches
- Two public/commercial piers
- Boat launching facilities
- Boat moorings
- Boat and engine services
- Sailing and charter boat services
- Public restrooms
- Beach concessions
- Surfing and swimming
- Hiking Trails
- Aquaculture
- Lighthouse Tours
- Coastal access
- Public parking
- Commercial fishing
- Land storage of boats and gear
- Camping
- Laundry and shower facilities
- Wildlife Viewing
- Kayaking and stand up paddle boarding
- Transient boater services
- Restaurants
- Fresh and live fish
- Fuel and ice facility
- Boat yard repair facilities
- Public Safety: Harbor Patrol/Lifeguards

Special events that can be accommodated at District facilities include weddings, family reunions, fundraisers, commercial events, boat races, swim races, an organized run, bike races, tournaments, derbies, and organized beach clean-up.

District areas and facilities available to host special events include Avila Beach east of the Avila Pier, Avila Beach west of the Avila Pier, the Olde Port Beach, Fisherman's Beach, and the Coastal Gateway Multi-Purpose Room.

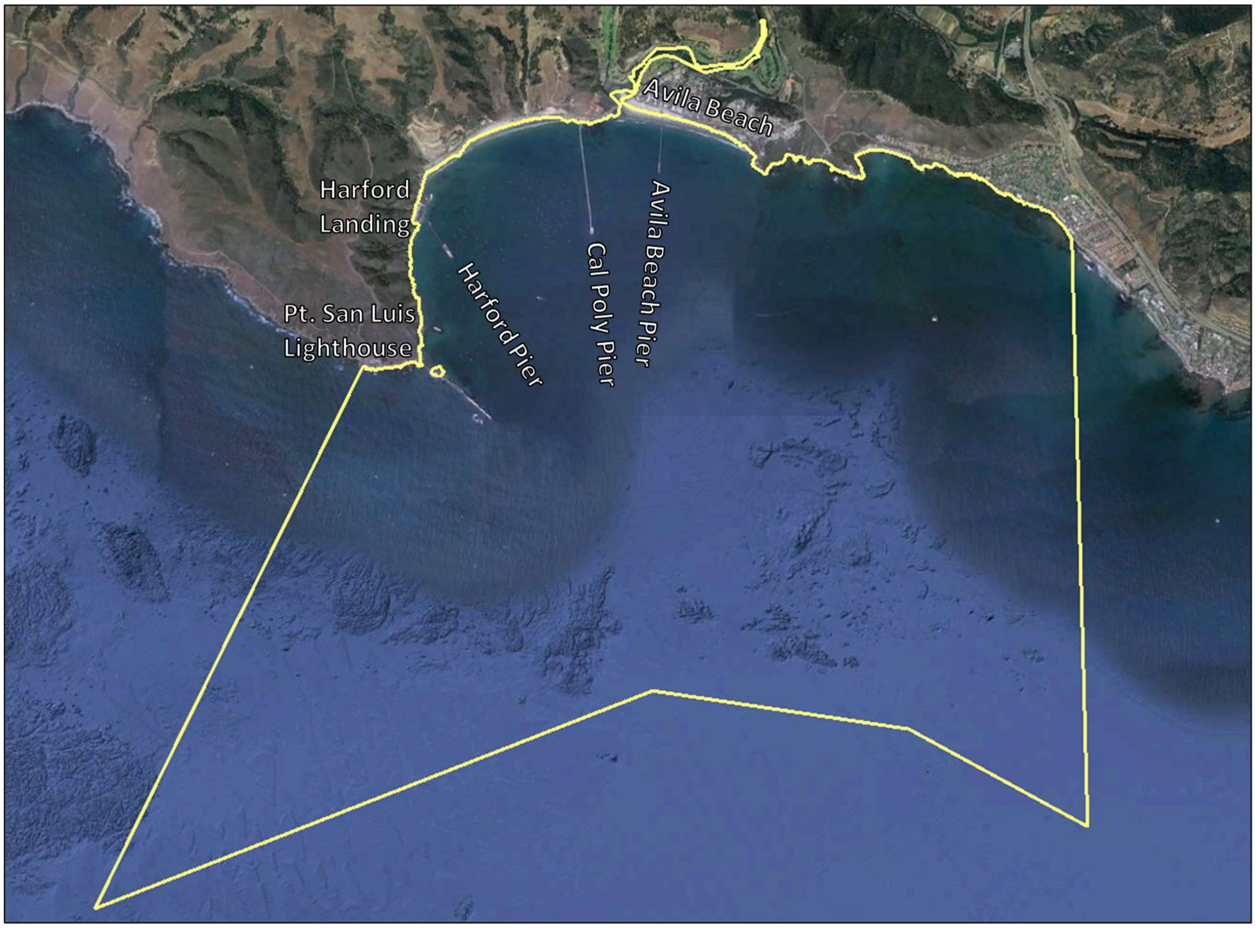

Figure 1-1: Port San Luis State Grant Area Boundary.

1.3. Scope of Work

The present report is a complete sea-level rise (SLR) vulnerability assessment for Port San Luis, as required in response to Assembly Bill 691.

AB 691 requires trustees to assess sea-level rise impacts to granted lands. First, they must inventory vulnerable natural and built resources and facilities. Then, they must consider the impacts of sea-level rise and related coastal processes that are projected to be exacerbated by sea-level rise such as coastal erosion on the vulnerable assets identified.

The sea-level rise projection adopted for this analysis is the California Ocean Protection Council, *OPC (2018),* medium to high risk aversion, high emissions scenario, which projects 0.7 feet of sea-level rise by 2030, 1.8 feet by 2050, and 6.7 feet by 2100.

The vulnerability assessment covers the State Grant Area delineated on the California State Lands Commission (CSLC) grant plat, which includes the sovereign tidelands and submerged lands of Port San Luis. The boundary of the State Grant Area is indicated by the yellow outline in Figure 1-1.

The AB 691 Assessment includes:

1. Assessment of Impacts of Sea-Level Rise
    - Impacts of storms and extreme climatic events, changing shorelines, and trends in relative local sea level on vulnerable natural and built resources and facilities, including public trust resources and values such as public access, commerce, recreation, coastal habitats, and navigability.
2. Maps of 2030, 2050, and 2100 impacts.
3. Estimate of financial costs to address the impacts of sea-level rise.
    - Replacement or repair costs of resources and facilities that could be impacted by sea-level rise, and non-market values of recreation and ecosystem services, and public trust resources that could be impacted by sea-level rise.
    - Anticipated costs of 2030, 2050, and 2100 sea-level rise adaptation/mitigation measures, and potential benefits of such strategies and structures.
4. Description of how trustee proposes to protect and preserve resources and structures that would be impacted by sea-level rise.
    - Proposed mitigation/adaptation measures, timeframe for implementation, plans to monitor impacts of sea-level rise, and regional partnerships that address sea-level rise vulnerability or increase resiliency.

2. Assessment of Impacts of Sea-Level Rise

Sources of flood hazards at Port San Luis include San Luis Obispo Creek (fluvial flooding), the Pacific Ocean (coastal flooding), and tsunamis generated by large submarine earthquakes along the Pacific Rim.

The primary impact area associated with flooding from San Luis Obispo Creek is the low-lying portion of the City of Avila Beach along the lagoon at the mouth of the creek. This portion of the city is protected by a levee along Avila Beach Drive and a seawall along Avila Beach.

Coastal flooding and tsunamis have the potential to impact the majority of the region. The central California coastline is exposed to waves generated by winter and summer storms originating in the Pacific Ocean. It is not uncommon for these storms to cause 15-foot breakers. The occurrence of such storm events in combination with high astronomical tides, El Niño effects, and strong winds can cause significant wave runup and allow storm waves to reach higher-than-normal elevations along the coastline. High coastal water levels also have the potential to affect runoff from San Luis Obispo Creek (backwater effect). The Port San Luis Breakwater was constructed to reduce wave action at Port San Luis and Avila Beach and enhance the commercial harbor function.

Tsunamis are associated with large submarine earthquakes along the Pacific Rim and are relatively rare. While devastating tsunamis have occurred in recent times and are documented in the historical record, no major tsunami impact have been documented at Port San Luis.

2.1. Land Use

Table 2-1 and Table 2-2 list natural and built resources and District facilities. Locations of the respective facilities and resources are shown on the Area Map, Appendix A, Plate 1.

These facilities and resources are potentially vulnerable to one or more of the following Sea-Level Rise related hazards that could impact them directly or indirectly:

- Sea-Level Rise, causing dry land and intertidal areas to become permanently submerged.
- Rising tides, which encroach on low-lying land areas and increase the frequency and duration of flooding.
- Erosion, which encroaches on shorelines and land areas.
- Storm events and associated wave impacts encroaching on low-lying areas.

Table 2-1: Inventory of District Facilities and Assets

#	Facility
1	Harbor District Facilities: Harbor District Main Office (Parsons Building), Maintenance Shop and auxiliary buildings, Coastal Gateway Building, Trailer Boat Launch Building, PSL Boatyard Office, Harford Pier Canopy and Buildings, Harbor Patrol Office, Lifeguard HQ, Boat/Gear Storage, Public Showers and Restrooms, Lighthouse, Lift Station Buildings.
2	Mobile Hoist Pier and Boat Lift, Olde Port Beach Public Boat Launch, Trailer Boat Sport Launch & Fueling Dock, and Harford Pier Davit Hoists.
3	Harford Landing Parking Lot, Avila Beach Parking Lot, Woodyard RV Camping Parking, Nobi Point RV Camping Parking, and Coastal Gateway RV Camping Parking.
4	Piers: Harford Pier and Avila Beach Pier.
5	Dredge and Disposal areas.
6	Harford Landing Jetty and Revetment.

The dredge and disposal parcels leased to the District enable the District to dredge up to 250,000 cubic yards of material annually to maintain navigable depths, and to utilize the dredged material for beach replenishment on granted lands.

Table 2-2: Inventory of Vulnerable Natural Resources

#	Resource
1	Beach Areas, including: Fisherman's Beach, Olde Port Beach, Avila Beach, West Bluff Beach, Pirate's Cove, Coast Guard Beach.
2	San Luis Obispo Creek.
3	Bob Jones Trail, Lighthouse Trail (part of the Pecho Coast Trail).

2.2. Public Access

The primary public recreation areas at Port San Luis are the coastal and beach areas, and the two piers Harford Pier and the Avila Beach Pier. The primary means of access to these areas is via Avila Beach Drive and Front Street along Avila Beach. A number of coastal trails exist atop the bluffs.

Refer to the following appendices for popular activities around the Port, adopted from *EAB (2017)*:

- Harford Landing: Appendix B, Plate 1.
- Avila Beach Drive: Appendix C, Plate 1.
- Avila Beach: Appendix D, Plate 1.

2.3. Habitat

The portion of the lower San Luis Obispo Creek granted to the district extends from the mouth of the lagoon at Avila Beach upstream past the golf course. Habitat within this area has been identified as Northern Coastal Salt Marsh, *CSLO (2003)*. The marsh habitat is limited to isolated patches and narrow strips within the lower portion of the creek. Representative plant species with this habitat include pickleweed *(Salicornia virginica)* and saltgrass *(Distichlis spicata)*.

Based on available satellite imagery the extent of marsh area varies from year to year. The total extent of marsh area is estimated to less than 1 acre in size.

2.3.1. Wildlife

Sensitive wildlife species sighted in the lower portion of San Luis Obispo Creek include southern steelhead, tidewater goby, pallid bat, and California red-legged frog, *CSLO (2003)*.

Sensitive wildlife species with the potential to occur in the lower portion of San Luis Obispo Creek include southwestern pond turtle, monarch butterfly, two-striped garter snake, Coast range newt, yellow warbler, yellow-breasted chat, Copper's hawk, California Spotted owl, and willow flycatcher.

2.4. Social Equity and Community Vulnerability

Sea-level rise related impacts to social equity and community vulnerability can be expressed via impacts to beach access, displacement, contamination risk, emergency service and disaster response, and also social and economic implications of adaptation options, *PI (2012)*.

Social vulnerability to sea-level rise and climate change hazards in general can be evaluated by identifying social groups who may be particularly impacted by sea-level rise. Categories considered in this regard can include: People over 65 living alone, the extent of the population under 18 years of age, renters, households speaking little English, people of color, low income areas, population without high school education, residents living in group quarters, unemployed, women who have recently given birth, outdoor workers, foreign born residents, residents with lack of access to grocery stores, overweight/obese youth, households without a vehicle, and households without air conditioning.

The Harbor District service area/sphere of influence is defined by the voting/taxation boundaries covering about half of San Luis Obispo County across several communities including Grover Beach, Nipomo, Arroyo Grande, Pismo Beach, and Oceano. Refer to Figure 2-1 for an overview of the Harbor District service area and sphere of influence.

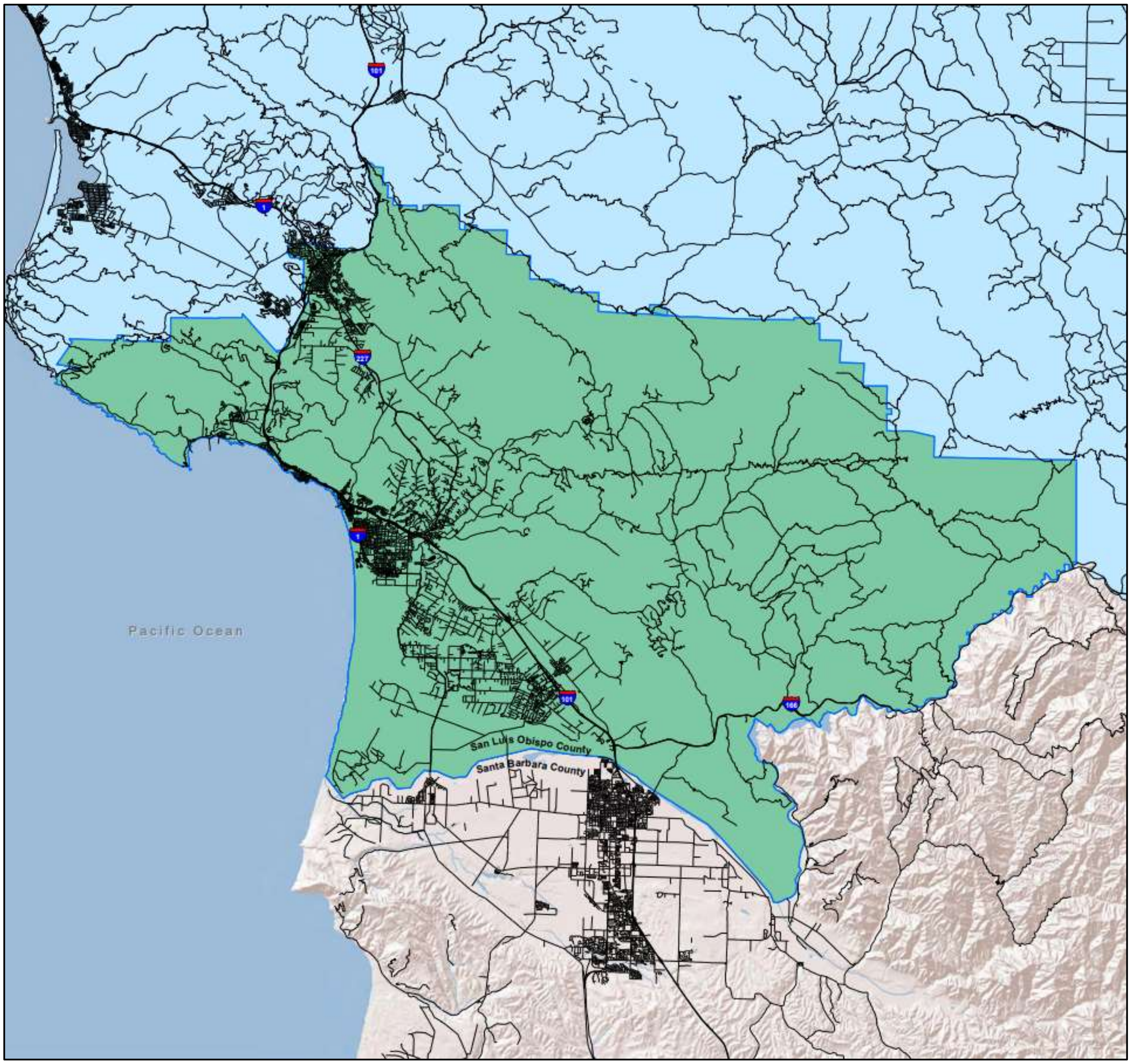

Figure 2-1: Port San Luis Harbor District Service Area and Sphere of Influence (area shaded in green).

Table 2-3 and Table 2-5 summarize social vulnerability index scoring from *PI (2012)* for census blocks within the service area and sphere of influence in the vicinity of Port San Luis. The overall vulnerability levels across the census block groups range from low (L) to medium (M) vulnerability.

Table 2-3: Factors Affecting Social Vulnerability to Sea-Level Rise and Climate Change Hazards (Census Block Groups 110 to 118).

Factors	Census Block Group							
	110	111.01	111.02	111.03	115.02	116	117	118
Living Alone over 65	0.11	0.04	0.05	0.15	0.10	0.12	0.14	0.11
Population under 18	0.14	0.08	0.11	0.09	0.26	0.21	0.13	0.21
Renters	0.55	0.88	0.76	0.48	0.19	0.14	0.39	0.13
Households speaking little English	0.03	0.05	0.06	0.06	0.03	0.01	0.03	0.01
People of Color	0.25	0.31	0.23	0.32	0.16	0.06	0.15	0.16
Low Income	0.41	0.55	0.46	0.43	0.12	0.09	0.19	0.10
Population w/o High School Diploma	-0.90	-0.91	-0.89	-0.89	-0.91	-0.97	-0.93	-0.97
Living in Group Quarters	0.05	0.00	0.03	0.00	0.12	0.00	0.01	0.00
Unemployed	0.03	0.08	0.07	0.04	0.03	0.02	0.03	0.03
Women giving birth within last 12 months	0.04	0.00	0.01	0.04	0.04	0.04	0.02	0.00
Outdoor Workers	0.07	0.03	0.04	0.03	0.09	0.11	0.10	0.11
Foreign Born	0.07	0.09	0.09	0.09	0.06	0.03	0.05	0.04
Lack Access to Grocery Stores	28.00	4.00	0.00	0.00	0.00	38.00	59.33	0.00
Overweight/Obese Youth	0.20	-	0.36	-	-	0.20	0.36	0.32
Impervious Land Cover	0.28	0.44	0.44	0.17	0.02	0.03	0.27	0.18
Treeless Area	0.05	0.02	0.01	0.01	0.12	0.19	0.11	0.09
Households without a Vehicle	0.09	0.07	0.02	0.05	0.07	0.03	0.03	0.00
Pre-term Birth Rate	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Households without Air conditioning	0.06	0.06	0.06	0.06	0.12	0.07	0.07	0.15
Vulnerability Index Score	**-0.30**	**-0.24**	**-0.29**	**-0.36**	**-0.48**	**-0.63**	**-0.32**	**-0.67**
Vulnerability Level	**L**	**M**	**L**	**L**	**L**	**L**	**L**	**L**

Table 2-4: Factors Affecting Social Vulnerability to Sea-Level Rise and Climate Change Hazards (Census Block Groups 119.01 to 124.02).

Factors	Census Block Group								
	119.01	119.02	120	121	122	123.01	123.02	124.01	124.02
Living Alone over 65	0.18	0.14	0.13	0.10	0.05	0.05	0.05	0.06	0.07
Population under 18	0.18	0.24	0.17	0.24	0.26	0.16	0.22	0.29	0.25
Renters	0.25	0.47	0.51	0.58	0.48	0.22	0.24	0.28	0.17
Households speaking little English	0.04	0.08	0.13	0.05	0.16	0.05	0.02	0.14	0.06
People of Color	0.18	0.30	0.39	0.23	0.49	0.26	0.14	0.53	0.28
Low Income	0.20	0.29	0.28	0.38	0.47	0.19	0.15	0.27	0.17
Population w/o High School Diploma	-0.93	-0.85	-0.87	-0.88	-0.74	-0.90	-0.96	-0.74	-0.88
Living in Group Quarters	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployed	0.02	0.06	0.00	0.07	0.04	0.02	0.03	0.05	0.05
Women giving birth within last 12 months	0.04	0.08	0.04	0.07	0.01	0.09	0.06	0.05	0.05
Outdoor Workers	0.06	0.09	0.11	0.03	0.17	0.15	0.16	0.13	0.13
Foreign Born	0.04	0.12	0.16	0.09	0.19	0.10	0.03	0.13	0.09
Lack Access to Grocery Stores	0.00	12.00	15.00	23.75	0.00	13.75	1.00	13.00	39.00
Overweight/Obese Youth	0.34	0.30	0.48	0.35	0.47	0.40	0.33	0.36	0.48
Impervious Land Cover	0.28	0.47	0.48	0.44	0.42	0.04	0.01	0.08	0.10
Treeless Area	0.02	0.01	0.02	0.03	0.02	0.11	0.17	0.03	0.05
Households without a Vehicle	0.03	0.06	0.04	0.05	0.04	0.02	0.02	0.02	0.02
Pre-term Birth Rate	0.09	0.09	0.08	0.10	0.09	0.10	0.10	0.09	0.10
Households without Air conditioning	0.15	0.15	0.06	0.06	0.05	0.19	0.19	0.21	0.21
Vulnerability Index Score	**-0.45**	**-0.07**	**-0.15**	**-0.08**	**-0.01**	**-0.43**	**-0.60**	**-0.18**	**-0.25**
Vulnerability Level	**L**	**M**	**M**	**M**	**M**	**L**	**L**	**M**	**M**

2.5. Sea-Level Rise

Current guidance for California recommends evaluation of SLR impacts using a scenario-based analysis. This method is founded on the approach by the Intergovernmental Panel on Climate Change (IPCC) to understand how SLR and other drivers interact to threaten health, safety, and resources of coastal communities. Comprehensive SLR guidance for California was first developed by the National Research Council, *NRC (2012).* The guidance relied on the best available science at the time to identify a range of sea-level rise scenarios including high, low, and intermediate projections, taking into account regional factors such as El Niño and extreme storm events that affect ocean levels, precipitation, and storm surge. This approach allows planners to understand the full range of possible impacts that can be reasonably expected based on the best available science, and build an understanding of the overall risk posed by potential future SLR.

The best available science and most recent guidance is provided by the California Ocean Protection Council in *OPC (2018)* and has been adopted for this vulnerability assessment. Table 2-5 summarizes SLR scenarios adopted from *OPC (2018)* for time horizons out to 2150. The columns outlined in dark blue reflects the OPC guidance for risk levels, which include low risk aversion, medium to high risk aversion, and extreme risk aversion.

Figure 2-2 depicts the *OPC (2018)* SLR projections from Table 2-5 in graphical form, where the *Medium to High Risk Aversion* scenario with high emissions is indicated by the red line. The projected sea-level rise for planning horizons 2030, 2050, and 2100 is indicated by the red circles. Present day conditions for 2020 is indicated by the black circle (E) denoting existing condition.

The horizontal blue bands provide an indication of when the adopted levels of sea-level rise could be experienced under the other *OPC (2018)* scenarios, e.g. low risk aversion under a low or high GHG emissions scenario or extreme risk aversion indicated by the purple line for the H++ scenario.

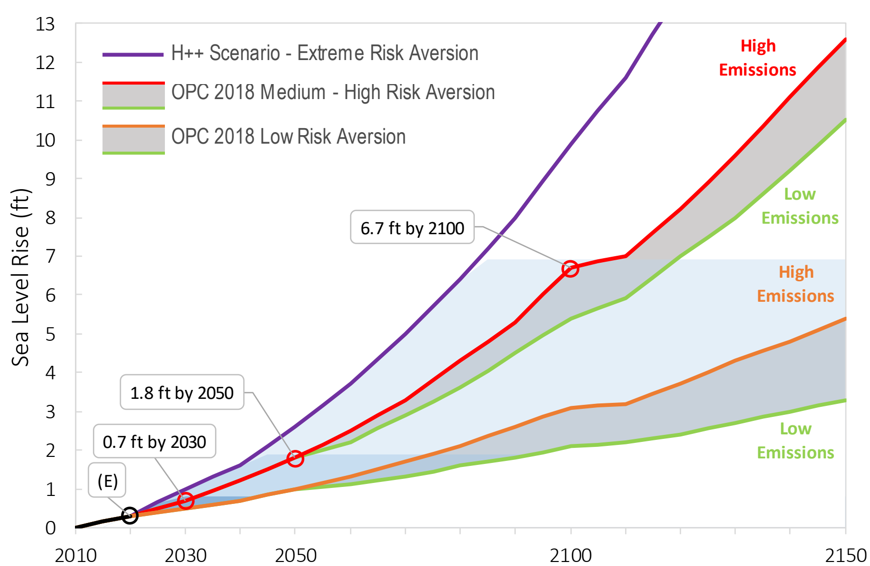

Figure 2-2: OPC Sea-Level Rise Projections.

Table 2-5: Sea-Level Rise Projections for Port San Luis, *OPC (2018)*.

		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	0.5	0.7	1.0
	2040	0.5	0.3 -	0.7	0.8	1.2	1.6
	2050	0.7	0.5 -	1.0	1.2	1.8	2.6
Low emissions	2060	0.8	0.4 -	1.1	1.4	2.2	
High emissions	2060	1.0	0.6 -	1.3	1.7	2.5	3.7
Low emissions	2070	0.9	0.5 -	1.3	1.7	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 -	2.1	2.8	4.3	6.4
Low emissions	2090	1.1	0.6 -	1.8	2.5	4.5	
High emissions	2090	1.8	1.1 -	2.6	3.4	5.3	8.0
Low emissions	2100	1.3	0.7 -	2.1	2.9	5.4	
High emissions	2100	2.1	1.3 -	3.1	4.1	6.7	9.9
Low emissions	2110*	1.4	0.8 -	2.2	3.1	5.9	
High emissions	2110*	2.3	1.5 -	3.2	4.2	7.0	11.6
Low emissions	2120	1.5	0.8 -	2.4	3.5	7.0	
High emissions	2120	2.6	1.8 -	3.7	4.9	8.2	13.8
Low emissions	2130	1.6	0.9 -	2.7	4.0	8.0	
High emissions	2130	2.9	2.0 -	4.3	5.7	9.6	16.2
Low emissions	2140	1.7	0.9 -	3.0	4.5	9.2	
High emissions	2140	3.2	2.1 -	4.8	6.4	11.1	18.7
Low emissions	2150	1.9	0.8 -	3.3	5.1	10.5	
High emissions	2150	3.6	2.3 -	5.4	7.3	12.6	21.5

The SLR scenario adopted for the vulnerability assessment is the *Medium – High Risk Aversion* scenario, assuming high greenhouse gas (GHG) emissions. The CSLC AB 691 Assessment requires planning horizons to be considered for 0.7 feet or SLR by 2030, 1.8 feet or SLR by 2050, and 6.7 feet of SLR by 2100. Table 2-6 summarizes the sea-level rise projections for these planning horizons.

Table 2-6: Summary of SLR by 2030, 2050, and 2100.

Year	2030	2050	2100
Sea-Level Rise	0.7 feet	1.8 feet	6.7 feet

2.6. Trends in Local Relative Sea Level

Local relative sea-level rise reflects the change in sea-level by combining climate change with vertical movement of the landmass. Vertical land motion can occur due to tectonic activity, isostatic rebound which is adjustment of the earth due to compression from the ice masses during the last ice age, and subsidence which can result from extraction of underground resources on consolidation of weak soils.

Figure 2-3 shows estimates of vertical land motion (VLM) for California and Nevada from *JGR (2016)*. GPS imaging was employed to track vertical land motion data over a period of five years, accounting for groundwater withdrawal, elastic bedrock uplift and tectonic uplift. Red colors indicate uplift and blue colors indicate subsidence. The intersection of the black horizontal and vertical lines reflects the location of Port San Luis, where uplift is around 0.5 mm per year. At this rate the land will rise by 1.6 inches by 2100.

The vertical land motion in this case reduces the relative sea level rise at Port San Luis, but the effect is minimal as the projected rise in sea level is an order of magnitude larger than the VLM.

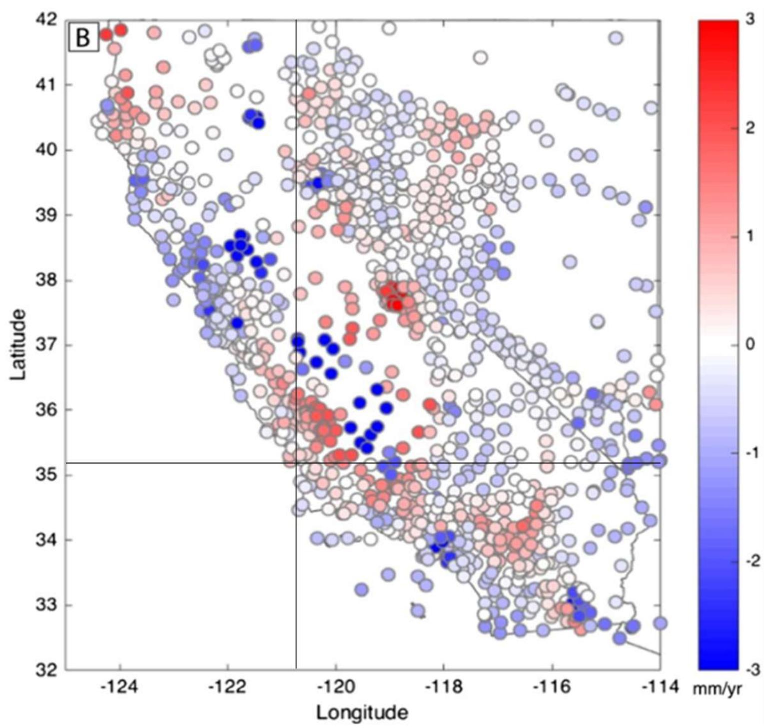

Figure 2-3: Rates of Vertical Land Motion, CA and NV, *JGR (2016)*.

2.7. Sea-Level Rise Scenarios

Coastal flooding is projected to increase with sea-level rise. Additional factors that can exacerbate coastal flooding events include high tides, storm surge, and El Niño effects. These elements can increase the severity and frequency of flooding.

- Tides occur regularly with about two high tides and two low tides each day. The highest tides (spring tides) occur twice a month during the full moon and the new moon. Around December and January when a new or full moon occurs at the same time as the sun is at its closest to the earth, the tides run higher. These higher perigean spring tides are commonly known as king tides. See Figure 2-4 for a photo of a king tide at Harford Landing.

- Storms and Storm surge can occur as a combination of wind shear over the water and low atmospheric pressure. Strong southerly wind and low barometric pressure can produce large waves and storm surge at Port San Luis. Examples of past storm events include:

  - Feb 2, 2019 - two boats ended up on the beach, pier landing damaged.
  - March 1, 2014 - Avila Pier received significant damage.
  - March 1, 1983 - Unocal Pier destroyed; good portion of Avila Pier lost.

- El Niño (and La Niña) are cycles of warming and cooling of the ocean, typically lasting 9 to 12 months. They often commence in June or August and reach their peak during December through April, and subsequently decay over May through July. Their periodicity is irregular, occurring every 3 to 5 years on average. The warming associated with El Niño produces a rise of the ocean level, which can be on the order of 6 to 13 inches. The period of elevated (or lowered) ocean levels can be on the order of months, while the peak highs and lows occur on a scale of days to weeks.

Figure 2-4: King tide at Harford Landing, January 11, 2020.

Table 2-7 provides a breakdown of tidal datums and extreme water levels for existing conditions, and projected water levels with SLR for 2030, 2050, and 2100. The sea-level rise projection reflects the *Medium to High Risk Aversion* OPC Scenario, assuming *High Emissions*.

The conditions adopted for mapping of sea-level rise related flood impacts are highlighted in yellow. In terms of frequency, these reflect flooding as follows:

- Daily inundation of areas below the Mean High Water (MHW) line.
- Annual inundation of areas flooded by king tides.
- Extreme inundation in the event of a 100-year (1% annual chance) storm.

These can be described further as follows:

- Mean High Water. The Mean High Water (MHW) tide level is an average of all of the high tides occurring over a tidal epoch (19-year cycle). In coastal areas, the MHW tide line defines the shoreline, and in terms of sea-level rise sets the threshold above which daily tides will likely result in coastal flooding.
- King Tides. Extreme high tides (perigean spring tides) which occur annually in January and December. King tides produce enhanced high-tide flooding, and for several days in succession can be envisaged as a precursor to future flooding due to sea level rise.
- 1% Annual Chance Storm. Representative of an extreme storm event with an average recurrence interval of 100 years. This scenario reflects the FEMA 1% annual chance event. The extreme water level associated with this scenario accounts for storm surge, high tide, El Niño effects, and wave action. The FEMA FIRM for Avila Beach is shown on Plate 2.

Table 2-7: Tidal Datums and Extreme Water Levels for various SLR Scenarios.

Condition	Existing	Sea Level Rise (feet) by [1] 2030	2050	2100
		0.7	1.8	6.7
	Water Level (feet NAVD88)			
1% Annual Chance Storm [2]	+10.0 to +33.0	+10.7 to +33.7	+11.8 to +34.8	+16.7 to +39.7
King Tides	+7.0	+7.7	+8.8	+13.7
MHHW	+5.3	+6.0	+7.1	+12.0
MHW (Shoreline)	+4.5	+5.2	+6.3	+11.2
MSL	+2.7	+3.4	+4.5	+9.4
MLW	+1.0	+1.7	+2.8	+7.7
MLLW	-0.1	+0.6	+1.7	+6.6

1) State of California Sea-Level Rise Guidance, OPC (2018) Update.

2) Wave runup associated with coastal flooding can reach elevations ranging from +10 to +33 feet NAVD88. The 1% annual chance flood water surface elevation associated with fluvial flooding from San Luis Obispo Creek ranges from +13.4 feet NAVD88 at the mouth of the lagoon to +16.0 feet NAVD88 up the creek.

MHHW – Mean Higher High Water; MSL – Mean Sea Level; MLLW – Mean Lower Low Water
MHW – Mean High Water; MLW – Mean Low Water

2.7.1. Wave Overtopping

The waterfront edge at Harford Landing is exposed to wave overtopping annually during winter storms. The orange shading in Figure 2-5 indicates the areas that are subject to wave overtopping. Figure 2-6 shows an example of conditions during a significant wave overtopping event.

Figure 2-5: Areas exposed to wave overtopping.

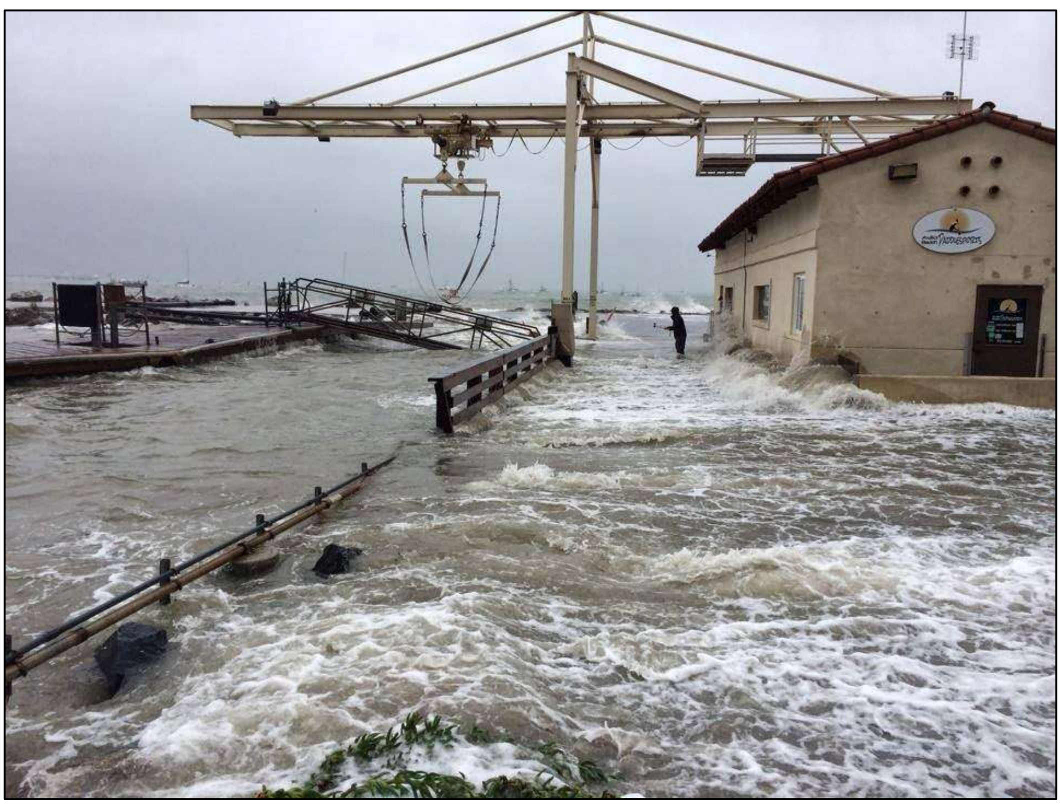

Figure 2-6: Wave overtopping at the Port San Luis Boat Lift (Olde Port Boat Launch).

3. Maps of 2030, 2050, and 2100 Impacts

The NOAA Office of Coastal Management maintains a program to collect coastal topographic data nationwide. The USACE, NOAA, and USGS acquired LiDAR topographic data for Port San Luis in 2016, *NOAA (2020b), Dewberry (2016)*. An excerpt of the LiDAR is shown in Appendix A on Plate 3. The topographic data is referenced to the California State Plane Coordinate System, Zone V (FIPS 0405), with elevations referenced to the North American Vertical Datum of 1988 (NAVD88).

3.1. Guide to Flood Maps

Maps of existing conditions and 2030, 2050, and 2100 sea-level rise flood extents were developed using the LiDAR Digital Elevation Model (DEM). The flood maps included in Appendix A provide information on flood extents and flood depths for the general area. Mapping for Port San Luis/Harford Landing is provided in Appendix B, mapping for Avila Beach Drive is provided in Appendix C, and mapping for Avila Beach in Appendix D. Areas subject to inundation associated directly with coastal flooding are shaded in blue colors. Hues from light blue to dark blue indicate flood depths from 0.5 to 5.0 feet at one foot increments (see Figure 3-1). Shallow flooding less than ½ feet deep is indicated in yellow.

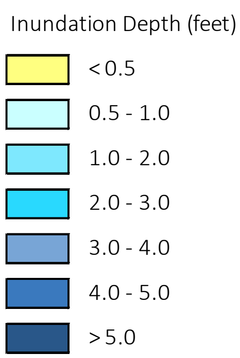

Figure 3-1: Flood Map Information

It should be noted that the mapping reflects current day conditions with sea level rise projections out to 2100. Flood mitigation projects that have already been implemented are thus reflected in the mapping effort, but ongoing and future planned project elements are not considered in the mapping effort. Planned Capital Improvement Projects (CIPs) are described and discussed in Section 6 on Sea-Level Rise Mitigation and Adaptation Measures.

3.2. Changing Shorelines

There are several different ways sea-level rise can affect shorelines. Along shorelines subject to wave action, the typical response of the shoreline to sea-level rise is to recede inland. This happens as the shoreline profile rebalances itself around the new higher mean sea level. This effect was described in 1962 by Per Bruun and is known as the *Bruun Rule*. In order to maintain the beach profile, subaerial material is eroded and shifted to the submerged portion of the profile. In undeveloped areas the effect may be pronounced recession of the shoreline. If there is an insufficient supply of sediment available to raise the shoreline profile in step with sea-level rise, the result can be accelerated erosion and deepening of the coastal waters. This in turn allows larger waves to impact the shore which further exacerbates erosion. These effects are the reason why shorelines often experience a higher degree of erosion during strong El Niño episodes occurring over the winter months. The El Niño conditions cause the ocean level to be higher which manifests as a temporary sea-level rise.

3.3. Daily Inundation Levels

A map of the present day MHW shoreline location is shown on Plate 5. Projected future shoreline locations are defined as areas below the MHW line that would be subject to daily inundation as a result of sea-level rise. Projections for sea-level rise by 2030, 2050, and 2100 are shown on Plate 6, Plate 7, and Plate 8. For details of flood risks at Harford Landing, along Avila Beach Dr., and at Avila Beach refer to the following appendices:

- Harford Landing, Appendix B, Plate 2 to 5 (existing conditions, 2030, 2050, and 2100).
- Avila Beach Drive, Appendix C, Plate 2 to 5.
- Avila Beach, Appendix D, Plate 2 to 5.

The primary areas that will be affected by rising sea level are:

- Harford Landing boat lift (Impacted by 2100).
- Fisherman’s Beach (Impacted by 2100).
- Olde Port Beach (Impacted by 2050). At this stage the revetment along Avila Beach Drive would be frequently exposed to wave action, including wind-waves, swell, and storm waves which would damage the revetment e.g. by displacing or undermining the armor stone.
- Revetment along Avila Beach Drive. (Impacted by 2050). At this stage the revetment along Avila Beach Drive would be frequently exposed to wave action, including wind-waves, swell, and storm waves which would damage the revetment e.g. by displacement or undermining of the armor stone.
- Avila Beach (Impacted by 2100).

The impacts may cause temporary restricted beach access on a daily basis, limiting public access to the recreational areas.

3.4. King Tides

Flood maps showing inundation associated with king tides were developed for existing conditions, and sea-level rise by 2030, 2050, and 2100. Refer to the following appendices:

- Harford Landing, Appendix B, Plate 6 to 9 (existing conditions, 2030, 2050, and 2100).
- Avila Beach Drive, Appendix C, Plate 6 to 9.
- Avila Beach, Appendix D, Plate 6 to 9.

The primary areas that are projected to be impacted by king tides are:

- Port San Luis boat lift and parking areas (Impacted by 2100).
- Fisherman's Beach (Impacted by 2050).
- Olde Port Beach (Impacted under existing condition).
- Revetment along Avila Beach Drive. (Impacted by 2050). At this stage king tides would bring the waterline close to the toe of the revetment along Avila Beach Drive. This means that wave action in the form of wind-waves, swell, and storm waves could potentially damage the revetment by displacement or undermining of the armor stone.
- Avila Beach (Impacted by 2050).

King tides may cause shallow flooding/ponding in some low-lying areas and usually happen 2 to 4 times during a year. It can cause flood issues for parking spots which can have potential revenue impact on the harbor.

3.5. 100-Year Storm Extreme Water Level

Flood maps showing inundation due to 100-year storm extreme water levels for the general area are shown on Plate 13 for existing conditions, and on Plate 14, Plate 15, and Plate 16 for sea-level rise by 2030, 2050, and 2100. The inundation mapping shown on Plate 13 for existing conditions corresponds approximately to the inundation extents delineated on FEMA Flood Insurance Rate Maps (FIRMs) for the area. Small differences may be due to the FEMA analysis that combined both coastal and fluvial flooding, and/or the use of differing topographic data for flood mapping.

Inundation maps for Harford Landing, along Avila Beach Dr., and at Avila Beach are provided in the following appendices:

- Harford Landing, Appendix B, Plate 10 to 13 (existing conditions, 2030, 2050, and 2100).
- Avila Beach Drive, Appendix C, Plate 10 to 13.
- Avila Beach, Appendix D, Plate 10 to 13.

Potential impacts to areas can be categorized as follows:

- Port San Luis/Harford Landing (about half of the area impacted under the existing condition and by 2030; the majority of the area impacted by 2050, and the entire area impacted by 2100). Refer to Table 3-1 for impacts in terms of area/extent and Table 5-3 for damages.
- Fisherman's Beach (Impacted under existing condition, and further impacted by 2030, 2050, and 2100). Refer to Table 3-2 for impacts in terms of area/extent and Table 5-4 for damages.
- Olde Port Beach and public boat lunch (Impacted under existing condition; upland area, including restrooms, parking areas, and lift station impacted by 2100). Refer to Table 3-2 for impacts in terms of area/extent and Table 5-4 for damages.
- Revetment along Avila Beach Drive. Storm waves would run up the revetment under existing conditions and reach higher elevations with sea-level rise. By 2100 wave runup would overtop the roadway and impact the lift station across the road. Refer to Table 3-2 for impacts in terms of area/extent and Table 5-4 for damages.
- Avila Beach (Impacted under existing condition); Pier and restrooms (Impacted by 2100). Refer to Table 3-3 for impacts in terms of area/extent and Table 5-5 for damages.

Sea-level rise impacts to the beach areas can lead to potential impacts to public access resulting in financial losses. For areas that are impacted under the existing condition sea-level-rise will intensify the adverse effects.

Daily tides and king tides are not projected to directly impact the Harford Pier, Cal Poly Pier and Avila Beach Pier. However, fixed landings on Harford Pier and Avila Pier would be significantly affected during King Tides or a 100-year storm scenario. A 100-year storm event could also cause damage to the piers. It is anticipated that sea-level rise would exacerbate the potential impacts. The years where wave action has caused damage to the piers in the past (1983 and 2014) have been El Niño years. During El Niño episodes, there is a general rise in the ocean level due to temperature change. This temporary rise in the ocean level can be seen as a form of sea-level rise, or a preview hereof. The indication is that the rise in ocean level, if coinciding with a large wave event is sufficient to enable the highest wave crests to impact the pier deck. The typical damage that often occurs under these conditions are uplifted deck boards.

3.6. Impacts to Public Trust Resources and Values

Potential impacts to public trust resources and values are considered in the following, including public access, commercial activities, recreation, coastal habitats, and navigation.

The primary impacts areas identified in *Protsman (2018)* are:

- Beach areas and low-lying areas for commercial and public recreational use.
- Coastal roads and low-lying parking areas.

- Culverts and stormwater outlets.

Facilities potentially impacted by future sea-level rise identified in this study are summarized in Table 3-1, Table 3-3, and Table 3-2 for facilities at Harford Landing, Avila Beach, and along Avila Beach Drive. Refer to Appendix A for flood hazards at Harford Landing, Appendix B for flood hazards along Avila Beach Drive, and Appendix C for flood hazards at Avila Beach.

The tables summarize the type of hazard, the frequency of occurrence, impacted facilities, and which years the respective facilities would be impacted per the flood mapping provided in Appendix A, B, and C. Blank cells in the tables indicate no impact.

3.6.1. Port San Luis / Harford Landing

The analysis summarized in Table 3-1 for Port San Luis / Harford Landing shows that facilities would not be impacted by Mean High Water tides and King tides until 2100. It is primarily the area around the Port San Luis Boat Lift (Olde Port Boat Launch) that would be affected. It should be noted that his analysis looks at the static water level only and does not include wave action that can occur annually over the winter months. It is known that the waterfront edge is impacted by wave action annually in the present-day setting, which would be exacerbated by sea-level rise without mitigation.

Estimates provided in Table 3-1 for the 100-year storm do include wave action, wave overtopping, and ponding in low-lying areas and indicate the extent of facilities that could be impacted. The findings show that for years 2020 and 2030 it is primarily the facilities and areas along the waterfront that would be impacted. With sea-level rise by 2050 and 2100, the entire area could be impacted by wave overtopping if exposed to a 100-year storm event.

Harford Pier is not expected to be impacted by sea-level rise in the near term.

3.6.2. Avila Beach Drive

Future sea-level rise is not anticipated to impact Avila Beach Drive which is located at grades above the projected sea-level rise elevations. A 100-year storm occurring by the end of the century could produce enough wave overtopping to impact the Old Port Beach area. Impacted facilities could include the restroom facilities, boat launch, and parking along Avila Beach Drive, and also the lift station on the opposite side of the road (it is estimated that wave runup and overtopping could sheet-flow across the road to the lift station building). The flood mapping indicates that an approximately 800-ft section of Avila Beach Drive would be significantly impacted by wave overtopping. Most of the overtopping would consist of heavy spray and water sheet-flowing over the roadway. Drivers would attempt to time breaks between waves which would be 8 to 12 seconds. A vehicle would have to drive at a speed of 45 mph or higher to make it past the 800-ft section. During large wave overtopping events, flood depths could be as deep as 1 to 2 feet. It would be an extremely dangerous condition for cars trying to pass. Six inches of water will reach the bottom of most passenger cars, can cause aquaplaning, loss of control and potential stalling. A foot of water will float many vehicles, and two feet of rushing water will carry away most vehicles, including SUVs and pickups.

The Woodyard and Nobi Point camping areas could experience significant amounts of spray during a 100-year storm event, but are not projected to impacted by wave overtopping.

3.6.3. Avila Beach

The results summarized in Table 3-3 show that facilities at Avila Beach would be impacted by king tides with sea-level rise by 2100. Impacted facilities would be the parking areas along Front Street and the restroom facilities by the Avila Beach Pier. The pier itself is not expected to be impacted by sea-level rise in the near term.

The occurrence of a 100-year storm event would more significantly impact the area due to the associated wave runup. However, the extent of impacts would be limited to facilities along Front Street as the terrain elevation increases on the inland side of Front Street.

3.6.3.1. Flood Impacts associated with Surface Runoff

The Avila Beach Parking lot has a low-lying area that normally floods with surface runoff during winter storms. The area drains by a duckbill valve to San Luis Obispo Creek. The valve needs to be higher than the creek level to work effectively, at least at low tide. Sea-level rise will reduce the ability of the system to gravity drain. Impacts to the parking would constitute a loss of revenue and decreased public access. Mitigation could include installation of to a pump system to discharge the floodwater.

Table 3-1: Sea-Level Rise Related Impacts to Facilities at Port San Luis / Harford Landing.

Sea-Level Rise Related Impacts to Facilities at Harford Landing			Year of Impact and Extent				
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	**Unit**
MHW Tide	Daily Inundation	Port San Luis Boat Lift				150	SF
MHW Tide	Daily Inundation	Restrooms				70	SF
MHW Tide	Daily Inundation	Parking/Paved Area				14,800	SF
King Tide	Annual Inundation	Port San Luis Boat Lift				150	SF
King Tide	Annual Inundation	Restrooms				70	SF
King Tide	Annual Inundation	76 Gasoline Tank				50	SF
King Tide	Annual Inundation	Mobile Boat Lift				800	SF
King Tide	Annual Inundation	Parking/Paved Area				78,700	SF
100-Year Storm	1% Annual Chance	Port San Luis Boat Lift	150	150	150	150	SF
100-Year Storm	1% Annual Chance	Restrooms	140	140	140	240	SF
100-Year Storm	1% Annual Chance	76 Gasoline Tank	100	100	100	100	SF
100-Year Storm	1% Annual Chance	Sewer Lift Station	100	100	100	100	SF
100-Year Storm	1% Annual Chance	Mobile Boat Lift	800	800	800	800	SF
100-Year Storm	1% Annual Chance	Parking/Paved Area	95,500	95,500	152,800	196,400	SF
100-Year Storm	1% Annual Chance	Boat Storage Yard	4,800	4,800	43,800	43,800	SF
100-Year Storm	1% Annual Chance	Maintenance Shop	850	850	1,800	1,800	SF
100-Year Storm	1% Annual Chance	Harbor Office			1,100	1,100	SF
100-Year Storm	1% Annual Chance	Supply Closet			40	40	SF
100-Year Storm	1% Annual Chance	Parsons Building			1,100	1,100	SF
100-Year Storm	1% Annual Chance	Sewer Lift Station			150	150	SF
100-Year Storm	1% Annual Chance	Fat Cat's Restaurant			1,600	1,600	SF
100-Year Storm	1% Annual Chance	Sport Launch Building			1,500	1,500	SF
100-Year Storm	1% Annual Chance	Laundry/Showers				450	SF

Table 3-2: Sea-Level Rise Related Impacts to Facilities along Avila Beach Dr.

Sea-Level Rise Related Impacts to Facilities along Avila Beach Dr.			Year of Impact and Extent				
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	**Unit**
100-Year Storm	1% Annual Chance	Olde Port Beach Sewer Lift Station				550	SF
100-Year Storm	1% Annual Chance	Fuel Facility/HazMat				200	SF
100-Year Storm	1% Annual Chance	Olde Port Beach Parking Areas				7,300	SF
100-Year Storm	1% Annual Chance	Olde Port Beach Restrooms				300	SF
100-Year Storm	1% Annual Chance	Olde Port Beach Boat Launch				3,600	SF

Table 3-3: Sea-Level Rise Related Impacts to Facilities at Avila Beach.

Sea-Level Rise Related Impacts to Facilities at Avila Beach			Year of Impact and Extent				
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	**Unit**
King Tide	Annual Inundation	Parking/Paved Area				7,700	SF
King Tide	Annual Inundation	Lifeguard Bldg. & Restrooms				2,000	SF
King Tide	Annual Inundation	Lifeguard Towers				100	SF
King Tide	Annual Inundation	Outlet				-	-
100-Year Storm	1% Annual Chance	Parking/Paved Area	21,800	21,800	21,800	21,800	SF
100-Year Storm	1% Annual Chance	Lifeguard Bldg. & Restrooms	2,000	2,000	2,000	2,000	SF
100-Year Storm	1% Annual Chance	Lifeguard Towers	100	100	100	100	SF
100-Year Storm	1% Annual Chance	Outlet	-	-	-	-	-

Assets potentially impacted by future sea-level rise are identified in the following along with the type(s) of sea-level rise related hazard, and approximate impact threshold, which gives an idea about the planning horizon within which to incorporate adaptations and mitigations to address sea-level rise related hazards.

3.6.4. Public Access

Potential impacts to public access would center on the beach areas. Most of the trails atop the bluffs are on higher ground and would not be impacted by sea-level rise. Access to Harford Pier and the Avila Beach Pier is away from the water so these are not immediately affected by sea-level rise. Sea-level rise impacts around the boat hoist area would impact boat launching. Wave overtopping along the waterfront has the potential to impact parking areas, public access, boat launching via the mobile boat lift, and in extreme cases businesses and Harbor District services.

3.6.5. Commerce

Sea-level rise hazards potentially impacting commercial activities include the parking areas along the shoreline which may be affected by wave overtopping and shallow flooding.

3.6.6. Recreation

Recreational assets potentially impacted by sea-level rise primarily includes: Fisherman's Beach, Olde Port Beach, Avila Beach, and Pirate's Cove.

3.6.7. Coastal Habitats

Areas of sensitive coastal habitat affected by sea-level rise primarily includes the small, isolated patches of salt marsh on the lower San Luis Obispo Creek.

3.6.8. Navigability

Navigability will not be significantly impacted by sea-level rise as the water depth increases with sea level rise. Anchor lines utilized within the mooring field may need to be adjusted for sea-level rise.

Sea-level rise may bring about other indirect impacts to navigability and recreational use of the mooring field. This includes overtopping of the breakwater which could lead to increasing wave agitation within the bay.

4. Tsunami Hazards

Tsunamis stem from submarine earthquakes along the Pacific Rim. Tsunamis are chiefly associated with large earthquakes on subduction faults that produce a substantial vertical displacement of the water body.

Table 4-1 lists tsunami conditions at Avila Beach based on several past studies, and also lists runup and wave heights of actual recorded events. While devastating tsunamis have occurred in recent times and have been documented in the historical record, no major tsunami impacts have been documented at Port San Luis. Cases where tsunami waves were recorded at Port San Luis are listed in *K&K (1968).* These events were associated with large earthquakes in 1946, 1952, and 1964.

The Harbor District received a tsunami advisory on February 27, 2010 and on September 16, 2015 and evacuated both piers and all beaches as result. A tsunami warning and event took place on March 11, 2011. All low lying areas were evacuated as a result. The tsunami damaged a ramp to a public floating landing.

Subsequent studies have established that earthquakes occurring along the Aleutian Islands have the largest potential to impact shorelines in California. The SAFRR study conducted by USGS was aimed at identifying a worst case but credible tsunami scenario for California. Studies by Cal-EMA consider the envelope of a range of tsunami scenarios and form the basis of tsunami hazard mapping for emergency planning purposes. The recent work by ASCE to consider tsunami hazards is focused on design of structures susceptible to tsunami exposure.

Table 4-1 illustrates that there is a large variation in terms of tsunami runup (flood elevation) across the scenarios from recorded to hypothetical. The present study therefore adopts the Cal-EMA tsunami mapping as the basis. This type of emergency response scenario is reasonable for planning purposes as there would be about 5 hours of warning time from the origin of an earthquake in the Aleutian Islands until arrival of the tsunami wave at Avila Beach. Estimated tsunami travel time is shown in Figure 4-1 where contours indicate travel time in hours. The origin is indicated by the white star.

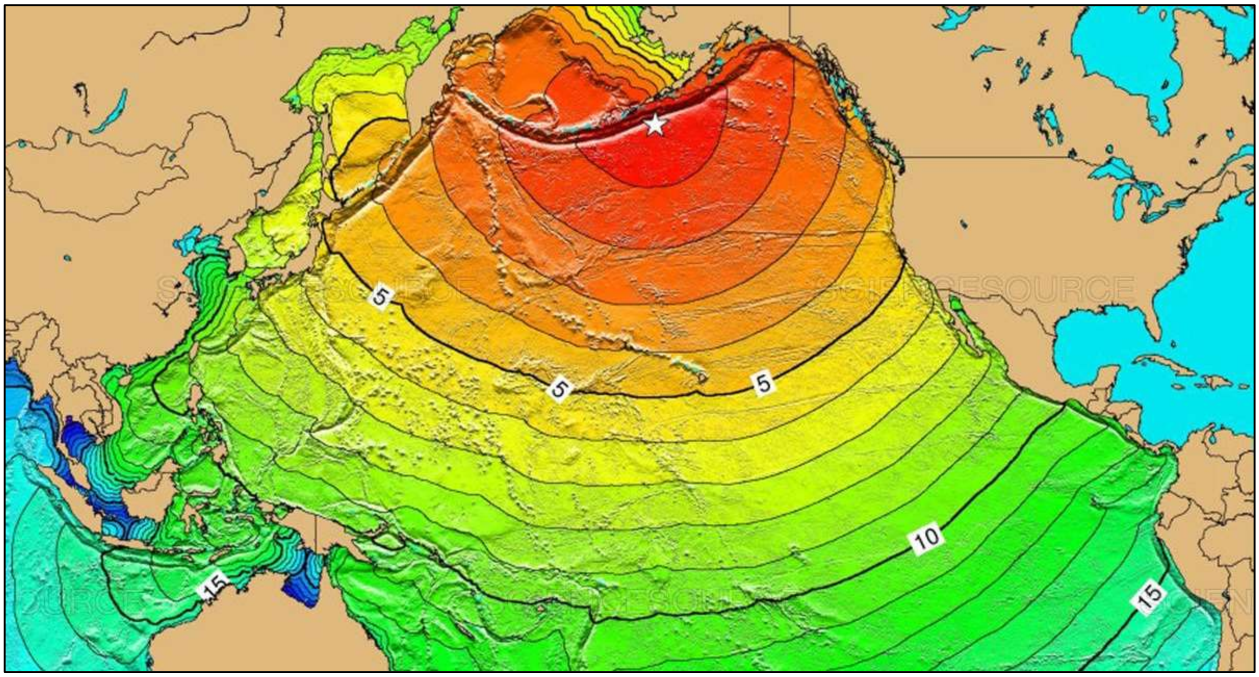

Figure 4-1: Tsunami travel time for origin along Aleutian Islands.

Table 4-1: Tsunami Hazards (hypothetical and recorded) at Port San Luis

Reference	Date	Return Period (years)	Wave Height (ft)	Runup Elevation (feet above MHW)	Source	Magnitude (Ms/Mw)
ASCE (2017)	Hypothetical	2,500	23.4	65.2	Pacific Basin	-
Cal-EMA (2009)	Hypothetical	350 to 1,000	-	40.0	Pacific Basin	-
SAFRR, USGS (2013)	Hypothetical	≈300	-	39.0	East Aleutian Islands, AK	9.1
USACE (1978)	Hypothetical	500	-	17.2	Aleutian Trench	8.0
USACE (1978)	Hypothetical	100	-	8.8	Aleutian Trench	7.5
K&K (1968)	1964/3/28	-	16.0	5.2	Gulf of Alaska	- / 9.2
K&K (1968)	1952/11/4	-	9.5	4.6	Kamchatka, Russia	8.2 / 9.0
K&K (1968)	1946/4/1	92	8.5	4.3	East Aleutian Islands, AK	7.3 / 8.6

Ms – Surface-Wave Magnitude
Mw – Moment Magnitude

Plate 17 to Plate 21 in Appendix A shows the extent of flooding associated with a Cal-EMA tsunami hazard scenario for existing conditions and conditions with future sea-level rise by 2030, 2050, and 2100. Plate 21 to Plate 24 indicate the depths of inundation associated with these exposure conditions.

The results show that tsunami runup could reach elevation 42 to 50 feet NAVD88 around San Luis Obispo Bay. The breakwater would be submerged and would have limited effect in any case on tsunami wave heights. Harford Pier, the CalPoly Pier, Avila Beach Pier, and low-lying coastal areas would be inundated.

Due to the significant runup elevations, the tsunami wave would be able to penetrate some distance inland up through Wild Cherry Canyon, Harford Canyon and up San Luis Obispo Creek. Tsunami inundation at Diablo Canyon Road would be limited as this road has a relatively steep grade. The tsunami maps show that sea-level rise generally raises the tsunami runup elevations by the amount of sea-level rise. Other than the increase in runup elevations, sea-level rise does not significantly exacerbate or alleviate tsunami hazards.

The tsunami inundation results presented are in line with existing published Cal-EMA tsunami inundation maps for emergency planning. In the event of issuance of a tsunami warning, the standard operating procedures for tsunami emergency planning established by San Luis Obispo County Office of Emergency Services, *SLOC (2016)* should therefore be followed.

4.1. Capital Improvement Projects

4.1.1. Harbor Terrace

The tsunami inundation mapping shown on Plate 17 to Plate 21 shows that the Harbor Terrace development would not be directly impacted by tsunami inundation as the development resides at elevation 50 feet NAVD88 and above.

Avila Beach Drive and the lower portion of Diablo Canyon Road by Fisherman's Beach would be inundated by wave tsunami runup, and ingress and egress to Harbor Terrace would therefore be temporarily impacted by flooding on the roadways. Per *ASCE (2016)*, the period of the primary tsunami wave is on the order of 40 to 50 minutes. Inundation cycles could therefore be 20 to 30 minutes (about half the wave period) during each incoming tsunami wave.

Given that there would be a time frame of around 5 hours from notice of a tsunami warning until arrival of the tsunami wave at Avila Beach, there would be options to evacuate via Avila Beach Drive, shelter in place on higher ground; and/or egress to Diablo Canyon Road to seek higher ground.

Notification and evacuation of site visitors at Harbor Terrace should follow the County standard operating procedures for tsunami emergency planning. Notification is usually delivered by phone calls, text messages, sirens, and through the media deployed via the Emergency Alert System (EAS). Emergency personnel will provide appropriate instructions. A tsunami hazard evacuation scenario would typically extend for up to 24 hours.

5. Financial Costs of Sea-Level Rise

Financial cost of sea-level rise are assessed in the following sections. This includes potential impacts to public access, commercial facilities, recreation, coastal habitat and navigation.

Elements that don't have a defined market value are termed non-market. These include recreational and habitat values. For these elements, their economic value is assessed based on non-market valuation methods, one being how much people would be willing to pay for them, e.g. beach visits, swimming, wildlife viewing, and fishing.

Cost estimates reflect present value of future cost with price escalation based on the U.S. Average Consumer Price Index (CPI) and index base period (1982-84 = 100), *BLS (2020)*.

5.1. Non-Market Losses

In this section, potential non-market losses due to sea-level rise are estimated for recreational activities. To determine the non-market values, economists suggest using the concept of willingness to pay, which is defined as the value of an individually consumed non-market good as the amount that an individual consumer would be willing to pay to consume the good or use the service (*Raheem et al., 2009*). These values are identified through empirical research (e.g., *Costanza et al., 2006*; *Raheem et al., 2009, 2012*). Resources from Center for the Blue Economy Library and Duke Marine Ecosystem Services Partnership, as well as the California Department of Boating and Waterways *CDWB (2011)* and *EPA (2009)* provided the basis for the analysis.

The primary non-market element potentially affected by sea-level rise is recreational use of the beaches. Beaches can provide a range of non-market economic values, which include recreational value, storm-buffering capacity, and provision of biological and ecological diversity *(CDBW, 2011)*. In California, beaches below the mean high water line are in public trust, and it is difficult to assign a market value for them. One of the recommended methods to determine the non-market values of a beach is to divide its value into use and non-use values. The use values include direct use benefits such as recreation (boating, birding, fishing, bathing), while indirect use benefits include flood control, and shoreline protection. The non-use values include biodiversity, cultural, and heritage existence benefits.

In practice it is challenging to assess non-market values. The Environmental Protection Agency provides guidance for the economic value of coastal ecosystems in California. EPA (2009) estimates a value of $16,946 per acre per year for activities associated with recreation and ecotourism.

The California Department of Boating and Waterways, *CDBW (2011)* also provide guidance on economic costs of sea-level rise to California coastal communities. CDBW (2011) recommends a non-market ecological value of $1,620 (present value of $2,000) per acre per year, which accounts for biodiversity and environmental values. The recreational value is estimated to be $16,200 per acre per year ($20,000 present value), i.e. 10 times the non-market ecological value.

The beaches at Avila Beach are fixed between hard points on the coast, and the primary loss of beach would therefore be due to the rise of the ocean level and to a much lesser degree coastal erosion. The erosion rate of the bluffs is estimated to be within a few inches per year at most.

The estimated aggregate non-market losses based on these values is summarized in Table 5-1.

Table 5-1: Aggregate Non-Market Loss due to SLR impacts to beaches.

Year	Beach Loss (acres)	Beach Loss (cy/year)	*CDBW (2011)*	*EPA (2009)*
2030	1.7	8,400	$188,000	$207,000
2050	7.3	17,800	$2,488,000	$2,729,000
2100	33.8	32,700	$39,421,000	$43,235,000

The dredging lease enables the District to dredge up to 250,000 cubic yards (cy) of material annually, which would be sufficient to compensate for the projected losses due to sea-level rise indicated in Table 5-1.

5.1.1. Habitat Losses

Economists classify coastal habitat as non-market. Estimates of habitat value for wetland and marsh areas vary hugely by area and use. Coastal habitat can contribute to value in many ways including: recreational access, birdwatching, aesthetic value, fisheries, flood protection, improving water quality, and general ecological sustainability. The wetland habitat in the lower San Obispo Creek occurs in small isolated patches and has relatively limited value. Additionally, these patches are subject to inundation, possibly erosion when large flows come down the creek. The ecological value estimated in *(CDBW, 2011)* is $1,620 per acre.

Table 5-2: Aggregate Non-Market Loss due to SLR impacts to Coastal habitat.

Year	Coastal Habitat Loss (acres)	*CDBW (2011) Low Estimate*
2030	1.0	$22,000
2050	1.0	$73,000
2100	1.0	$254,000

5.2. Facility Impacts

Cost impacts associated with sea-level rise related flood damage is assessed in the following. Potential impacts are summarized in Table 5-3, Table 5-4, and Table 5-5 for facilities at Harford Landing, Avila Beach, and along Avila Beach Drive.

The tables summarize the type of hazard, the frequency of occurrence, impacted facilities, and which years the respective facilities would be impacted. Flood damage was assessed based on the extent of flooding summarized in Table 3-1, Table 3-2, and Table 3-3 and as a percentage of the insured value of the respective facilities.

The damage percentages applied were scaled based on depth of flooding and taking 50% damage as an upper limit based on guidance from *RFF (2016)*. The scaling based on flood depth ensures a proportional distribution of damage across the various facilities. At Harford Landing for example, facilities along the waterfront will experience a higher percentage of damage than facilities located further inland along the toe of the bluff. Similarly, at Avila Beach, the lifeguard towers on the beach would be first in line taking the brunt of a 100-year storm. Scaling of the damage by flood depth also ensures that damage levels increase in proportion to the amount of projected sea-level rise.

Damage cost estimates are based on 2020 present values with an escalation for 2030, 2050, and 2100 based on the U.S. Average Consumer Price Index (CPI) and index base period (1982-84 = 100), *BLS (2020)*. Estimates have been rounded to the nearest $1,000.

Table 5-3: Sea-Level Rise Related Flood Damage Costs for Facilities at Port San Luis / Harford Landing.

SLR Related Flood Damage to Facilities at Harford Landing			Year of Impact and Extent				Insured Value
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	
MHW Tide	Daily Inundation	Port San Luis Boat Lift				$85,000	$523,100
MHW Tide	Daily Inundation	Restrooms				$12,000	$141,237
MHW Tide	Daily Inundation	Parking/Paved Area				$6,000	$103,600
Total						**$103,000**	**$767,937**
King Tide	Annual Inundation	Port San Luis Boat Lift				$227,000	$523,100
King Tide	Annual Inundation	Restrooms				$50,000	$141,237
King Tide	Annual Inundation	76 Gasoline Tank				$6,000	$28,661
King Tide	Annual Inundation	Mobile Boat Lift				$130,000	$523,100
King Tide	Annual Inundation	Parking/Paved Area				$119,000	$550,900
Total						**$532,000**	**$1,766,998**
100-Year Storm	1% Annual Chance	Port San Luis Boat Lift	$89,000	$123,000	$181,000	$616,000	$523,100
100-Year Storm	1% Annual Chance	Restrooms	$13,000	$25,000	$36,000	$157,000	$141,237
100-Year Storm	1% Annual Chance	76 Gasoline Tank	$2,000	$4,000	$7,000	$29,000	$28,661
100-Year Storm	1% Annual Chance	Sewer Lift Station	$3,000	$5,000	$10,000	$42,000	$41,848
100-Year Storm	1% Annual Chance	Mobile Boat Lift	$57,000	$87,000	$139,000	$469,000	$523,100
100-Year Storm	1% Annual Chance	Parking/Paved Area	$90,000	$137,000	$200,000	$1,042,000	$1,374,800
100-Year Storm	1% Annual Chance	Boat Storage Yard	$3,000	$10,000	$16,000	$209,000	$306,600
100-Year Storm	1% Annual Chance	Maintenance Shop	$4,000	$6,000	$16,000	$241,000	$376,632
100-Year Storm	1% Annual Chance	Harbor Office			$16,000	$145,000	$295,137
100-Year Storm	1% Annual Chance	Supply Closet			$3,000	$27,000	$52,310
100-Year Storm	1% Annual Chance	Parsons Building			$4,000	$134,000	$295,137
100-Year Storm	1% Annual Chance	Sewer Lift Station			$1,000	$48,000	$104,620
100-Year Storm	1% Annual Chance	Fat Cat's Restaurant			$6,000	$266,000	$502,176
100-Year Storm	1% Annual Chance	Sport Launch Bldg.			$6,000	$306,000	$523,100
100-Year Storm	1% Annual Chance	Laundry/Showers				$812,000	$6,657,757
Total			**$261,000**	**$397,000**	**$641,000**	**$4,543,000**	**$11,746,214**

Table 5-4: Sea-Level Rise Related Impacts to Facilities along Avila Beach Dr.

Sea-Level Rise Related Impacts to Facilities along Avila Beach Dr.			Year of Impact and Extent				Insured Value
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	
100-Year Storm	1% Annual Chance	Olde Port Beach Sewer Lift Station				$112,000	$313,860
100-Year Storm	1% Annual Chance	Fuel Facility/HazMat				$12,000	$26,042
100-Year Storm	1% Annual Chance	Olde Port Beach Parking Areas				$102,000	$235,956
100-Year Storm	1% Annual Chance	Olde Port Beach Restrooms				$84,000	$141,237
100-Year Storm	1% Annual Chance	Olde Port Beach Boat Launch				$354,000	$300,000
Total						**$664,000**	**$1,017,095**

Table 5-5: Sea-Level Rise Related Impacts to Facilities at Avila Beach.

Sea-Level Rise Related Impacts to Facilities at Avila Beach			Year of Impact and Extent				Insured Value
Hazard	**Frequency**	**Facility**	**2020**	**2030**	**2050**	**2100**	
King Tide	Annual Inundation	Parking/Paved Area				$1,000	$53,900
King Tide	Annual Inundation	Lifeguard Bldg. & Restrooms				$24,000	$324,322
King Tide	Annual Inundation	Lifeguard Towers				$45,000	$83,643
King Tide	Annual Inundation	Outlet				$2,000	$30,000
Total						**$72,000**	**$491,865**
100-Year Storm	1% Annual Chance	Parking/Paved Area	$6,000	$10,000	$16,000	$68,000	$152,600
100-Year Storm	1% Annual Chance	Lifeguard Bldg. & Restrooms	$13,000	$23,000	$63,000	$155,000	$324,322
100-Year Storm	1% Annual Chance	Lifeguard Towers	$27,000	$34,000	$46,000	$99,000	$83,643
100-Year Storm	1% Annual Chance	Outlet	$1,000	$2,000	$4,000	$22,000	$30,000
Total			**$47,000**	**$69,000**	**$129,000**	**$344,000**	**$590,565**

6. Sea-Level Rise Mitigation and Adaptation Measures

The following sections summarize efforts to protect and preserve trustee resources and structures, and provides estimates of anticipated costs for these measures.

6.1. Planned and Completed Capital Improvement Projects

Planned Capital Improvement Projects (CIPs) and projects completed in recent years, and measures to protect and preserve trustee resources and structures are outlined in the following.

6.1.1. Harbor Terrace

Harbor Terrace is a 32-acre upland coastal property developed for RV camping and overnight accommodations with a variety of complementary retail uses.

This development is on higher ground and not affected by sea-level rise.

6.1.2. Ongoing and Completed Projects

Ongoing and recently completed Capital Improvement Projects include:

- Ongoing Harford Pier redevelopment and maintenance
- Avila Pier rehabilitation project
- Underground Storage Tank (UST) replacement
- District Staff Landing (west)
- Mobile Hoist Pier extension project.

6.2. Proposed Capital Improvement Projects

Capital improvement projects identified as part of this sea-level rise vulnerability assessment are summarized in Table 6-1. In areas where broader sea-level rise related impacts are projected, the proposed improvements focus on providing mitigation for the general area. This is the case at Harford Landing where a parapet wall along the waterfront would help protect the area against sea-level rise and wave overtopping hazards. Similarly, for Avila Beach where the beach area and Front Street will be subject to the majority of sea-level rise and wave runup exposure. Upgrading the existing fence to a seawall will help protect Front Street and parking areas against wave runup and overtopping.

In areas where isolated impacts were found, local improvements are proposed. These primarily focus on floodproofing of exposed facilities.

Table 6-1: Proposed Capital Improvement Projects.

Area	Proposed Capital Improvement Projects	Frequency	Extent	Unit	Unit Cost	Total Cost ($)
Harford Landing	Repave waterfront parking/paved areas	Every 25 years	78,700	SF	$15	$1,181,000
	Incorporate parapet wall along waterfront	Once	1,500	LF	$1,200	$1,800,000
Avila Beach Drive	Floodproof lift station	Once	550	SF	$30	$17,000
Avila Beach	Replace beach promenade fence with sea wall	Once	1,440	LF	$1,200	$1,728,000
	Repave beach front parking/paved areas	Every 25 years	7,700	SF	$15	$116,000
	Floodproof restrooms	Once	1,400	SF	$30	$42,000

6.3. Adaptation and Mitigation Measures

Proposed adaptation measures are described in the following.

- Repair and improve revetment, jetty, and breakwater to better withstand effects of SLR.
- Continue beach nourishment via dredging to replenish areas of sediment loss.
- Establish alternative access route in the event Avila Beach Drive is inundated during high-water events.
- Design new facilities to be resilient to sea-level rise over the period of their intended service life. Upgrade or implement design improvements for flood-control structures that protect existing critical infrastructure. Flood-proof existing critical structures at risk. Reinforce bulkheads and relocate any infrastructure that is located underneath them. Relocate or redesign docks, boat launch sites, boardwalks and other at-risk infrastructure as water levels change, taking into account potential future climate impacts, best management practices and green infrastructure principles.
- Follow existing or develop new standards requiring that floodproof materials be used in the construction of new infrastructure and in the repair or protection of existing infrastructure. Elevate the surface or grade of facilities in low-lying areas with poor drainage or relocate them to higher areas. Locate utilities and critical facilities outside of areas susceptible to sea level rise to decrease the risk of service disruption.
- Prioritize inspection, maintenance, and repair of critical coastal structures, especially after large storm events. Adjust routine operations, maintenance and inspection, and capital budget expenses to prepare for more frequent and intense storms, wave overtopping and flooding. Nourish beaches to replenish sand.
- Work with local jurisdictions to incorporate consideration of climate change into ongoing land use planning efforts such as growth management, development planning, and adaptive management.
- Collaborate with local, regional, and state transportation and infrastructure agencies to identify and evaluate the options to mitigate potential risks to coastal infrastructure such as roads, coastal facilities, and erosion control or sea wall protection structures.
- Identify and invest in non-motorized transportation corridors (bike and pedestrian) that will provide alternatives if significant roadways are disrupted.
- Enhance the preparedness of district staff to respond to climate change related emergencies such as heat extremes, heavy rain, localized flooding, wave overtopping and other emerging public concerns.

- Educate the public about climate change and related impacts, e.g. via plaques at key locations of public access, or via outreach and education sessions to inform and engage the public in maintaining shoreline access for all.
- Improve communication and coordination between those that own and manage the shoreline (levees, marsh, beach) and those that own and manage the assets that are protected by these shorelines.
- Identify public transportation assets at risk of flooding that serve transit dependent users.
- Support expanded Community Emergency Response Team (CERT) training, refresher classes, and annual exercises that include flooding preparedness and response.
- Continue to monitor sea-level rise via local tide gauge.

6.3.1. Coastal Roads

As sea-level rise hazards will vary depending on the tides, flood impacts to coastal roads will be progressive. Any damage to roads would be repaired by SLO County or Caltrans, depending on ownership.

6.3.2. Culverts and Stormwater Outlets

Potential sea-level rise related erosion around culverts and stormwater outlets can likely be managed under the regular program for maintenance and upkeep by SLO county or Caltrans. The common method for preventing tidewaters from backing into culverts is to outfit these with tide gates. Pipe outlets for discharge are typically outfitted with backflow prevention devices such as duckbill valves and flap gates.

6.4. Sea-Level Rise Monitoring

There are already Federal incentives in place to monitor sea-level rise at Avila Beach. NOAA maintains a tide gauge at Port San Luis, NOAA Station #9412110, which enables a determination of the local sea-level rise trend. Figure 6-1 shows the latest data for Port San Luis, indicating that the current sea-level rise trend is estimated at 0.98 mm per year, which would be equivalent to a change of 0.32 feet in 100 years if the current trend remains.

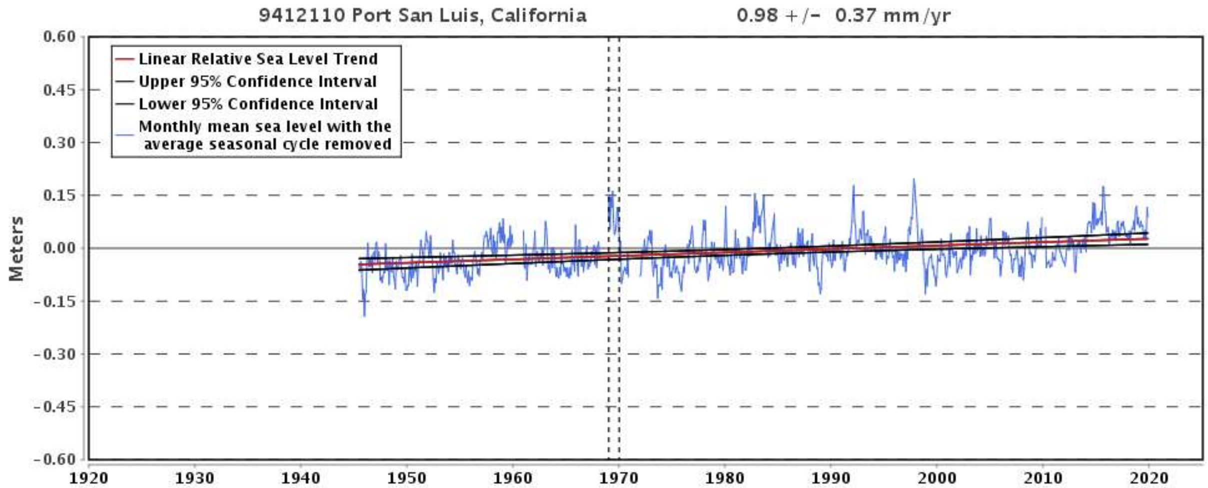

Figure 6-1: Relative sea-level trend for Port San Luis.

References

ASCE (2017). *Minimum Design Loads and Associated Criteria for Buildings and Other Structures.* ASCE Standard, ASCE/SEI 7-16. American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI). ISBN 9780784479964. Published by American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia, 20191-4382.

BLS (2020). *Consumer Price Index.* Bureau of Labor Statistics, Division of Consumer Prices and Price Indexes. United States Department of Labor, PSB Suite 3130, 2 Massachusetts Avenue, NE Washington, DC 20212-0001. https://www.bls.gov/cpi/factsheets/escalation.htm

Cal-EMA (2009). *California Official Tsunami Inundation Maps.* Tsunami Inundation Map for Emergency Planning. State of California, County of San Luis Obispo. Port San Luis Quadrangle , Pismo Beach Quadrangle. Scale 1:24,000. California Emergency Management Agency (Cal-EMA), California Geological Society (CGS), University of Southern California (USC). July 1, 2009. https://www.conservation.ca.gov/cgs/tsunami/maps

Costanza et al. (2006). *Quality of life: An approach integrating opportunities, human needs, and subjective well-being.* Ecological economics 61.2 (2007): 267-276.

CSLO (2003). *San Luis Obispo Waterway Management Plan.* Volume I, San Luis Obispo Creek Watershed. City of San Luis Obispo, Department of Public Works, 955 Morro Street, San Luis Obispo, California 93401 and County of San Luis Obispo, Flood Control District - Zone 9, 1050 Monterey Street, Room 207, San Luis Obispo, California 93408.

Dewberry (2016). *West Coast El Nino 2016 B16 LiDAR.* Report Produced for U.S. Geological Survey. USGS Contract: G10PC00020, Task Order: G16PD00366, Report Date: 11/03/2016. Produced by Dewberry & Davis LLC, 1000 N. Ashley Drive, Suite 801, Tampa, FL 33602-3718.

EAB (2017). *Interactive Map of Avila.* Enjoy Avila Beach. www.avilabeachpier.com

JGR (2016). *GPS Imaging of vertical land motion in California and Nevada: Implications for Sierra Nevada Uplift.* Journal of Geophysical Research. Solid Earth. W.C. Hammond, G. Blewitt, C. Kreemer. PMCID: PMC5114868. PMID: 27917328 Published online 2016 Oct 30. doi: 10.1002/2016JB013458.

K&K (1968). *Port San Luis Interior Configuration and Economic Feasibility Study.* Preliminary Report. Prepared for Port San Luis Harbor District. Prepared by Koebig & Koebic, Inc. Engineering-Architecture-Planning, Los Angeles, California. August, 1968.

NOAA (2020a). *Tides and Currents*. Center for Operational Oceanographic Products and Services (CO-OPS), 1305 East-West Highway, Silver Spring, MD 20910-3281. Phone: (301) 713-2815. https://tidesandcurrents.noaa.gov/

NOAA (2020b). *Coastal LiDAR.* National Oceanic and Atmospheric Administration, Office of Coastal Management. Data Access Viewer: *https://coast.noaa.gov/dataviewer/#/*

NRC (2012). *Sea-level rise for the coasts of California, Oregon, and Washington: past, present, and future*. National Academies Press.

OPC (2018). *State of California Sea-Level Rise Guidance.* California Ocean Protection Council, 2018 Update.

PI (2012). *Social Vulnerability to Climate Change in California.* Prepared for: California Energy Commission. Prepared by: Pacific Institute, Heather Cooley, Eli Moore, Matthew Heberger, and Lucy Allen. Pacific Institute, 653 13th St., Oakland, CA 95814. July 2012, Updated September 28, 2012.

Protsman (2018). *A Sea Level Rise Vulnerability Assessment and Adaptation Strategies for the County of San Luis Obispo.* A Professional Project presented to the Faculty of California Polytechnic State University, San Luis Obispo. In Partial Fulfillment of the Requirements for the Degree Master of City and Regional Planning by Jacqueline N. Protsman, June 2018.

Raheem et al. (2009). *The economic value of coastal ecosystems in California.* US Environmental Protection Agency, Office of Research and Development, 2009.

Raheem et al. (2012). *Application of non-market valuation to California's coastal policy decisions, Marine Policy.* 36.5 (2012): 1166-1171.

RFF (2016) *A Look at 35 Years of Flood Insurance Claims.* An analysis of more than one million flood claims under the National Flood Insurance Program. Carolyn Kousky and Erwann Michel-Kerjan. Resources for the Future, 1616 P St. NW, Suite 600, Washington, DC 20036. Published in Resources No. 191, Winter 2016.

SLOC (2016). *Tsunami Emergency Response Plan.* Prepared by San Luis Obispo County Office of Emergency Services. April 2016.

USACE (1978). *Type 16 Flood Insurance Study: Tsunami Predictions for the West Coast of the Continental United States.* Technical Report H-78-26. Prepared for Federal Insurance Administration, Department of Housing and Urban Development, Washington, D.C. 20314. Prepared by: James R. Houston, Andrew W. Garcia. Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. 39810. Final Report, December 1978.

USGS (2013). *Modeling for the SAFRR Tsunami Scenario – Generation, Propagation, Inundation, and Currents in Ports and Harbors.* Open-File Report 2013-1170-D. California Geological Survey Special Report 229. chap. D, in Ross, S.L., and Jones, L.M., eds., The SAFRR (Science Application for Risk Reduction) Tsunami Scenario. U.S. Department of the Interior. U.S. Geological Survey. The SAFRR Tsunami Modeling Group, 2013. http://pubs.usgs.gov/of/2013/1170/d/

Appendix A: Overall Regional Flood Maps

Port of San Luis Harbor District Area Map
FEMA FIRM
Area Topography, 2016 NOAA Coastal LiDAR
1939 Shoreline
Existing Conditions, 2030, 2050, and 2100 Maps of Tidal Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of King Tide Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of 100-Year Storm Flooding
Existing Conditions, 2030, 2050, and 2100 Maps of Tsunami Runup
Existing Conditions, 2030, 2050, and 2100 Maps of Tsunami Inundation

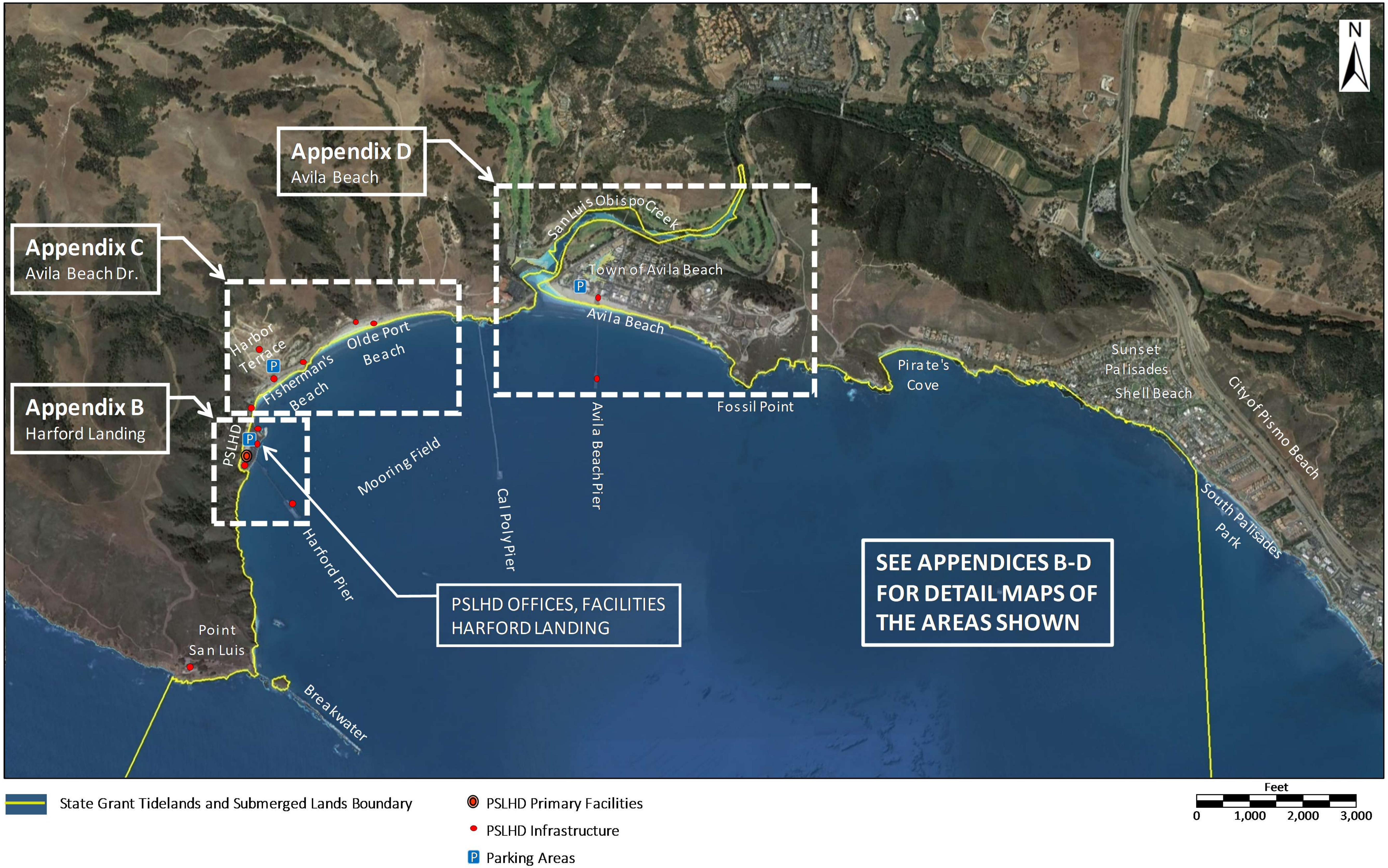

Plate 1: Port San Luis Area Map.

Plate 2: FEMA FIRM for Avila Beach.

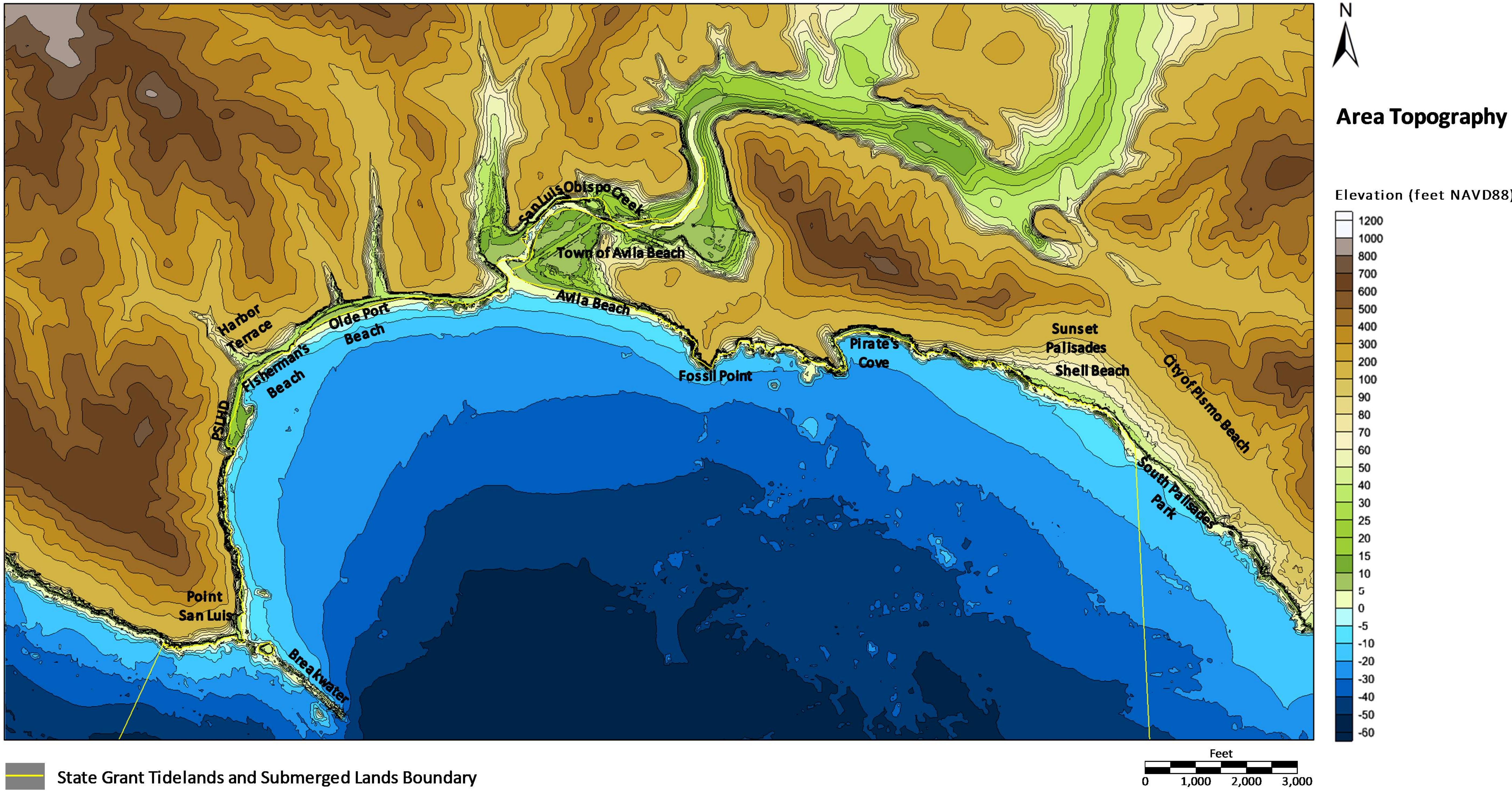

Plate 3: Area Topography, NOAA Coastal 2016 LiDAR.

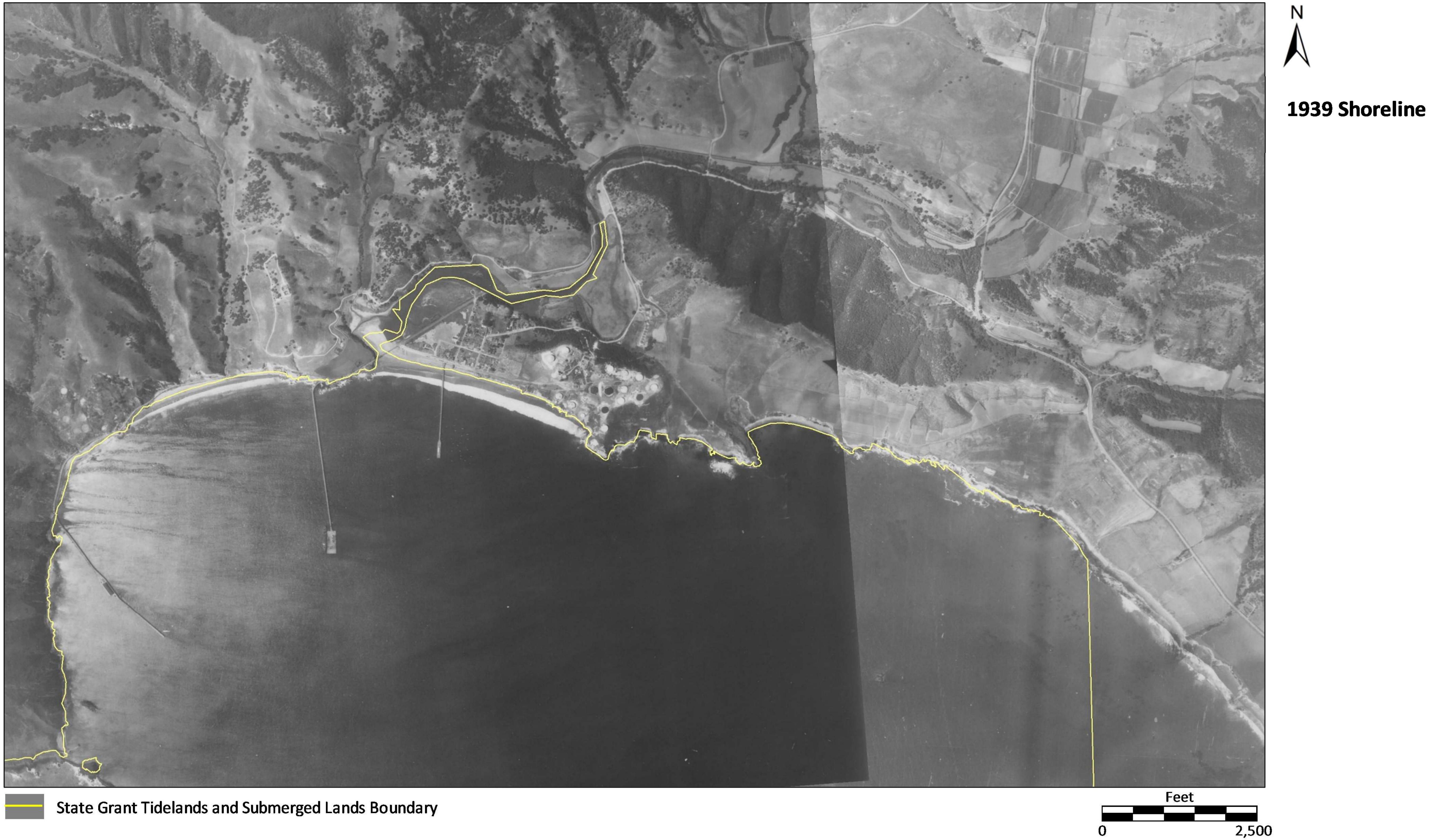

Plate 4: Avila Beach, 1939 Shoreline.

Plate 5: Flood Hazard Zones associated with Daily Inundation due to Rising Tides for Existing Conditions.

Plate 6: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2030.

Plate 7: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2050.

Plate 8: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2100.

Plate 9: Flood Hazard Zones associated with King Tides for Existing Conditions.

Plate 10: Flood Hazard Zones associated with King Tides and SLR by 2030.

Plate 11: Flood Hazard Zones associated with King Tides and SLR by 2050.

Plate 12: Flood Hazard Zones associated with King Tides and SLR by 2100.

Plate 13: Flood Hazard Zones associated with a 100-Year Storm for Existing Conditions.

Plate 14: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2030.

Plate 15: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2050.

Plate 16: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2100.

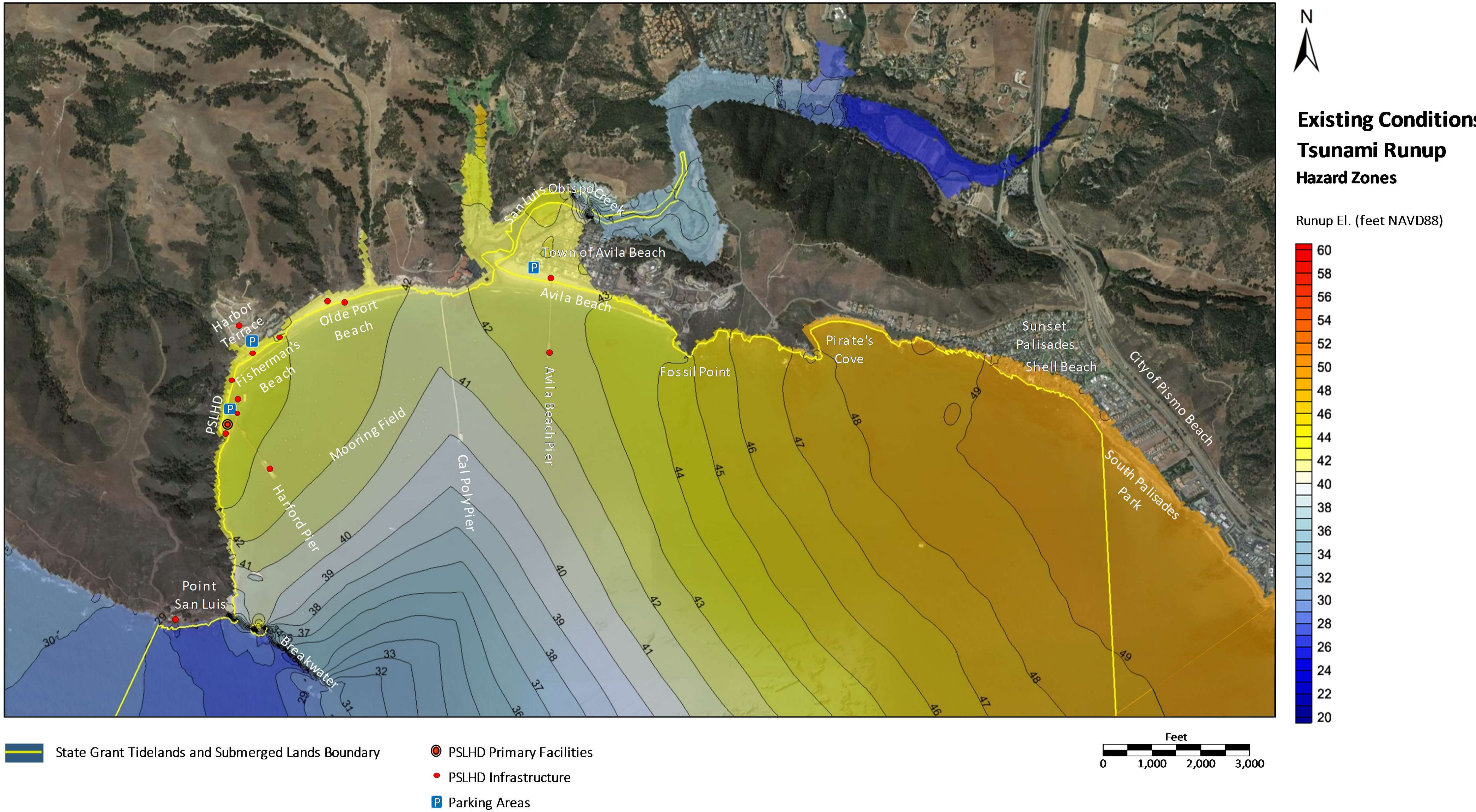

Plate 17: Wave Runup associated with Tsunami Hazards for Existing Conditions.

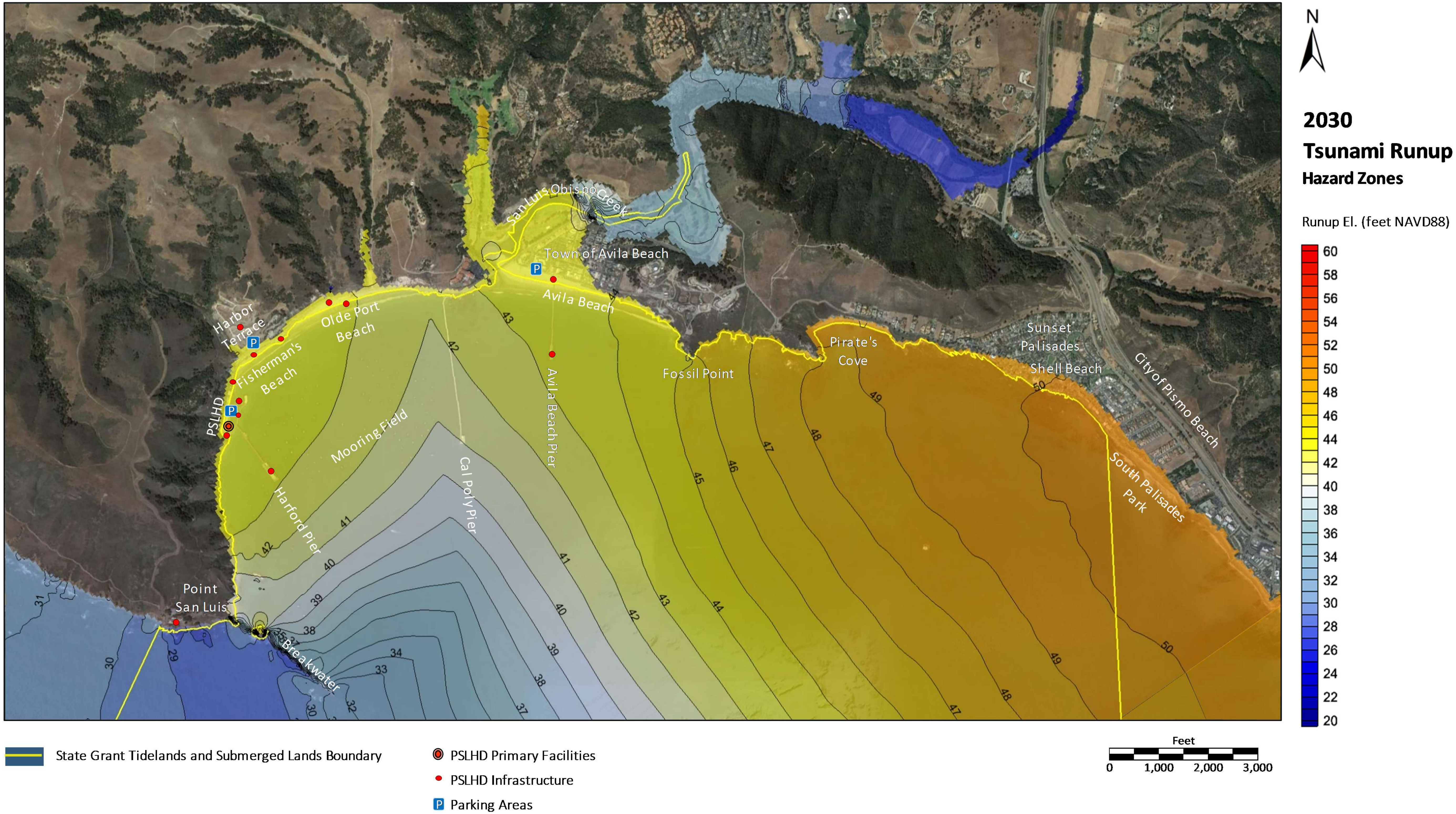

Plate 18: Wave Runup associated with Tsunami Hazards and SLR by 2030.

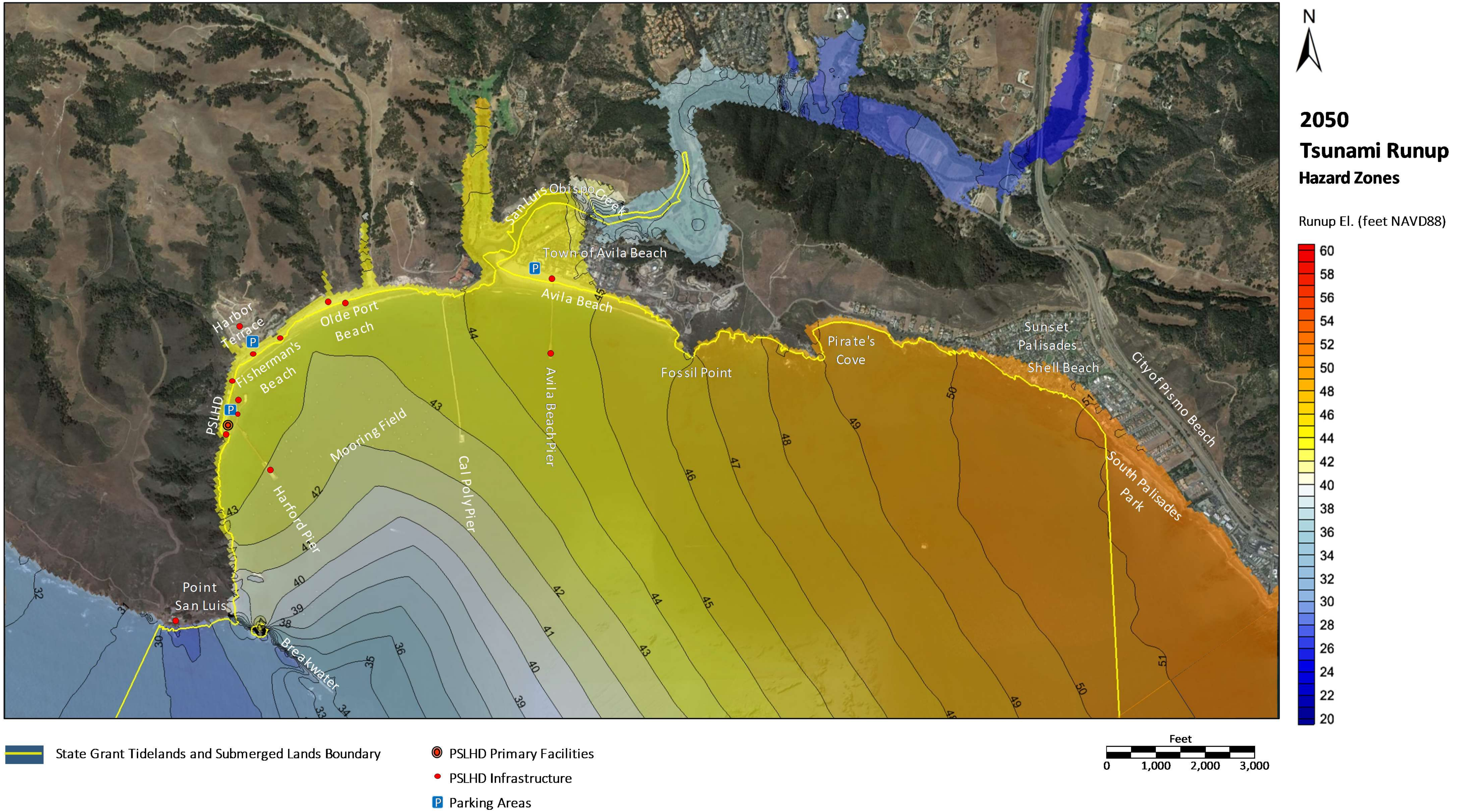

Plate 19: Wave Runup associated with Tsunami Hazards and SLR by 2050.

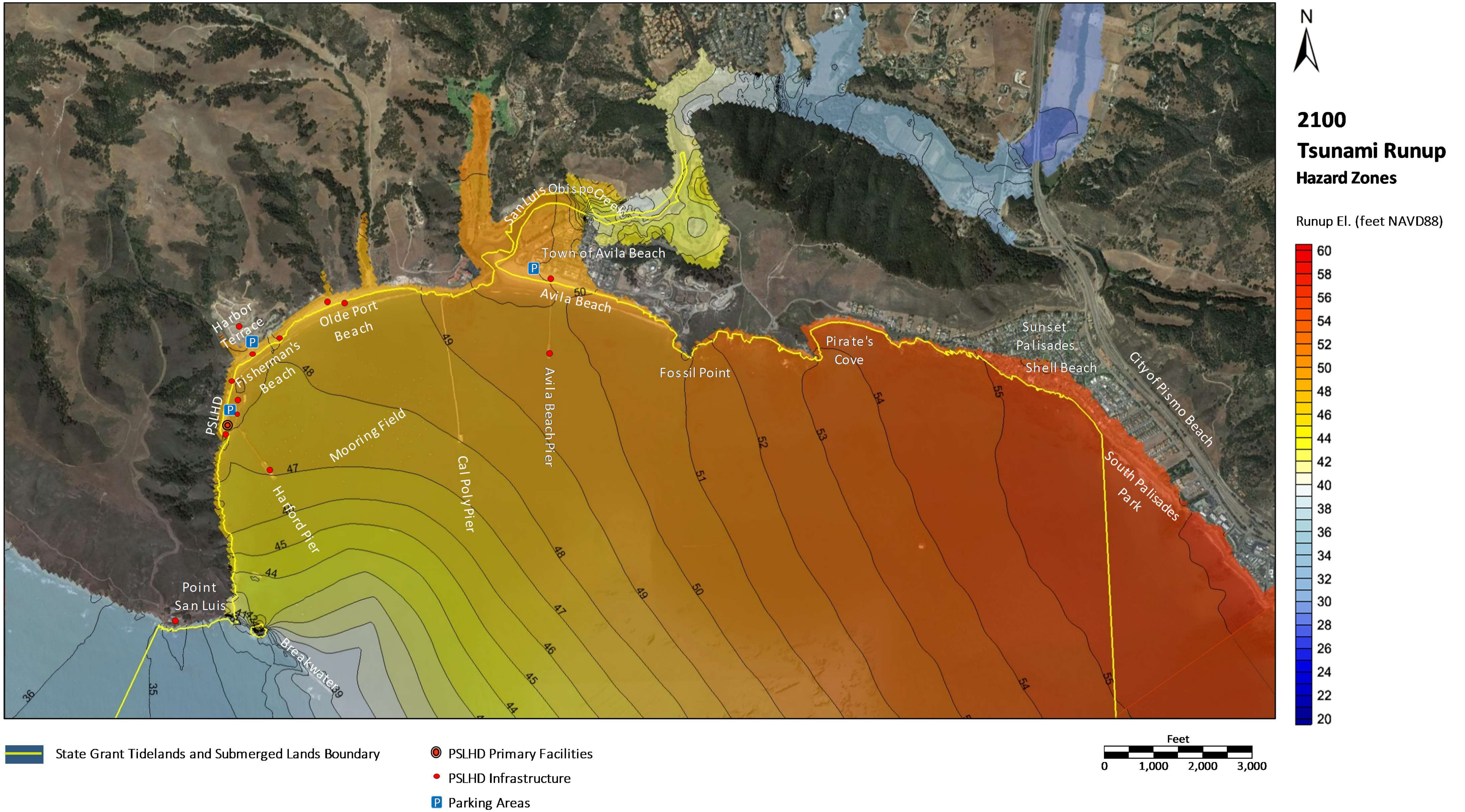

Plate 20: Wave Runup associated with Tsunami Hazards and SLR by 2100.

Plate 21: Inundation associated with Tsunami Hazards for Existing Conditions.

Plate 22: Inundation associated with Tsunami Hazards and SLR by 2030.

Plate 23: Inundation associated with Tsunami Hazards and SLR by 2050.

Plate 24: Inundation associated with Tsunami Hazards and SLR by 2100.

Appendix B

Port San Luis / Harford Landing

Area Map
Existing Conditions, 2030, 2050, and 2100 Maps of Tidal Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of King Tide Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of 100-Year Storm Flooding

Plate 1: Port San Luis/Harford Landing Area Map, EAB (2017).

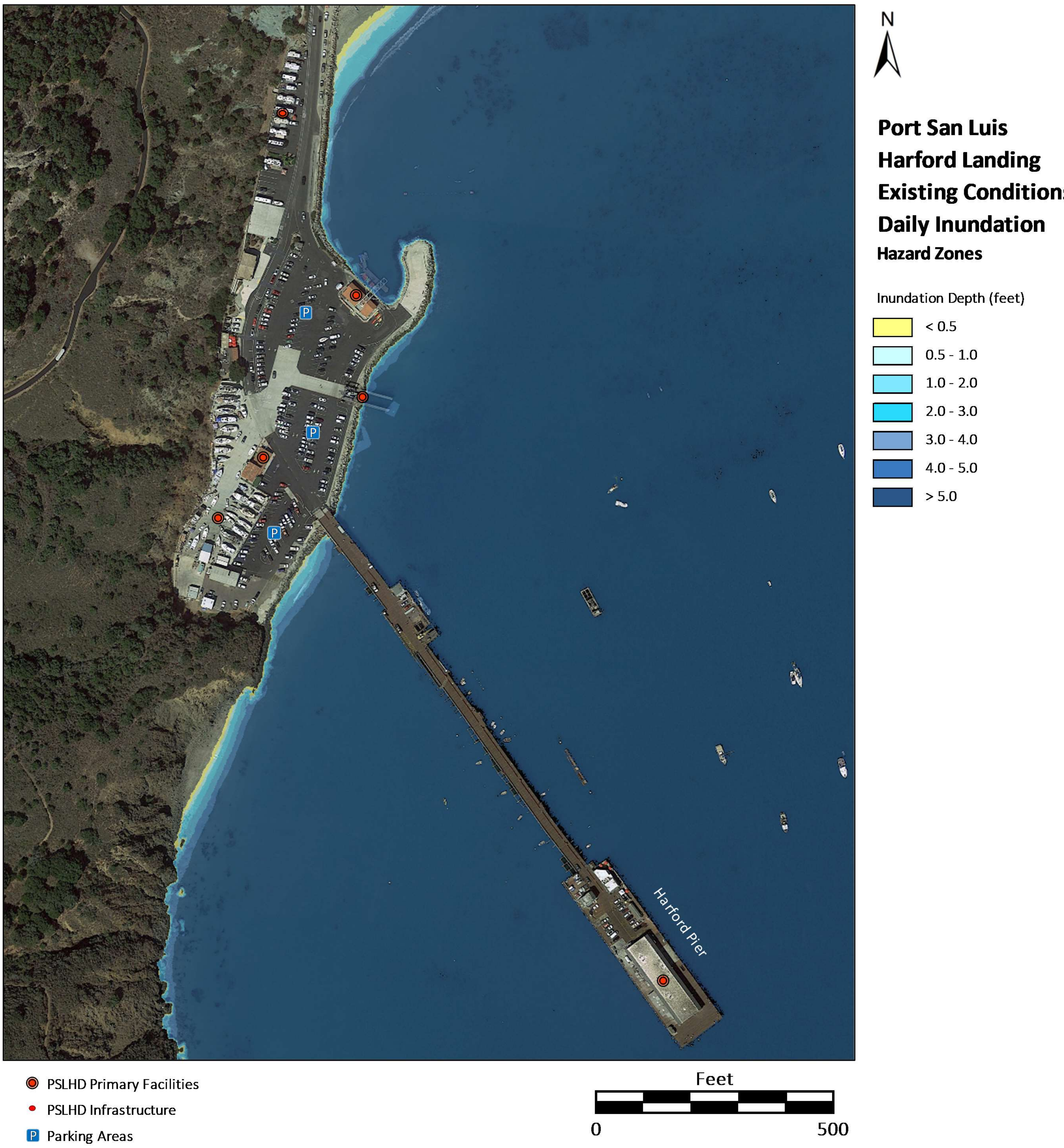

Plate 2: Flood Hazard Zones associated with Daily Inundation due to Rising Tides for Existing Conditions.

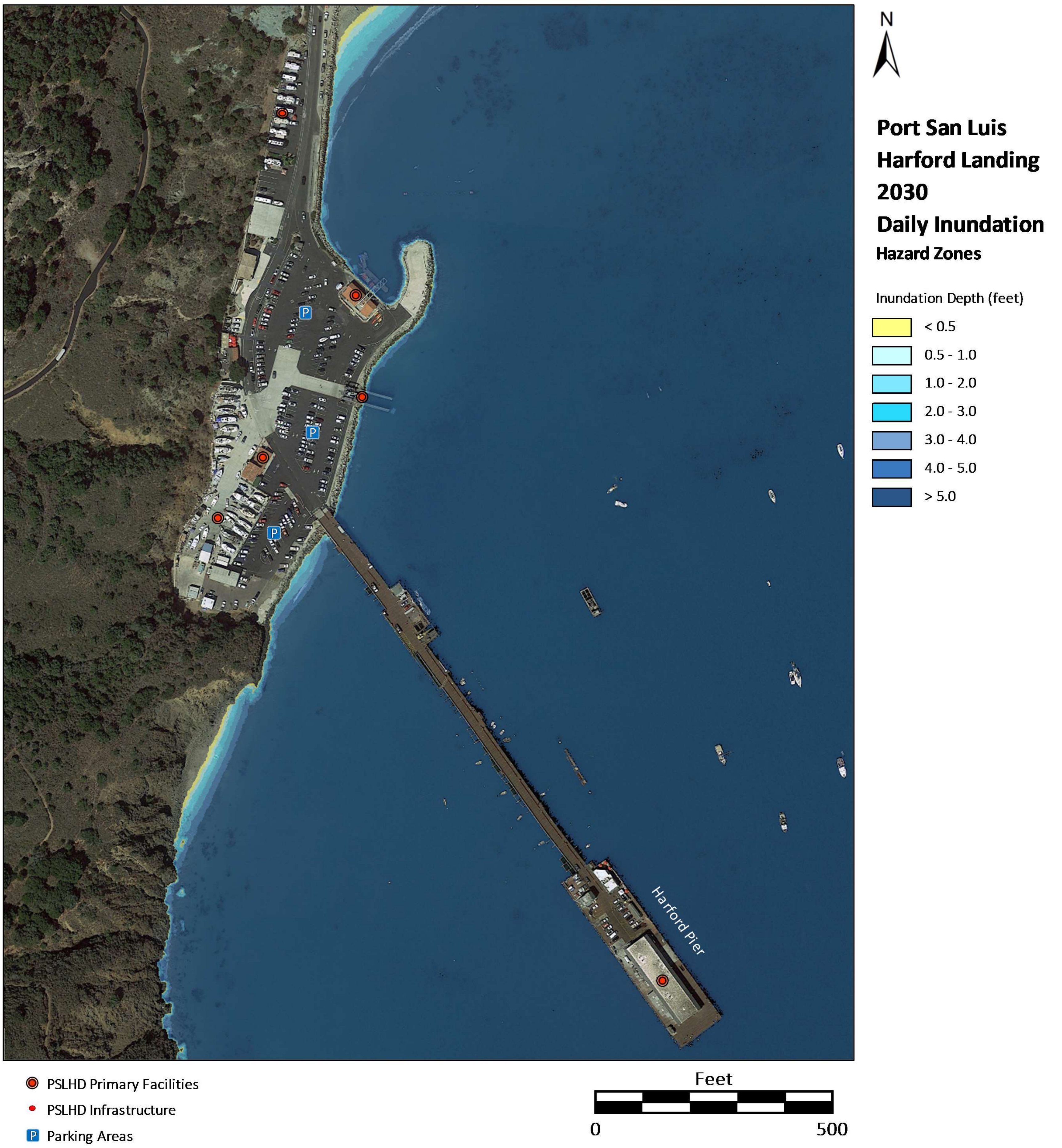

Plate 3: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2030.

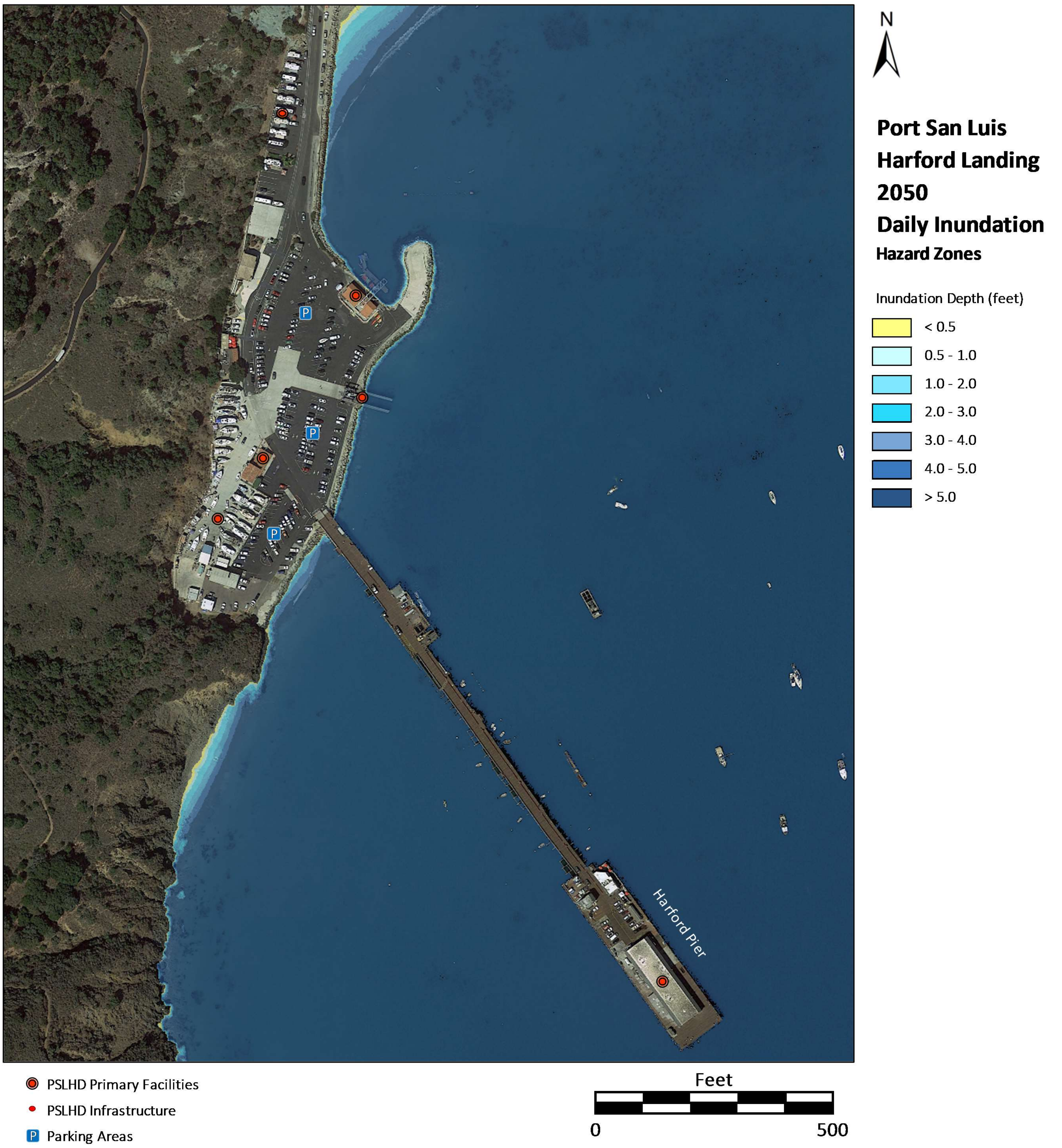

Plate 4: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2050.

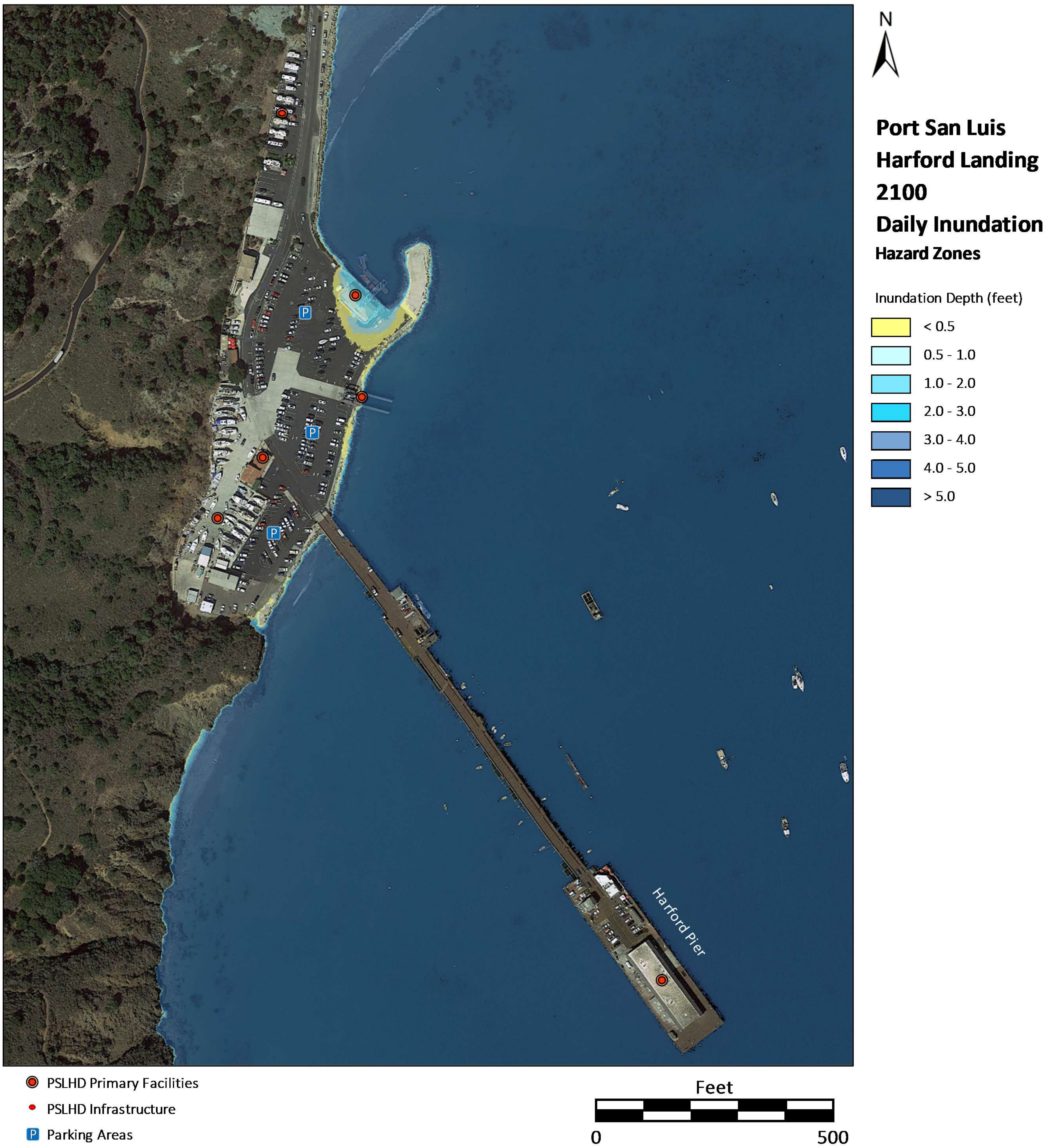

Plate 5: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2100.

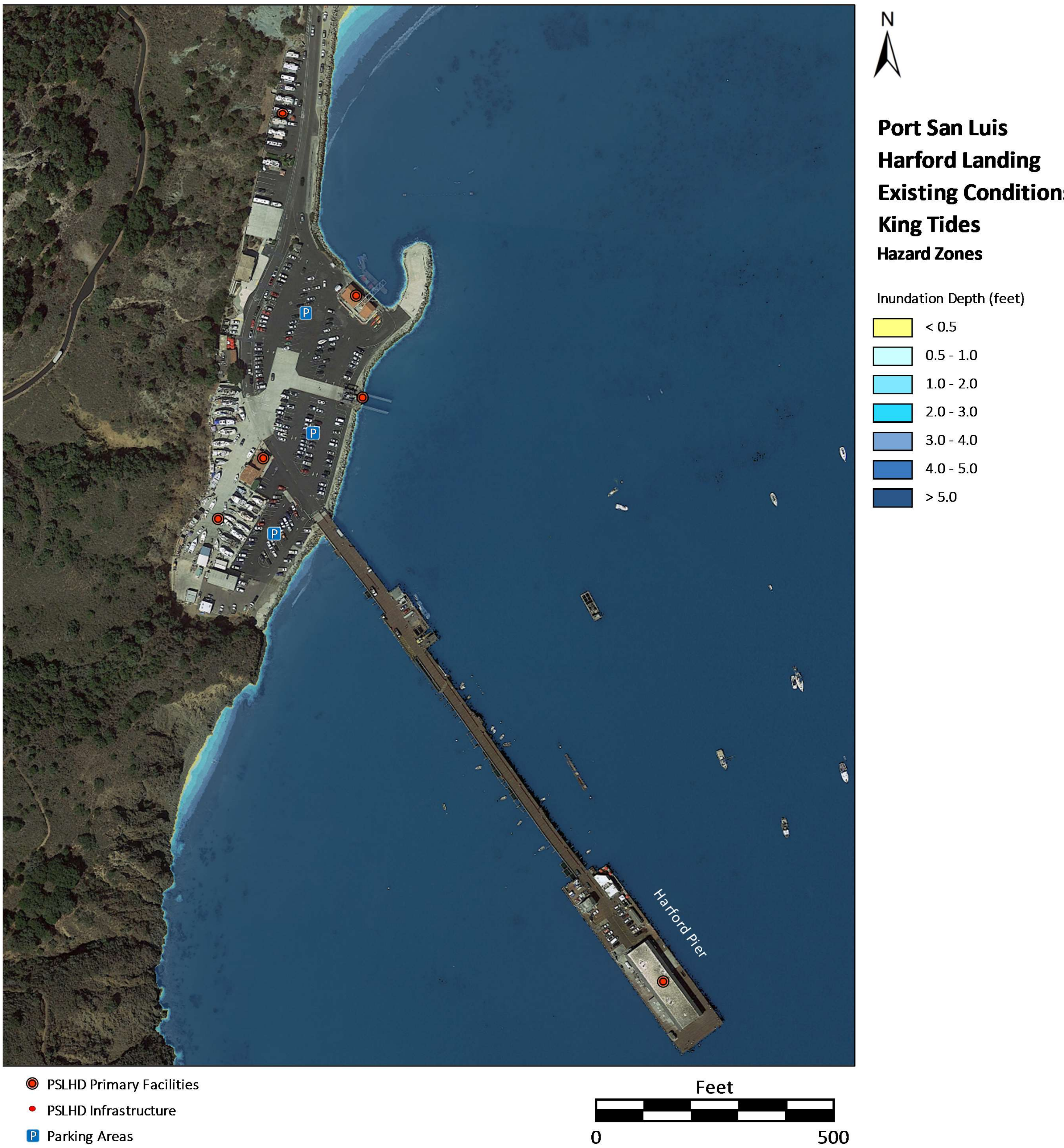

Plate 6: Flood Hazard Zones associated with King Tides for Existing Conditions.

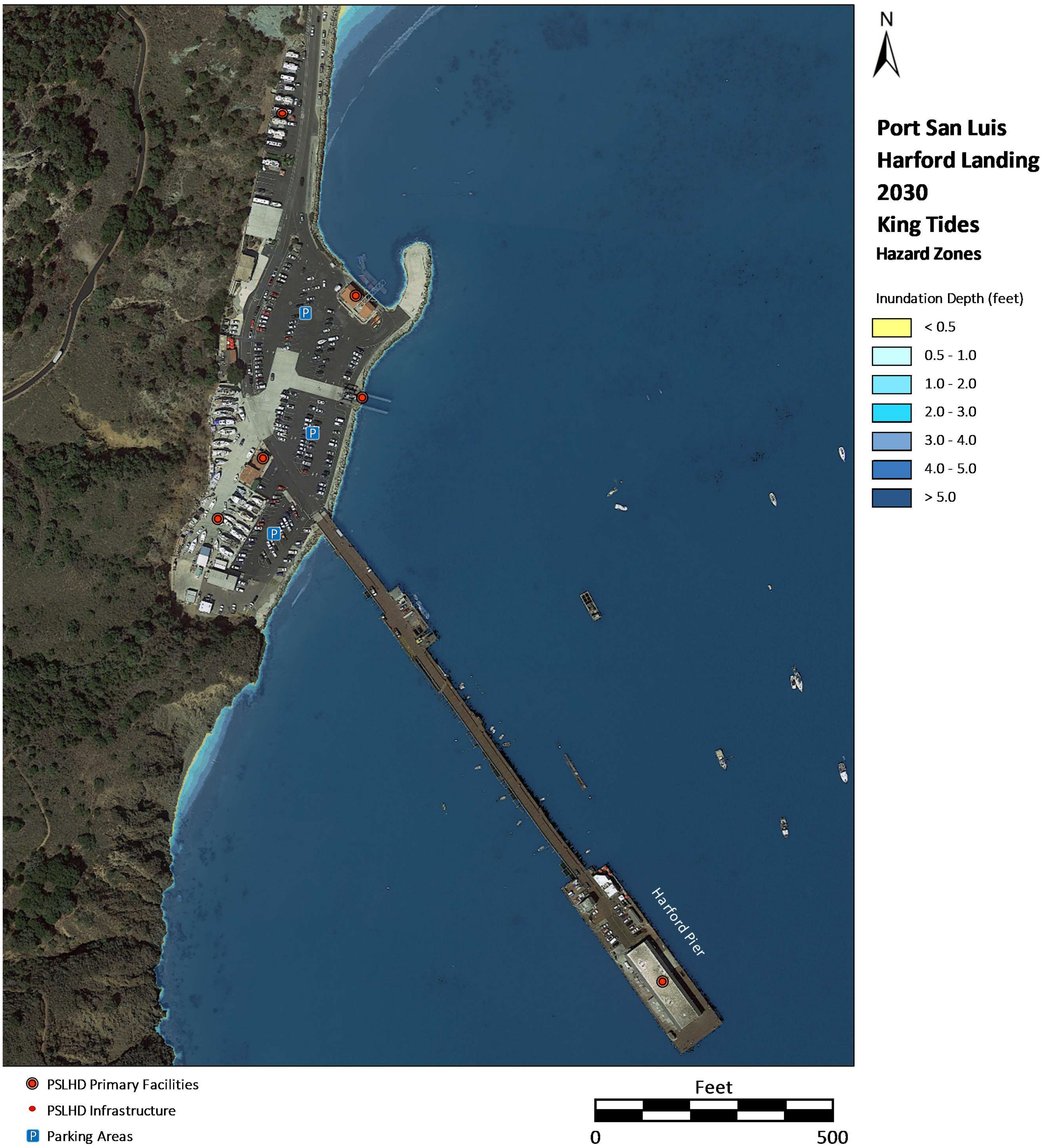

Plate 7: Flood Hazard Zones associated with King Tides and SLR by 2030.

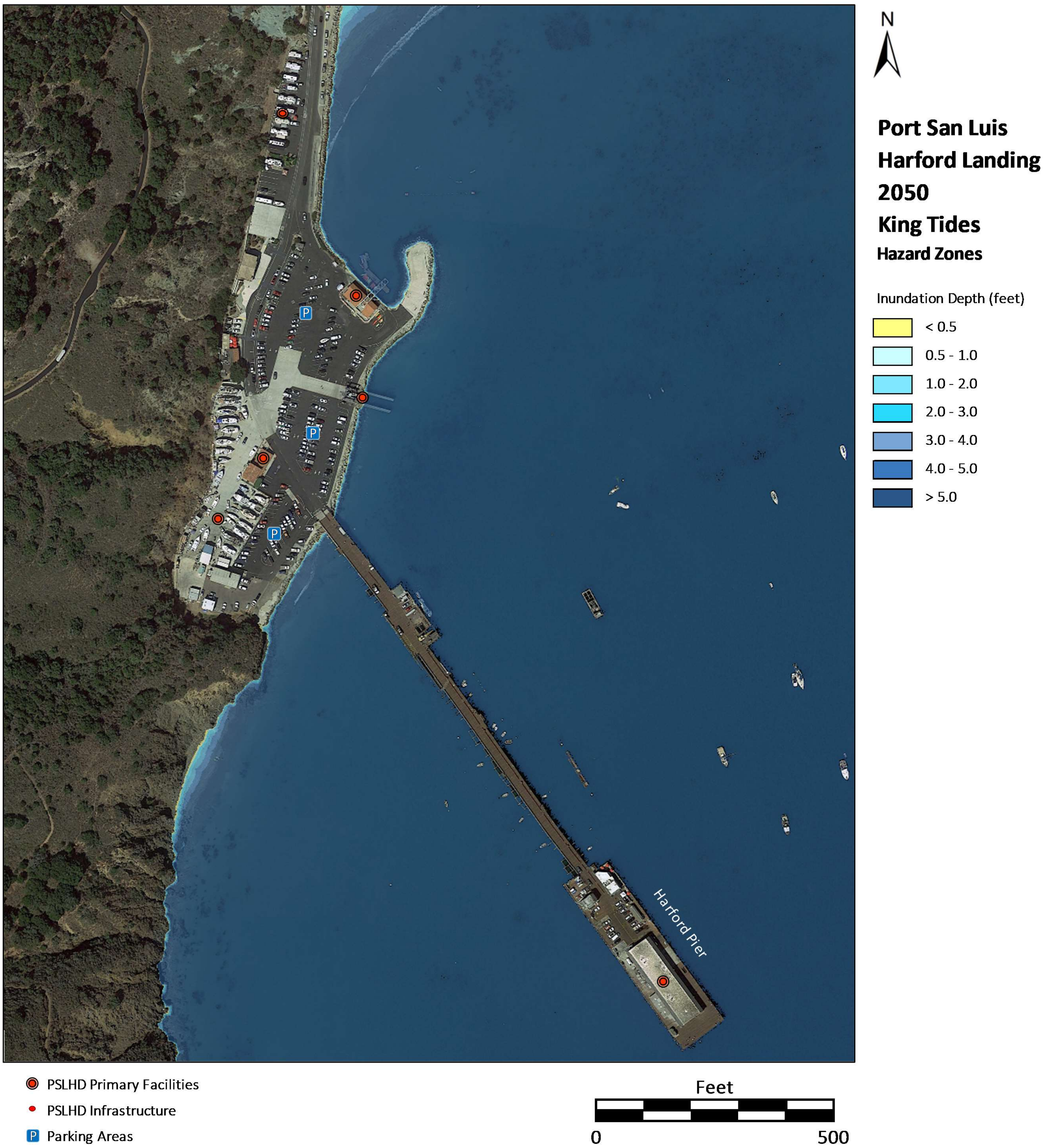

Plate 8: Flood Hazard Zones associated with King Tides and SLR by 2050.

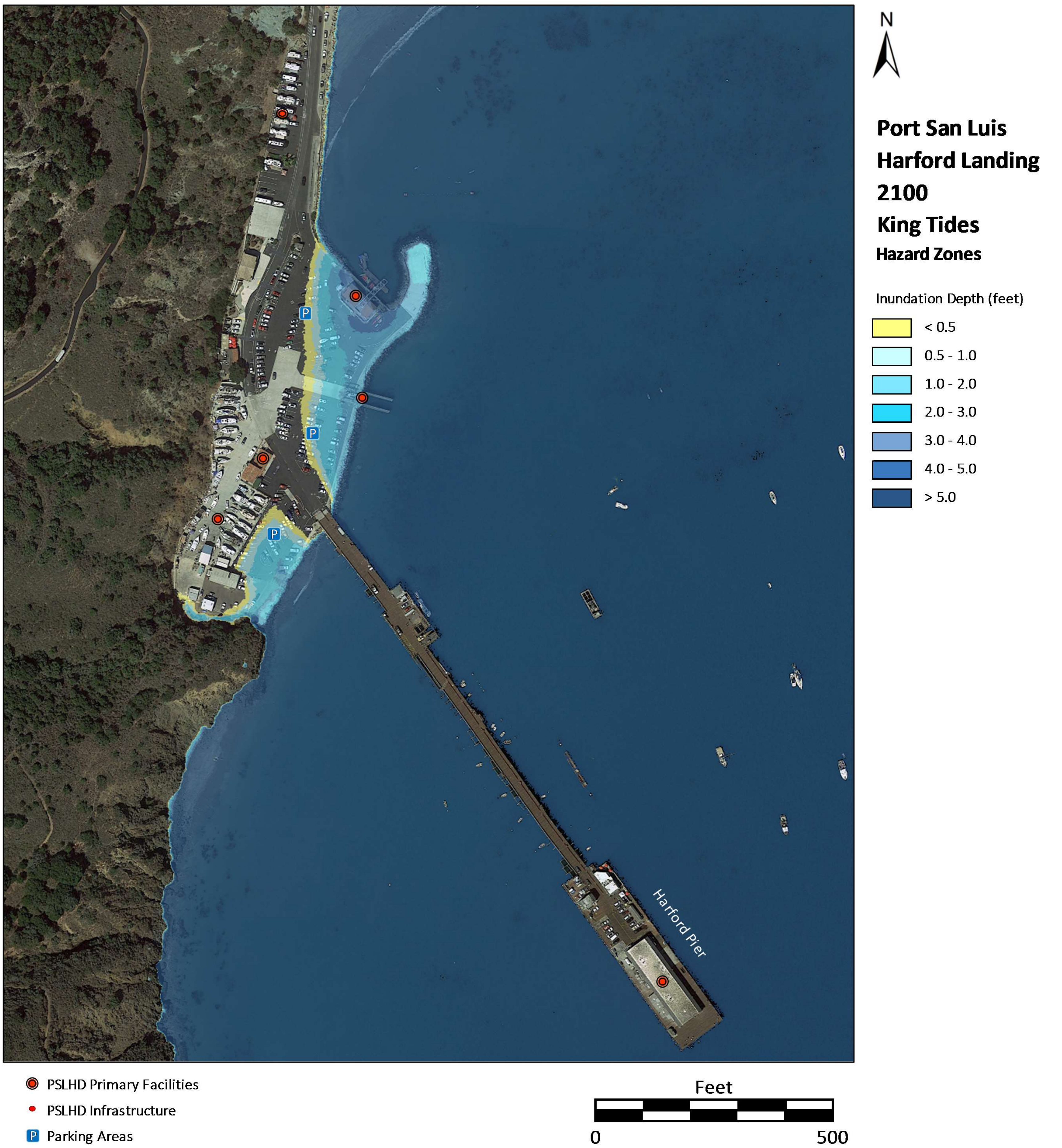

Plate 9: Flood Hazard Zones associated with King Tides and SLR by 2100.

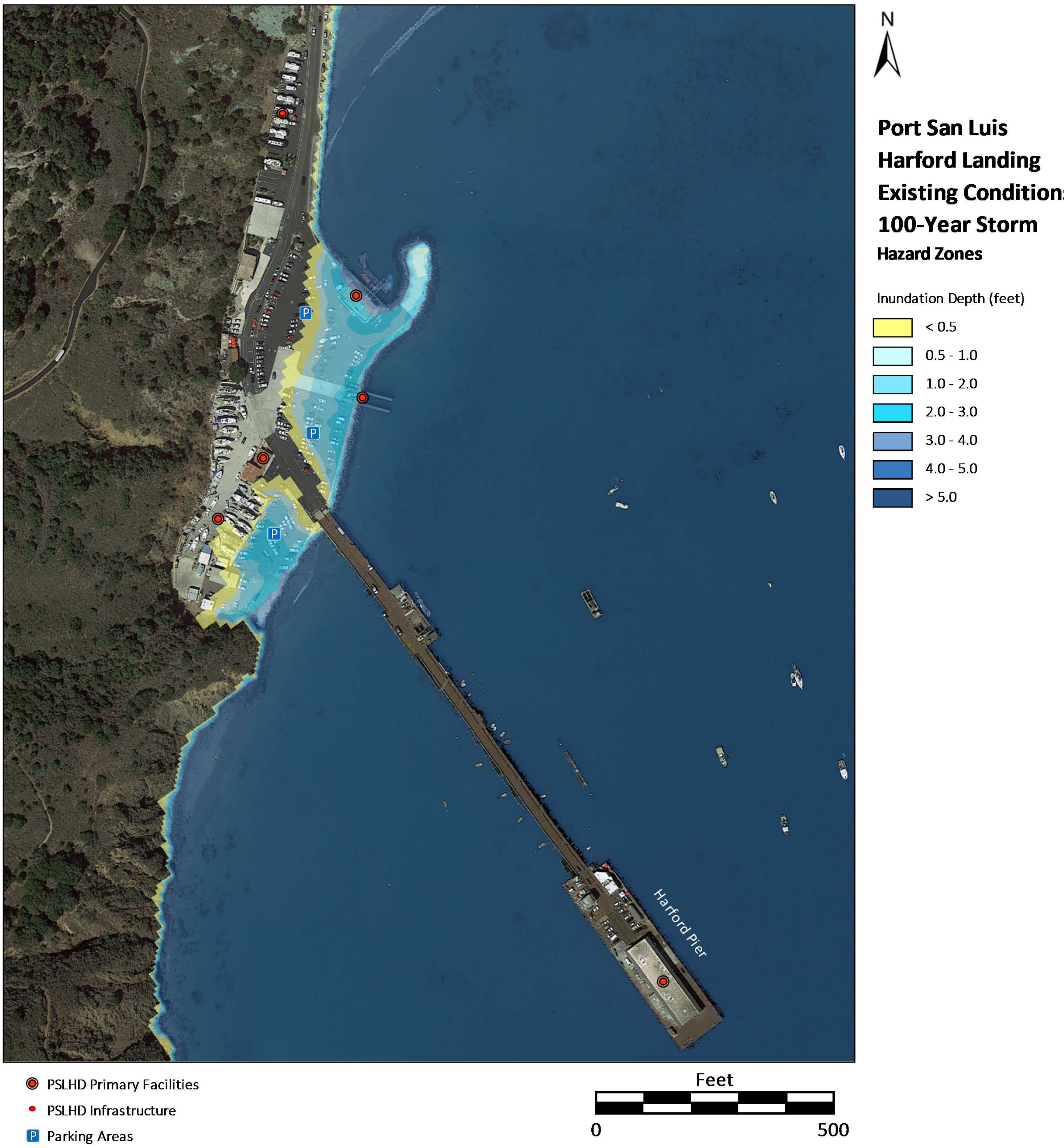

Plate 10: Flood Hazard Zones associated with a 100-Year Storm for Existing Conditions.

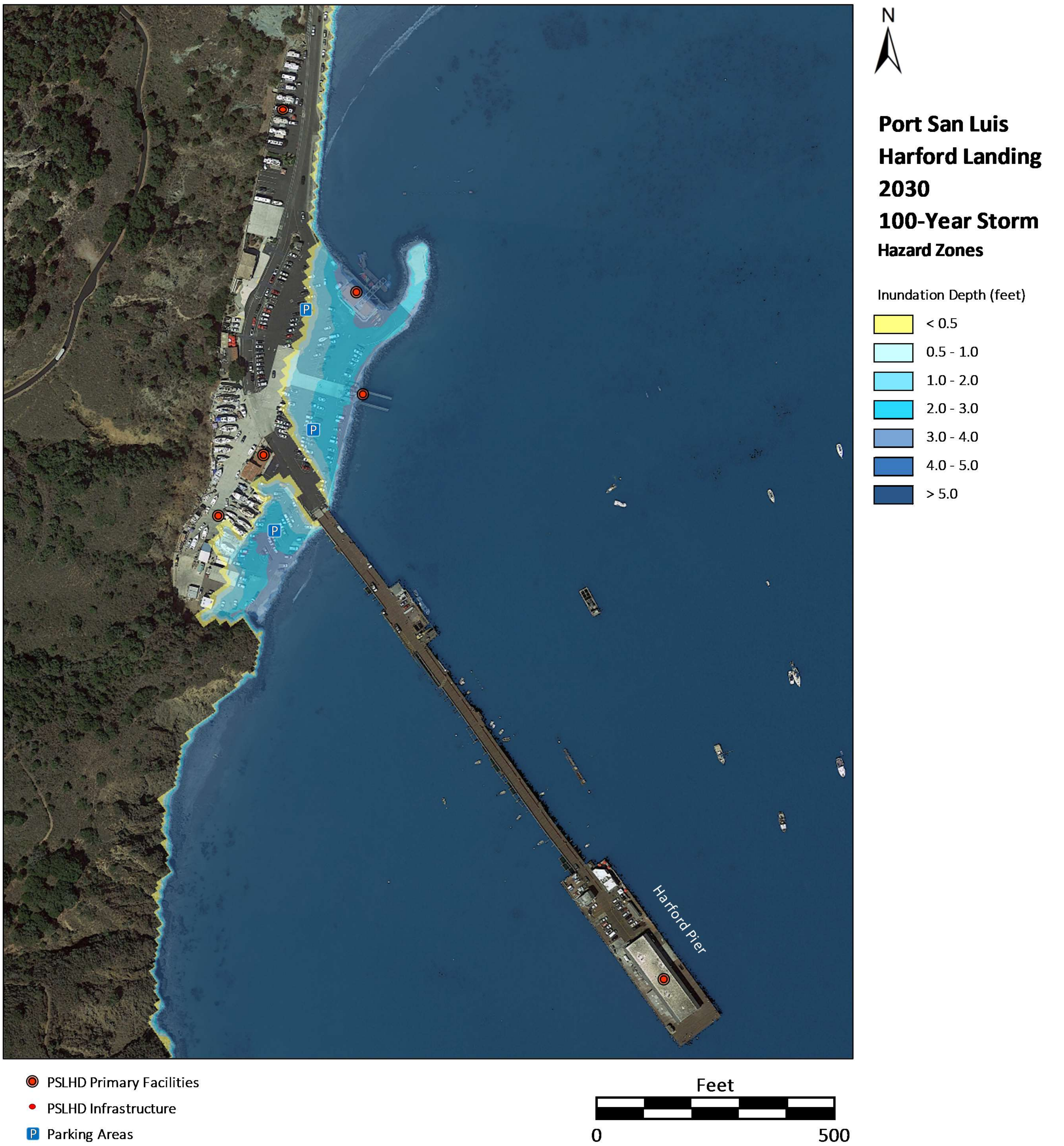

Plate 11: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2030.

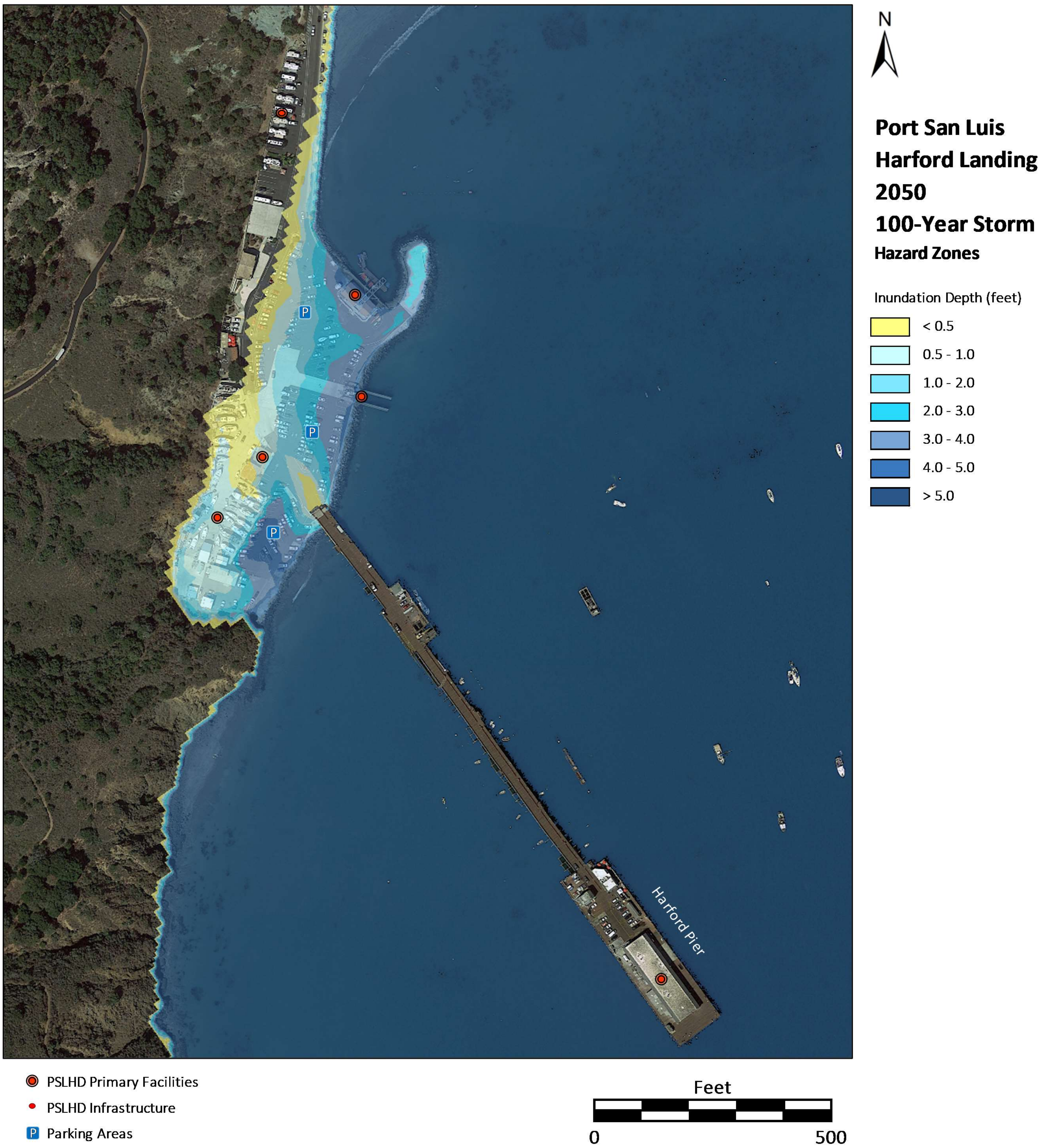

Plate 12: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2050.

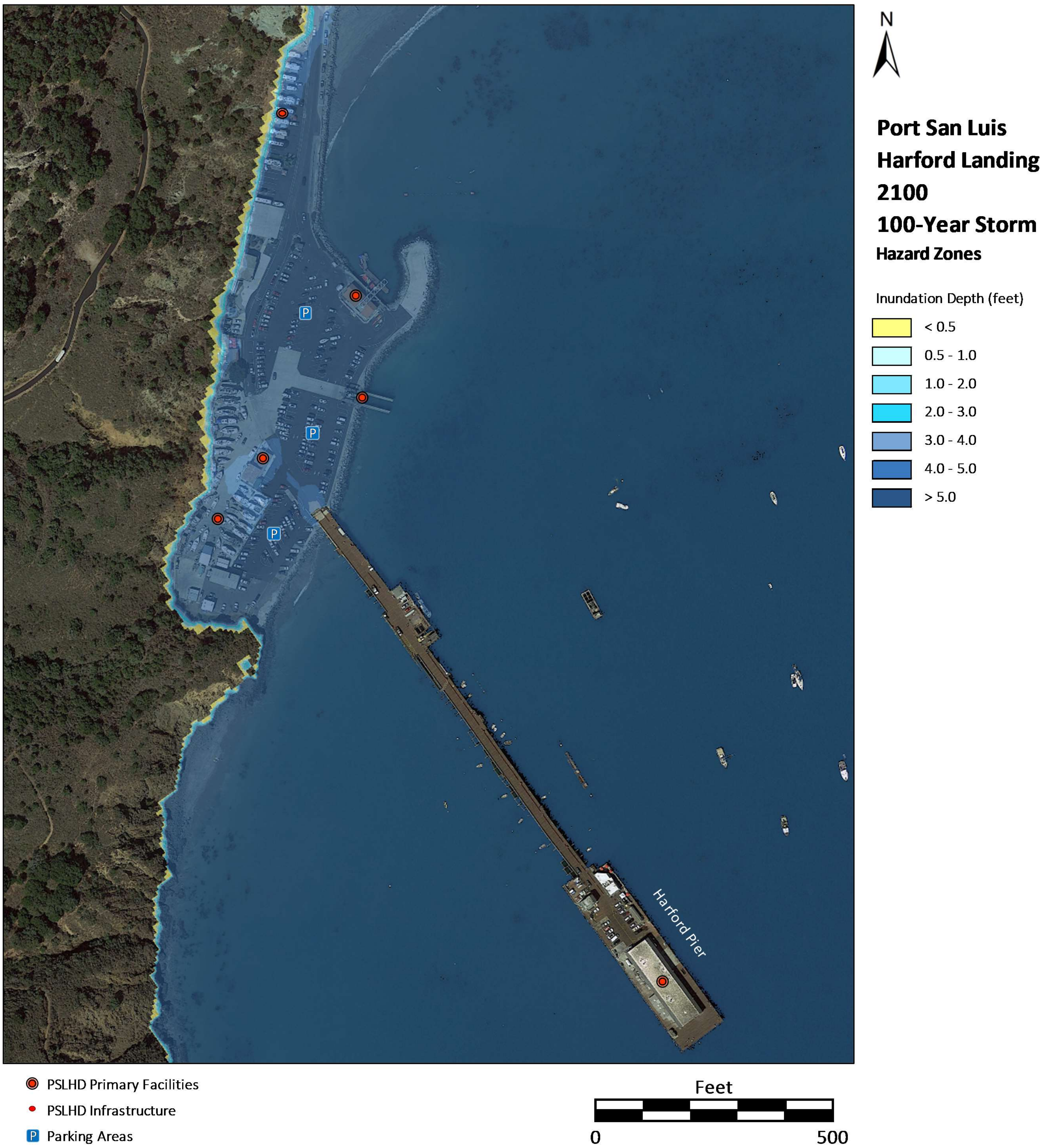

Plate 13: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2100.

Appendix C

Avila Beach Drive

Area Map
Existing Conditions, 2030, 2050, and 2100 Maps of Tidal Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of King Tide Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of 100-Year Storm Flooding

Plate 1: Avila Beach Drive Area Map, EAB (2017).

Plate 2: Flood Hazard Zones associated with Daily Inundation due to Rising Tides for Existing Conditions.

Plate 3: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2030.

Plate 4: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2050.

Plate 5: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2100.

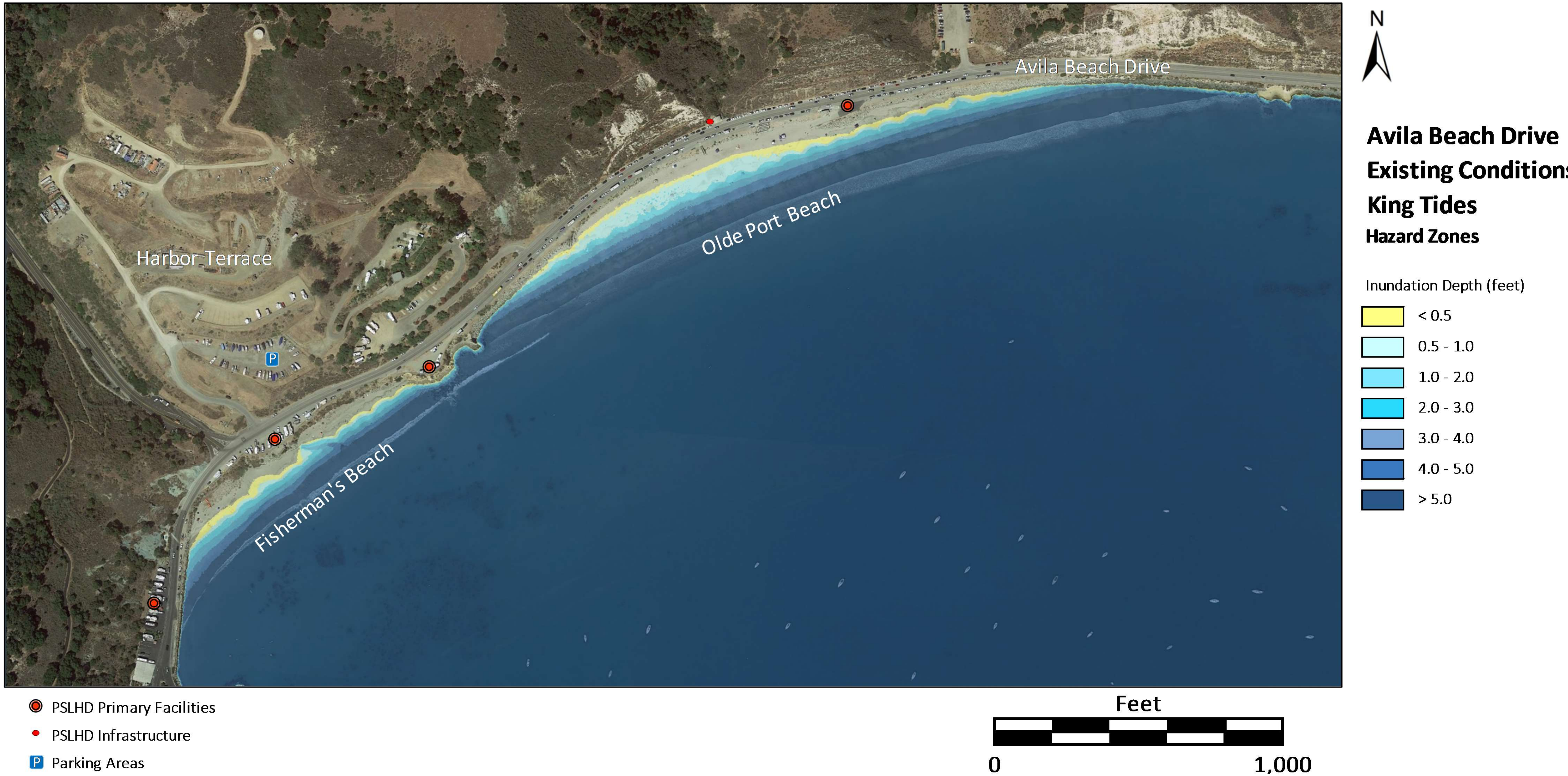

Plate 6: Flood Hazard Zones associated with King Tides for Existing Conditions.

Plate 7: Flood Hazard Zones associated with King Tides and SLR by 2030.

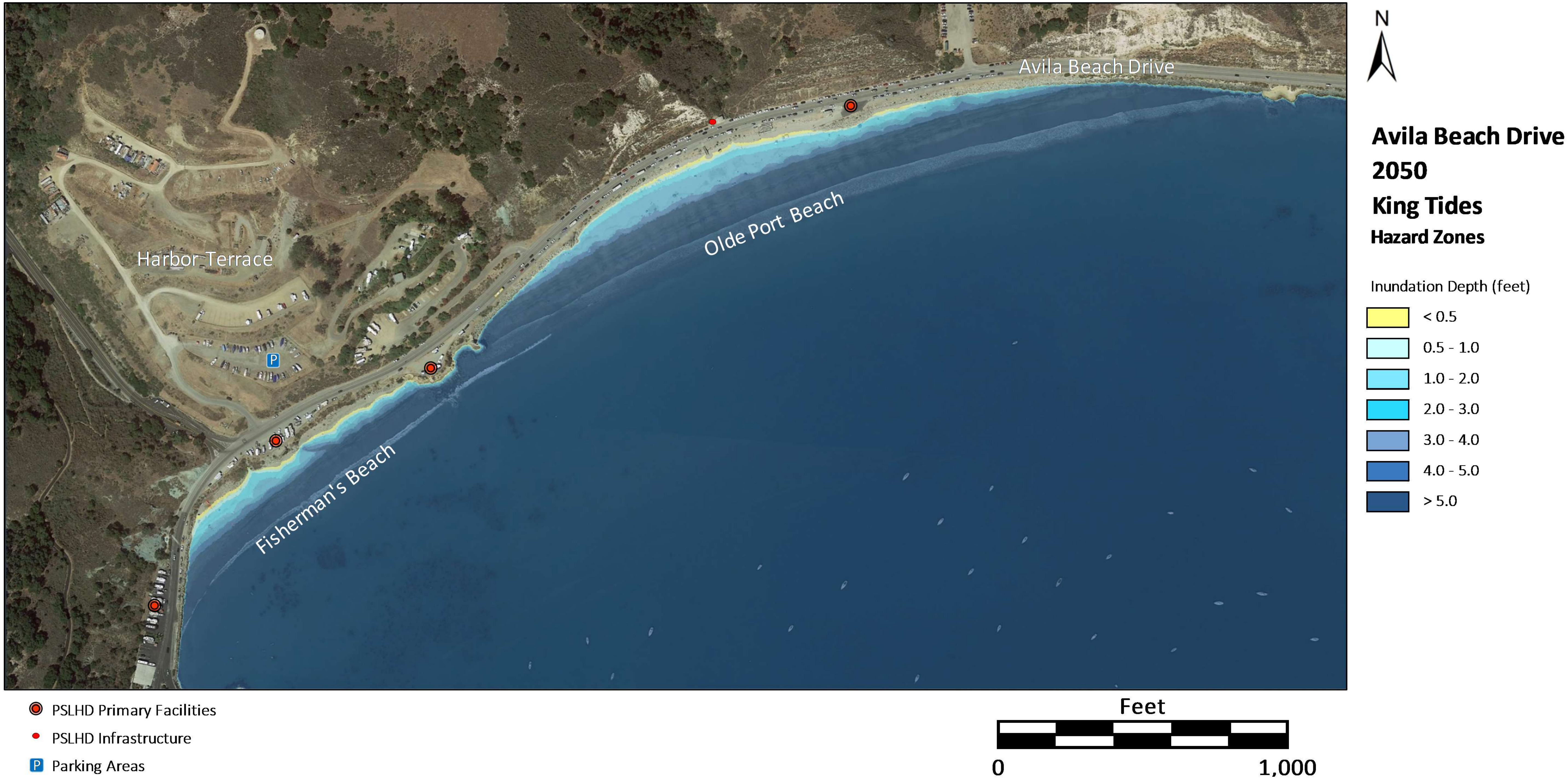

Plate 8: Flood Hazard Zones associated with King Tides and SLR by 2050.

Plate 9: Flood Hazard Zones associated with King Tides and SLR by 2100.

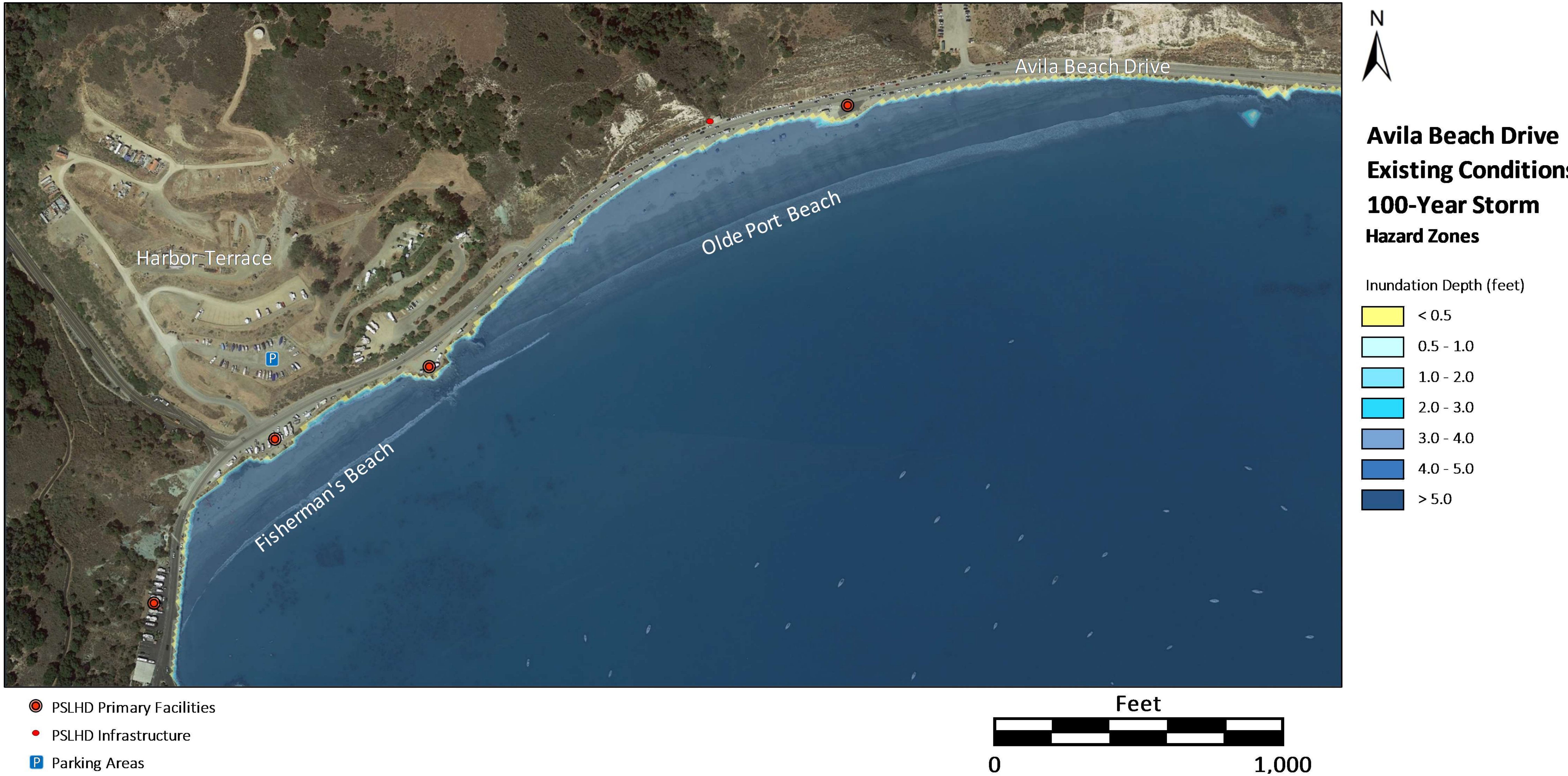

Plate 10: Flood Hazard Zones associated with a 100-Year Storm for Existing Conditions.

Plate 11: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2030.

N

Avila Beach Drive
2050
100-Year Storm
Hazard Zones

Inundation Depth (feet)

- < 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- > 5.0

- PSLHD Primary Facilities
- PSLHD Infrastructure
- P Parking Areas

Feet
0 1,000

Plate 12: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2050.

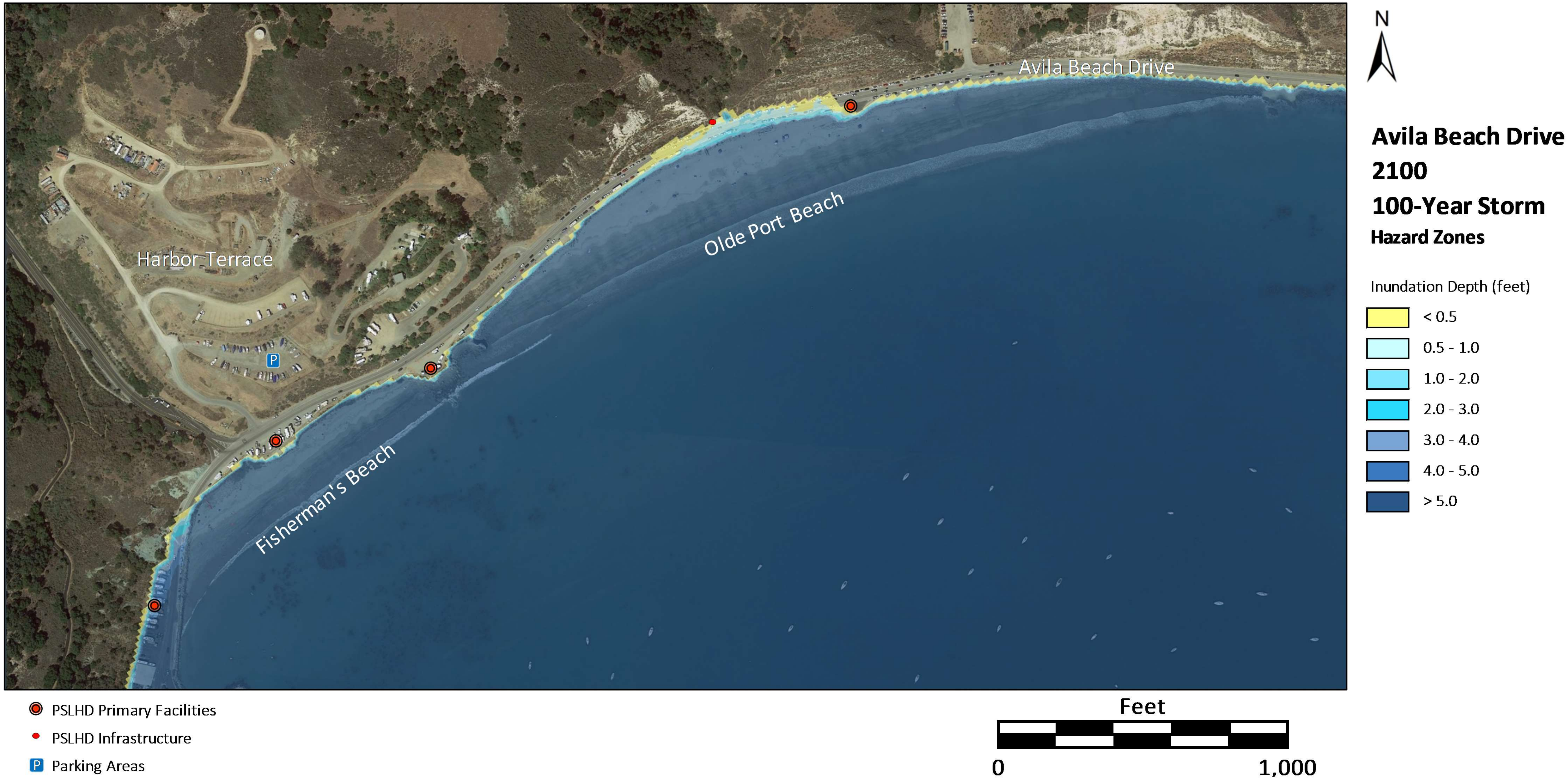

Plate 13: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2100.

Appendix D

Avila Beach

Area Map
Existing Conditions, 2030, 2050, and 2100 Maps of Tidal Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of King Tide Inundation
Existing Conditions, 2030, 2050, and 2100 Maps of 100-Year Storm Flooding

Plate 1: Avila Beach Area Map, EAB (2017).

Plate 2: Flood Hazard Zones associated with Daily Inundation due to Rising Tides for Existing Conditions.

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Plate 4: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2050.

Plate 5: Flood Hazard Zones associated with Daily Inundation due to Rising Tides and SLR by 2100.

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Plate 9: Flood Hazard Zones associated with King Tides and SLR by 2100.

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Plate 11: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2030.

Plate 12: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2050.

Plate 13: Flood Hazard Zones associated with a 100-Year Storm and SLR by 2100.