[FINAL]

City of Newport Beach – Public Trust Lands Sea Level Rise Vulnerability Assessment

Prepared For:

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Acronyms and Abbreviations

CCC	California Coastal Commission
CCSTWS-OC	Coast of California Storm and Tidal Wave Study for South Coast Region, Orange County
CDIP	Coastal Data Information Program
City	City of Newport Beach
CLUP	Coastal Land Use Plan
COAST	Coastal One-line Assimilated Simulation Tool
CoSMoS	Coastal Storm Modeling System (Version 3.0 Phase2)
CRSMP	California Regional Sediment Master Plan
CSLC	California State Lands Commission
CY	Cubic yards
DEM	Digital Elevation Model
EFGS	Ecological Functions Goods and Services
ENSO	El Niño Southern Oscillation
GHG	Greenhouse Gas
H++	Extreme SLR scenario due to rapid Antarctic ice sheet mass loss (OPC 2018)
HOWL	Highest Observed Water level
HPI	Housing Priced Index
IPCC	Inter-governmental Panel on Climate Change
LA	Los Angeles
LCP	Local Coastal Program
LOWL	Lowest Observed Water Level
m	Meter
M&N	Moffatt & Nichol
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
MSL	Mean Seal Level
MTL	Mean Tide Level
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
OCCRSMP	Orange County Coastal Regional Sediment Management Plan
OCOF	Our Coast, Our Future
OCPW	Orange County Public Works
OPC	Ocean Protection Council
PDO	Pacific Decadal Oscillation
RCP	Representative Concentration Pathway
SLR	Sea Level Rise
SLRVA	Sea Level Rise Vulnerability Assessment
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WTP	Willingness to Pay
yr	year

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1. Introduction

As a part of California State Lands Commission (CSLC) Assembly Bill 691, the City of Newport Beach (City) is proactively planning for sea level rise (SLR) impacts to Public Trust Lands within the City's jurisdiction. Recent SLR science and coastal hazards projections indicate that valuable assets on tidelands will be exposed to more intense coastal hazards, such as beach erosion and coastal flooding, in the future. This report evaluates the geographic extent and vulnerability of Public Trust Lands within the City to SLR and associated coastal hazards. This report is based on the best available science and includes SLR projections released by the Ocean Protection Council (OPC) report *State of California Sea Level Rise Guidance (OPC 2018)*.

The OPC was created by state law in 2004 to protect ocean health, and all of its actions are viewed through the lens of climate change. The OPC works to implement flexible and agile approaches to respond to the evolving knowledge base and unanticipated changes when they occur. These include impacts to coastal communities by storms, erosion, and SLR, and to ecosystems as a result of a changing climate. The following responsibilities are under state mandate of the OPC:

- Coordinate activities of ocean-related state agencies to improve the effectiveness of state efforts to protect ocean resources within existing fiscal limitations
- Establish policies to coordinate the collection and sharing of scientific data related to coast and ocean resources between agencies
- Identify and recommend to the Legislature changes in law
- Identify and recommend changes in federal law and policy to the Governor and Legislature

The effects of SLR on coastal hazards, such as shoreline erosion, storm related flooding and bluff erosion were evaluated using results of the Coastal Storm Modeling System (CoSMoS), a multi-agency effort led by the United States Geological Survey (USGS).

1.1 Study Approach

The purpose of this Sea Level Rise Vulnerability Assessment (SLRVA) is to understand how rising seas could impact coastal resources within Public Trust Lands in the City. The term "coastal resource" is used to describe both natural and manmade features that provide a benefit to the City, its residents, businesses, and visitors. The term "asset" is used to describe a specific resource or facility being evaluated. Key questions that guide the vulnerability assessment are illustrated in Figure 1-1. The first step is to identify how coastal hazards may change with various increments of SLR. By comparing predicted hazard zones based on magnitudes of SLR with coastal resources in the City, analyses identify effects that could be significant in the City. The vulnerability of an individual asset or resource is dependent on three factors:

- **Exposure** refers to the type, duration, and frequency of coastal hazard a resource is subject to under a given SLR scenario. A resource that experiences daily tidal, wave, or water level fluctuations would be considered to have a greater SLR exposure than a resource that only experiences some minor flooding during an extreme wave or storm event.

- **Sensitivity** is the degree to which a resource is impaired by exposure to a coastal hazard. For example, a restroom with a shallow foundation would be more sensitive to undermining from erosion than a pile-supported structure like the City's Municipal Pier.

- **Adaptive capacity** is the ability of a resource to adapt to changing coastal hazards. Beaches function as a natural buffer between the ocean waves and upland areas and have the ability to adapt due to sand transport (sand will migrate upward and landward in response to rising sea levels) if sufficient sand exists in the littoral system and landward space is available for this migration. Infrastructure typically has a low inherent adaptive capacity because increased coastal hazards can exceed the design capacity, requiring improvements to maintain the same level of protection.

The SLRVA informs the City of potential consequences to tidelands and key SLR thresholds for the City to consider. Understanding the vulnerabilities and their magnitude is critical to prioritizing adaptation strategies. This information may be used by the City to support policies and adaptation strategies as part of future City planning to improve coastal resiliency in the City.

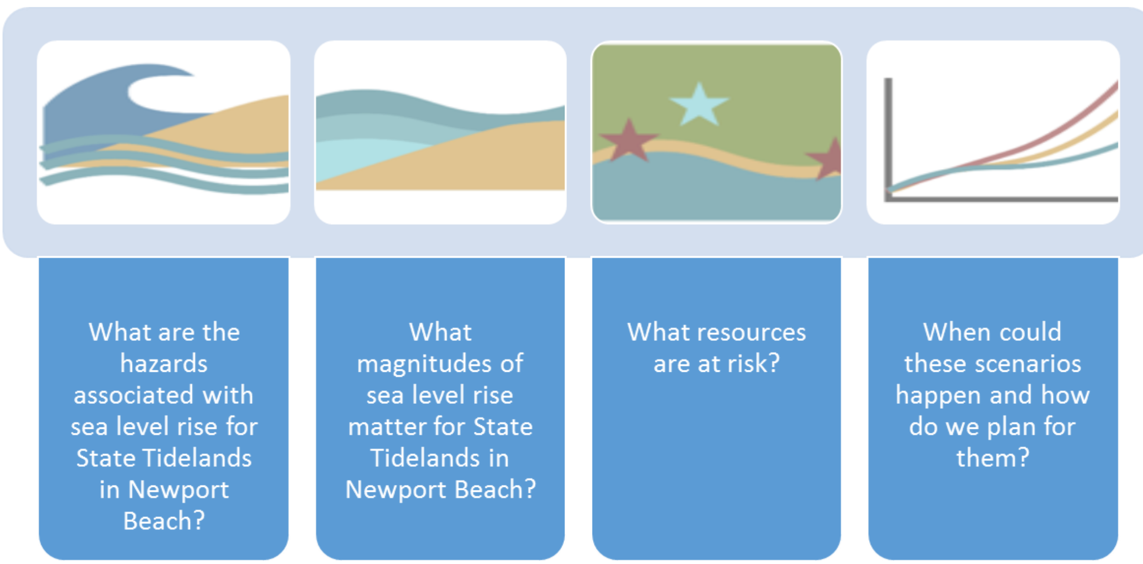


Figure 1-1: Key Questions for a Vulnerability Assessment

1.2 Coastal Setting

The City has one of the most geographically unique, scenic, and diverse shorelines in the state. Its charm and allure are undeniable. The coastline is very accessible and offers a wealth of scenic, cultural, and recreational opportunities for locals and visitors alike. Much of the community's identity and tourism draw are due to the vibrant beach culture and variety of coastal assets. The coast here has something for everybody: sandy beaches and surf; a world-class harbor for recreational and commercial boats; numerous waterfront public spaces; piers with fishing opportunities; an ecological reserve in Upper Newport Bay; public trails; and beach and bayside boardwalks with scenic views. Per the City's Coastal Land Use Plan (CLUP), almost all beaches along the Pacific Ocean are public and access to the bay is available via parks, public beaches, walkways, and boardwalks.

The coast of Newport Beach is heavily populated and extends from the mouth of the Santa Ana River southward towards the City of Laguna Beach. The stretch of coast between the river and the harbor entrance to Newport Bay consists of sandy beaches with several prominent coastal structures and development sites. Coastal structures include the groin field between 28th Street and 56th Street in West Newport Beach, a public pier at 21st Place (Newport Pier), another public pier at Main Street (Balboa Pier), and the ocean jetties of the harbor entrance (USACE 2002). The most prominent development site within tidelands is the harbor itself in Lower Newport Bay. The harbor has 17 miles of bulkhead wall, six islands with residential development, more than a dozen mooring sites for boats, and over 1,100 docks that support a mix of commercial, private, marina, and recreational boaters.

Between Newport Pier and the harbor entrance is Balboa Peninsula, a relatively low and flat 3-mile long sand spit, with sandy beaches and coastal foredunes that are backed by low-lying residential and commercial development. The Peninsula separates Newport Bay from the Pacific Ocean. The Newport Submarine Canyon, just offshore of the Newport Pier, plays a significant factor in the nearshore wave climate and continually shapes the shoreline. A favorite local surf spot, named the Wedge, is known for big waves, and is located next to the west jetty to the harbor entrance channel.

The City is exposed to a variety of coastal hazards including beach erosion, bluff erosion, and coastal flooding (Griggs et al. 2005). The City is at the southern end of the Huntington Beach littoral sub-cell, which spans from the east jetty of Anaheim Bay to the west harbor entrance jetty of Newport Bay. Sediment discharge from the Santa Ana River is the primary sediment source for this reach. The stretch of coast between the harbor entrance channel and City of Laguna Beach is comprised of narrow beaches and pocket beaches backed by steep coastal bluffs with rocky outcroppings. Sand from cliff and bluff erosion is the primary sediment source for this reach (Patsch and Griggs 2007). In 2016/2017, opportunistic beach nourishment was performed to help protect beach facilities and recreational opportunities in the City of Newport Beach. Coastal processes are described in Section 2 of this report.

1.3 Study Area

Figure 1-2 shows the study area for tidelands that are managed by the City. Figure 1-3 shows the study areas divided into three reaches, referred in this report as West Newport Beach, Balboa Peninsula Beach, and Big Corona Beach (Reach 1, 2, and 3 respectively), as well as Big Canyon Park, located in Upper Newport Bay. The tidelands span from the Newport Bay entrance channel to areas inside the harbor and up the coast towards the east Santa Ana River Jetty, and includes areas such as:

- Tidelands and submerged lands in Newport Bay,
- Tidelands, submerged lands, and filled lands bordering upon, in, and under the Pacific Ocean,
- Filled tidelands,
- Fee title to upland property,
- Waterways dedicated or reserved for same,
- 1998 trust additions (per Council Resolution 98-85 and minutes), and
- Semeniuk Slough.

1.3.1 West Newport Beach (Reach 1)

West Newport Beach stretches from the mouth of the Santa Ana River downcoast to the Newport Pier and the Newport Submarine Canyon. Do to this juxtaposition between two highly influential geologic features, the beach along this segment of the coast demonstrates a dynamic behavior that is unique. The beach between 28th Street and 56th Street is an erosional "hot spot;" i.e., the narrowest beach in Newport and the epicenter of historic shore protection efforts. An aerial photograph showing the key features of West Newport is shown in Figure 1-4. Lower West Newport (southeast of 46th Street) is relatively narrow and vulnerable to direct wave action and potential damage during extreme storm wave events. This beach is significantly influenced by effects of the Newport Submarine Canyon on approaching waves and resulting currents due to its position and orientation relative to the canyon. The beach widths along this segment of the coast experience a greater range of change than other City beaches (M&N 2006a).

A field of eight rubble mound groins exists at the beach from 28th Street to 56th Street. The beach is widest at the northwest end near the Santa Ana River and narrowest at 44th Street, and remains relatively narrow toward Newport Pier. The beach immediately upcoast from Newport Pier is very narrow. West Newport faces southwest and is exposed to ocean swell approaching from the west and from the south. This beach serves as a "pass through" for sand moving to adjacent beaches on either side of the pier, but is less able to retain sand itself; thus, it is concave-shaped when viewed from the air. The Santa Ana River, Newport Submarine Canyon, and man-made groin field have played a significant role in the historical shoreline evolution within this area. It is one of the most intensely-used beaches in the City and is a popular surfing area (M&N 2006a).

1.3.2 Balboa Peninsula Beach (Reach 2)

Balboa Peninsula is located between Newport Pier to the west and the Newport Harbor entrance channel to the east. The shoreline along Balboa Peninsula is wider than West Newport due to historic artificial beach nourishment from Newport Bay, the existence of lower wave energy under most conditions, and a setback of development farther from the water compared to West Newport. Despite its currently wide condition, analysis of long-term shoreline behavior indicates a slight erosional trend landward toward the homes. Erosion has also been documented over time by the City Marine Safety staff (Turner and Bauer, Personal Communication 2005). Structures are not presently vulnerable to direct impacts from waves and not in imminent danger. However, this beach exhibits low elevations along the back portion of the beach between 15th Street and Island Street, resulting in ponding on the berm during storm conditions, and the beach at E Street has flooded in the past during high storm waves and high tides (M&N 2006a).

Figure 1-5 shows an aerial view of the Balboa Peninsula. The Peninsula is the remnant of a historic sand spit formed by sand from the Santa Ana River, and beach sand is trapped on the downcoast end by the West Jetty to the Harbor entrance. The Peninsula faces predominantly south and is exposed mainly to ocean swells and storms from the south, with some exposure to waves from the west. This beach is also influenced by effects of the Newport Submarine Canyon, but those effects do not lead to the degree of change experienced at West Newport due to the location and orientation of this beach relative to the canyon. It serves the community as an important recreational area. Due to its expansive area and location farther from the major highways, the beach is typically less intensely-used than other City beaches, with the exceptions of areas near available parking. Surfing occurs along the Peninsula at various sites such as "The Point" on the west end and "The Wedge" at the east end, and at certain locations in between depending on surf conditions.

1.3.3 Big Corona Beach (Reach 3)

Big Corona is a City-operated “pocket” beach that lies directly downcoast of the east Harbor entrance channel and west of the rocky outcrop at Inspiration Point in Corona del Mar. This Reach also includes the much smaller pocket beach east of Inspiration Point, named Little Corona. The wide sandy beach is approximately a half-mile long and stabilized by the east Harbor Jetty and the rock headland at Inspiration Point. Sand does not move significantly out of the pocket and, as a result, the beach is relatively wide. However, City staff has indicated anecdotal evidence of beach retreat toward the east end of the beach over time. Little Corona Beach represents a very small seasonal beach.

Figure 1-6 shows Big Corona Beach. The site faces due south and is only exposed to ocean waves from that direction. It is an intensely-used recreational area but does not present a frequent surfing opportunity. Surfing only occurs there under conditions of high southern swell and mainly during lower tides. It is a fairly stable beach with fewer problems than other City beaches, with the exception of the most eastern end of the beach. The east end of Big Corona Beach has been observed to have become narrower over time with the ocean encroaching on a concrete public access ramp (Turner, Personal Communication 2006). The City has placed rock rip-rap along the base of the ramp to protect it from coastal erosion, but high tide appears to reach the bottom of the ramp under average tide and wave conditions, as observed by Moffatt & Nichol (M&N) on July 19, 2006. High tides combined with high waves could potentially damage the access infrastructure.

1.3.4 Big Canyon Park

Situated on the eastern bluff of Upper Newport Bay, Big Canyon is the largest remaining natural canyon on the east side of Newport Bay. The park is topographically high in elevation and is shown in Figure 1-7. It has been informally designated as a Nature Park, but it has been heavily influenced by the construction of a salt evaporation pond, historical placement of dredge and fill material, interim restoration efforts, and other human activities. Stockpiling of dredge fill during the 1950s and 1960s within Big Canyon Creek raised the elevations within the canyon and consequently channelized the creek to the north. The creek now winds through the Nature Park in a general southeast to northwest direction and then discharges into Upper Newport Bay (Newportbay.org/projects/bigcanyon). Per the City’s CLUP, the park provides hiking trails from Jamboree Road to Upper Newport Bay Ecological Reserve.

1.4 Coastal Resources

The coastal resources defined in this assessment come from GIS data provided by the City with additional assets determined through analysis of data provided by the City and/or other regional and federal agencies. The inventory of coastal resources and specific assets within tidelands were analyzed in this study and are summarized in Table 1-1.

Table 1-1: Coastal Resource Inventory

Resource	Specific Assets	Data Source
Parks and Beaches	• City-operated Parks • City-operated Beaches	City of Newport Beach GIS
Submerged Waterways	• Harbor Entrance Channel • Lido Channel • Turning Basin	City of Newport Beach GIS
Boating Infrastructure	• Public, Commercial, Marina, and Private Docks • Mooring Areas	City of Newport Beach GIS
Upland Development	• Lifeguard Headquarters • Parking Lots • Streets and Walkways • Restrooms • Bulkhead Wall • Commercial Areas • Stormdrain Utilities (Storm Drains and Catch Basins) • Wastewater Utilities (Pump Stations)	City of Newport Beach GIS

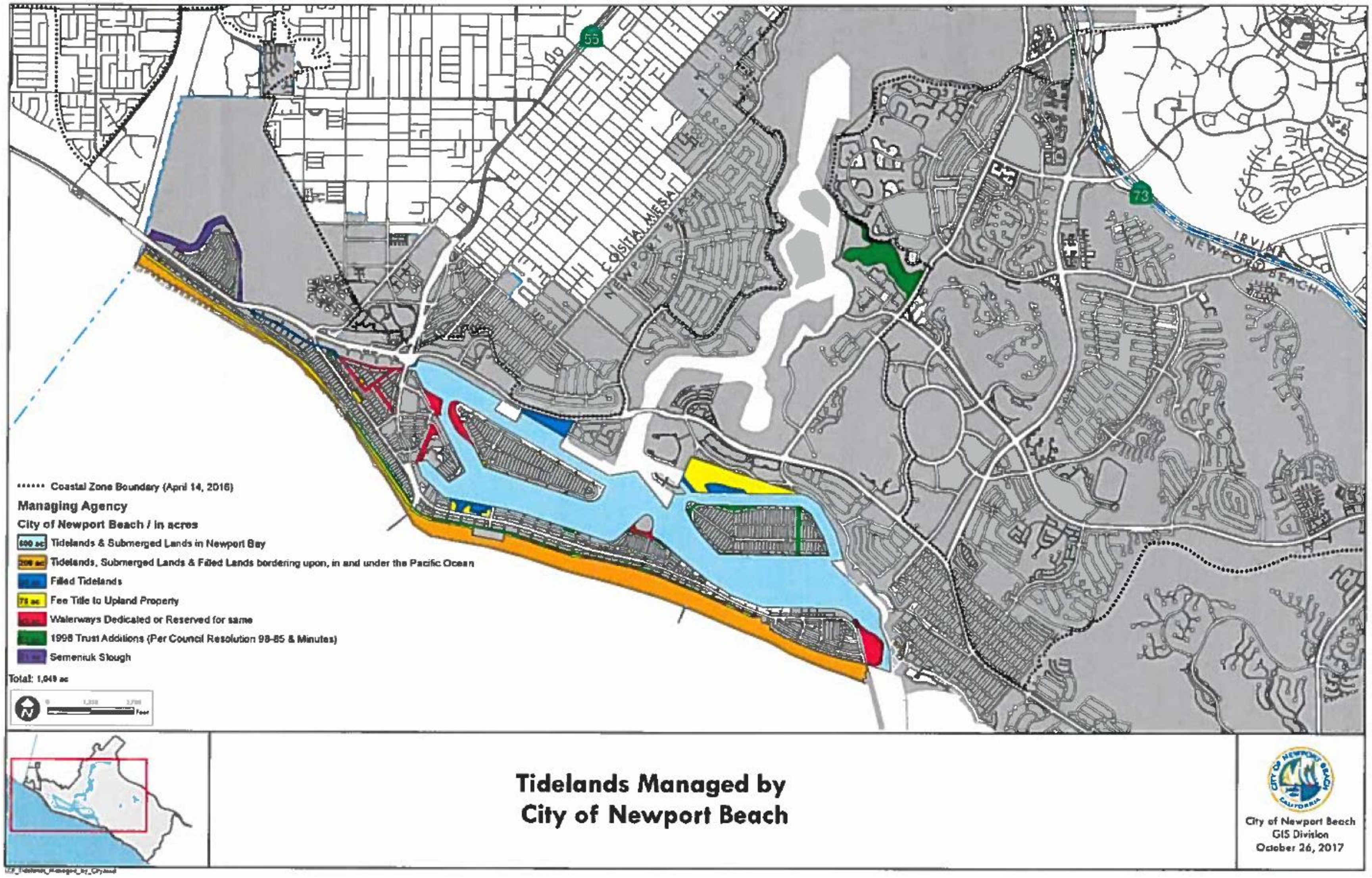


Figure 1-2: Tidelands Map

Figure 1-3: Study Areas

Figure 1-4: The Beach at West Newport

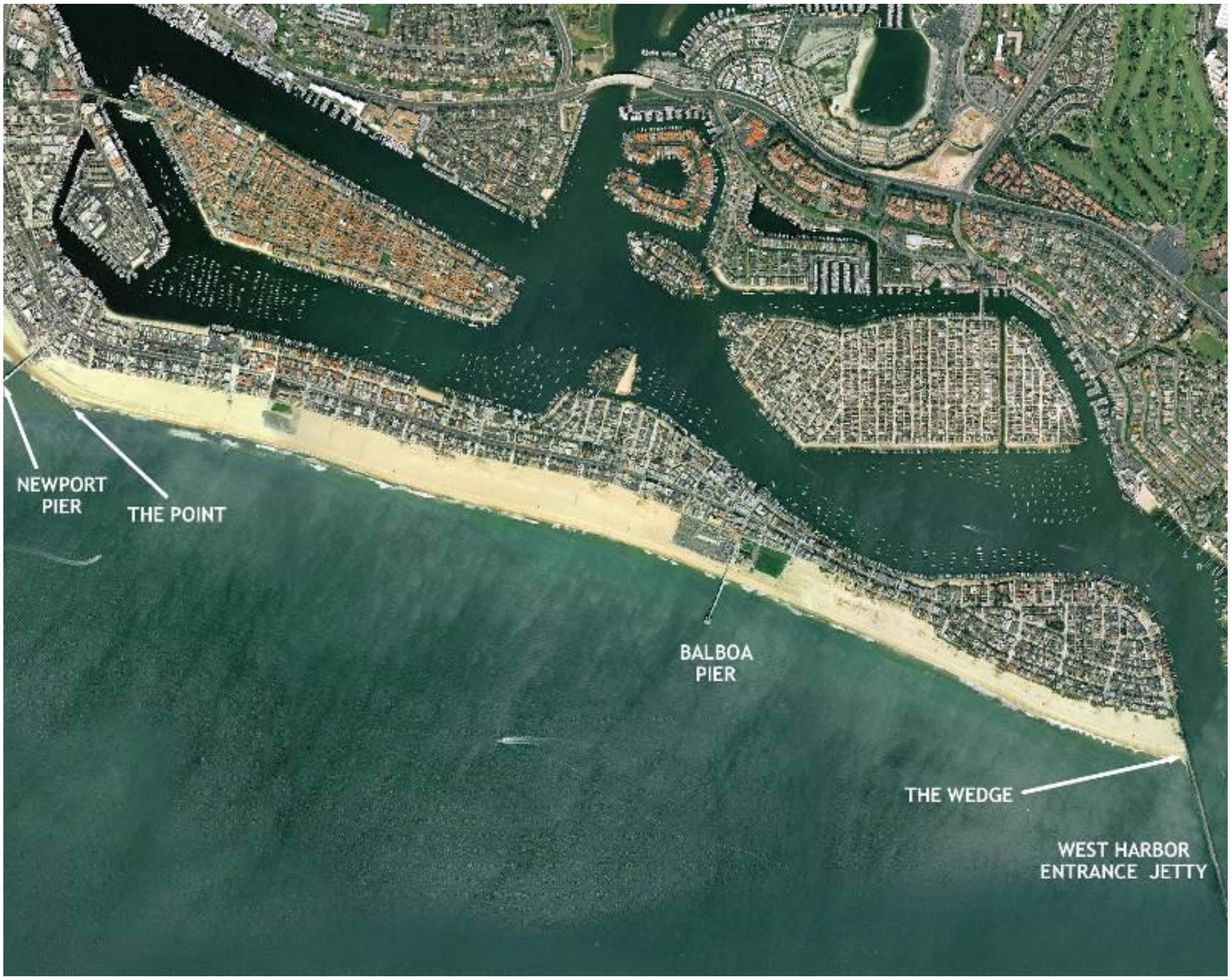


Figure 1-5: The Beach along Balboa Peninsula

Figure 1-6: The Beach at Big Corona

Figure 1-7: Big Canyon Park

2. Coastal Processes

Coastal processes refer to the waves, water levels, and transport of sediment that shape the coastline of Newport Beach. These dynamic processes are largely driven by natural forces, but are also affected by anthropogenic activities (i.e., development, coastal structures, and beach nourishment). This section describes historic coastal processes and how they have affected the shoreline along Newport Beach. The influence of SLR on coastal processes will be discussed in Section 4.

2.1 Littoral Processes and Sediment Supply

A littoral cell is a coastal compartment or physiographic unit that contains sediment sources, transport paths, and sediment sinks (Patsch and Griggs 2007). West Newport Beach is located within the Huntington Beach Littoral Sub-Cell. This littoral cell extends from the west jetty of Newport's harbor entrance channel upcoast to the east jetty of Anaheim Bay. The shoreline is oriented in a northwest-southeast direction and is exposed to a complex wave climate which, on balance with seasonal fluctuations, drives a general southeastward sediment transport (i.e., towards Newport Bay entrance channel).

Beaches within the study area range from wide at the western end, narrowing towards the Newport Pier, and widening again towards the Balboa Peninsula and west jetty of the harbor entrance channel. The beach between Newport Pier and the Santa Ana River Jetty is characterized by eight manmade groins, installed to maintain beach width and prevent erosion.

The primary sources of littoral sediment for Newport Beach are the Santa Ana River, bluff erosion at Huntington Cliffs, and beach nourishment programs. The sediment losses are often observed at the Anaheim Bay, Newport Bay, and Newport Submarine Canyon sediment sinks (Everest 2013). Sediment inputs are detailed in Table 2-1.

Table 2-1: Sediment Sources and Sinks to Huntington Beach Littoral Cell (Everest 2013)

Sediment Source	Location	Details	Effects on Newport Beach
Beach Nourishment	Placement at Surfside-Sunset Beach. Sourced from Anaheim Bay and offshore.	20+ million cubic yards (cy) Placed between 1945-2009	Increases West Newport Beach widths at average rate of 4.1 feet/year (Gadd et al. 2006)
	Placement at Newport Beach. Sourced from the Santa Ana River, Balboa Peninsula, Newport Harbor, and Newport Beach.	9+ million cy Placed between 1935-2009	Beach widening (Mesa 2011)
River Discharge (Calculated for the period of 1963-1995)	Santa Ana River	33,000 cy/year	Sand added to the system
Beach Nourishment (Nearshore/Offshore Placement)	Nearshore off of the groin field	1,200,000 cy (1992)	Sand added to the system
Beach Nourishment (Nearshore/Offshore Placement)	Nearshore off of the groin field	40,000 cy (2005)	Sand added to the system
Beach Nourishment (Nearshore/Offshore Placement)	Nearshore off of the groin field	600,000 cy (2017)	Sand added to the system
Sediment Transport (Calculated for the period of 1963-1995)	Anaheim Bay	10,000 cy/year	Sand lost from the system
	Newport Bay	3,000 cy/year	Sand lost from the system
	Newport Submarine Canyon	1,000 cy/year	Sand lost from the system
	Offshore	78,000 cy/year	Sand lost from the system
Land Subsidence	Huntington Beach oil fields	72,000 cy/year	None
Summary	From 1963-1997, the Huntington Beach Littoral Cell saw an increase of beach width and volume, averaging 4.1 feet/year and 4.7 cy/foot-year, respectively (Gadd et al. 2006)		

2.2 Water Levels

The National Oceanic and Atmospheric Administration (NOAA) tide gauge in Newport Harbor (9410580) has been recording water levels since 1955 (i.e., 63 years). Table 2-2 shows tidal datums from the recorded water level data at this gauge.

Table 2-2: Tidal Elevations for NOAA Gauge 9410580, Newport Beach, CA

Datum	Elevation (feet-MLLW)
Highest Observed Water Level (HOWL)	**+7.66**
Mean Higher-High Water (MHHW)	**+5.41**
Mean High Water (MHW)	**+4.67**
Mean Tide Level (MTL)	**+2.80**
Mean Sea Level (MSL)	**+2.77**
Mean Low Water (MLW)	**+0.92**
Mean Lower-Low Water (MLLW)	**+0.00**
Lowest Observed Water Level (LOWL)	**-2.35**

The tides in Newport Beach are mixed semidiurnal, with two high tides and two low tides of differing magnitude occurring each day. Astronomical tides make up the most significant amount of the total water level. Typical daily tides range from MLLW to MHHW, a tidal range of about 5.4 feet based on the tidal station at Newport Harbor (NOAA station 9410580). During spring tides, which occur twice per lunar month, the tide range increases to about 7 feet due to the additive gravitational forces of the sun and moon. During neap tides, which also occur twice per lunar month, the forces of the sun and moon partially cancel out, resulting in a smaller tide range of about 4 feet. The largest spring tides of the year are sometimes referred to as "King" tides and result in high tides of 7 feet or more above MLLW and tidal ranges more than 8 feet.

2.3 Extreme Water Levels

NOAA provides estimates of extreme water levels based on recorded water level data. Since 1923 (95 years) water levels have been recorded at Los Angeles (LA) Outer Harbor, where the tide gauge has captured events of extreme low and high water levels. Due to the long time record, the NOAA extreme water level data at LA Outer Harbor Station 9410660 is used in this work, and Table 2-3 gives the monthly highest and lowest water levels with the 1%, 10%, 50%, and 99% annual exceedance probability levels. The extreme water levels in Table 2-3 are used in this work for flood vulnerability analysis of present day conditions; i.e., SLR projections are not included.

Table 2-3: Annual Exceedance Probability Levels, NOAA Station 9410660

Annual Exceedance Probability	Elevation (feet NAVD88)	Recurrence Interval
1%	+7.7	**100 years**
10%	+7.4	**10 years**
50%	+7.1	**2 years**
99%	+6.7	**1 year**
99%	-1.3	**1 year**
50%	-1.7	**2 years**
10%	-2.0	**10 years**
1%	**-2.3**	**100 years**

In addition to astronomical tides, factors such as sea level anomalies (El Niño events) and storm surge also contribute to the water levels along Newport Beach. These events can increase the predicted tides over the course of several days to several months. An example of this occurred on November 25, 2015 when a king tide of about 7 feet above MLLW was predicted, but a water level of 7.82 feet was measured at NOAA station 9410660 in LA. The tide series from this event is shown in Figure 2-1. The predicted astronomical tide was elevated by 0.82 feet due to a sea level anomaly related to the strong El Niño and high ocean temperatures during the 2015-2016 winter season (Doherty 2015).

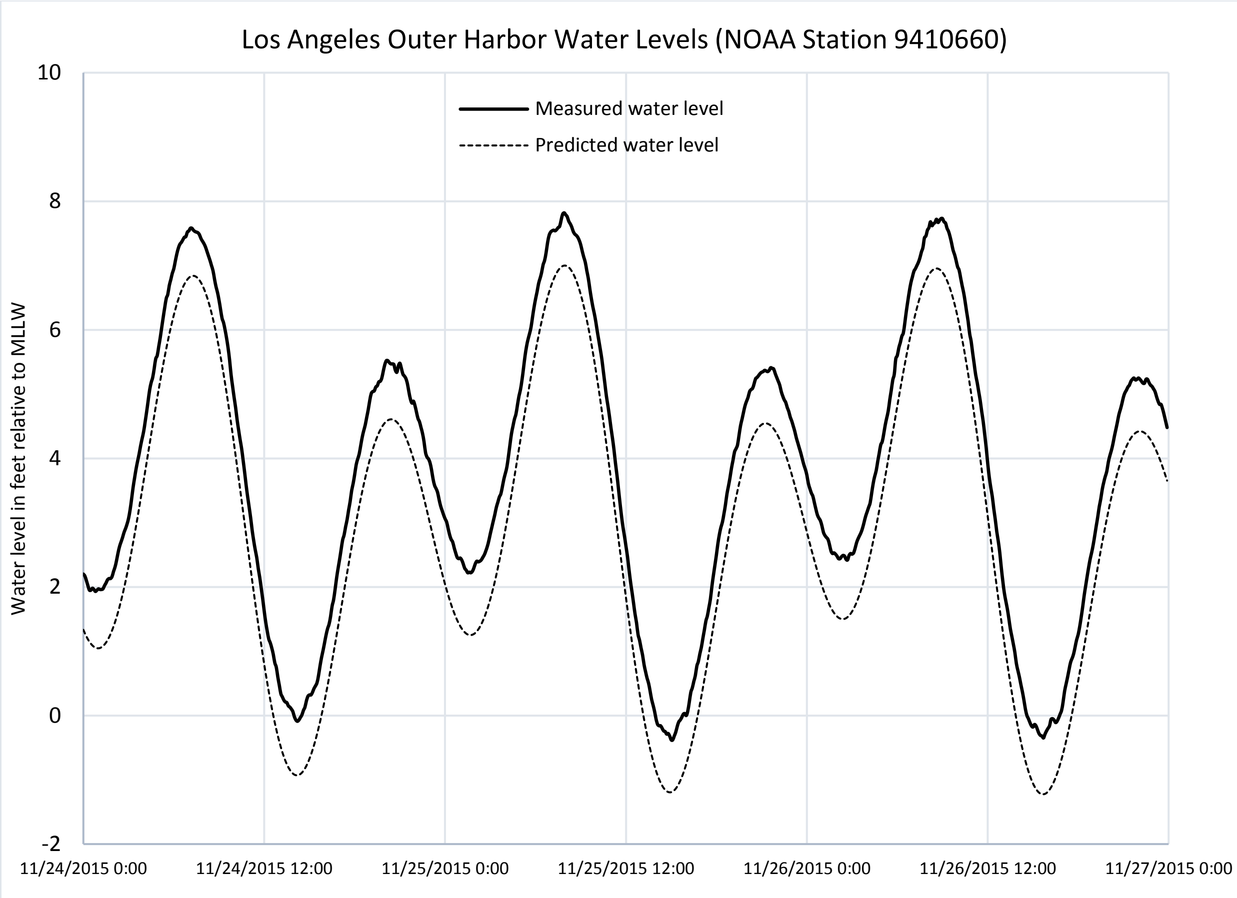


Figure 2-1: November 2015 Water Levels (NOAA Station 9410660)

2.4 Pacific Climate Cycles

Several climate cycles impact water levels on the US West Coast. The two primary climate cycles that govern climate patterns on the Pacific Coast are the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Extreme ENSO events can increase the sea level on average between 0.3 to 0.7 feet, while PDO could also result in 0.7 feet increase in water level (NRC 2012). Increased water levels resulting from ENSO events may be expected every four to seven years, with four or five strong events each century. During the major ENSO event occurring in the 1997-1998 season, monthly MSLs in Southern California were increased by up to 1 foot (USACE 2002).

2.5 Wave Climate

Waves act to carry sand in both the cross-shore and longshore directions and can also cause short-duration flooding events by causing dynamic increases in water levels. Consequently, the wave climate (or long-term exposure of a coastline to incoming waves) and extreme wave events are important in understanding future SLR vulnerabilities.

The general wave exposure of Newport Beach is characterized by south swells in summer, which are typically smaller wave heights with long wave periods, and west-northwest swells in winter months that have much larger wave heights (i.e., 10-yr, 50-yr wave heights) and typically shorter wave periods due to the storms' closer proximity to the coast. While extreme wave events have historically caused damage to City facilities, the year-round wave exposure is also an asset to the surfing community of Newport Beach. Exposure to a wide range of swell make for consistent waves at a variety of breaks along the coast and contributes to the popularity of surfing in Newport Beach, as shown in Figure 2-2.

Figure 2-2: Surfing at the Wedge, Newport Beach, CA

Typically, during summer and fall seasons, tropical hurricanes off Baja California and Antarctic storms generate potentially destructive waves to Southern California. Newport Beach is affected because of its south-facing shoreline and the lack of any protective offshore islands. Also, approximately 500 feet offshore from Newport Pier, in 25 feet of water depth, is the Newport Submarine Canyon. The canyon was formed by the Santa Ana River when sea level was much lower than today. Waves passing over the canyon refract such that the waves are focused away from Newport Pier in both directions upcoast and downcoast (see Figure 2-3). This wave refraction causes longshore currents to move currents northward on the north side of the canyon head and move currents southward on the south side (Griggs and Savoy 1985).

Wave refraction can result in wave focusing at certain locations along the shore. Within the curved embayment of West Newport Beach, wave amplification increases with distance away from the canyon toward the northwest for swells approaching from the south. As southern swell refracts more than swell approaching from the west at this location, waves will possess greater wave energy and increased potential to transport sand in the direction from Newport Pier toward the Santa Ana River mouth (M&N 2006a).

Newport Submarine Canyon also causes wave energy to diminish in the vicinity of the canyon head and leads to sedimentation and the formation of a sand protrusion near Newport Pier (i.e., Newport Point or "The Point"). Figure 2-3 also shows Newport Point, which acts as an anchor to the shore near the location of the canyon and creates the benefit of stabilizing the western portion of the shore along Balboa Peninsula. Newport Point serves to fix the position of the beach at the downcoast end of West Newport (M&N 2006a).

Swells from the south are more commonly the cause of high surf at Newport Beach and resulting coastal erosion. As described by M&N (2006a), every significant erosion event at Newport Beach coincided with a high waves incident from the southern direction. Summer southern swell waves exhibit longer periods than those in the winter because they are generated by storms that are farther from California and travel farther to reach this shore (M&N 2006a).

At most locations, summer southern swell exemplifies milder conditions than winter storm waves; this results in beach-building rather than erosion and wider beaches rather than narrower beaches. At Newport Beach, however, this general seasonal trend is reversed (M&N 2006a).

Depending on the direction of the approaching swells, Newport Beach is more sheltered from winter storm waves (compared to nearby Huntington Beach, for example). Therefore, during winter, Newport Beach experiences less of a typical pattern of high winter waves and corresponding beach narrowing. Due to southern swell, the beaches become narrower in the summer at Newport Beach (M&N 2006a). Note, however, that during an extremely severe winter storm event, the beaches are still susceptible to being overtopped by wave runup despite generally being wider during the winter. For example, in January 1988, coastal flooding occurred near 20th Street and 36th Street when wave runup overtopped the beach backshore and flooded the parking lot at Newport Pier (see *Section 2.7 History of Coastal Storm Damage*). The most extreme events occur along the coast when large wave events coincide with high water levels, such as the El Niño storm event that occurred in 1988.

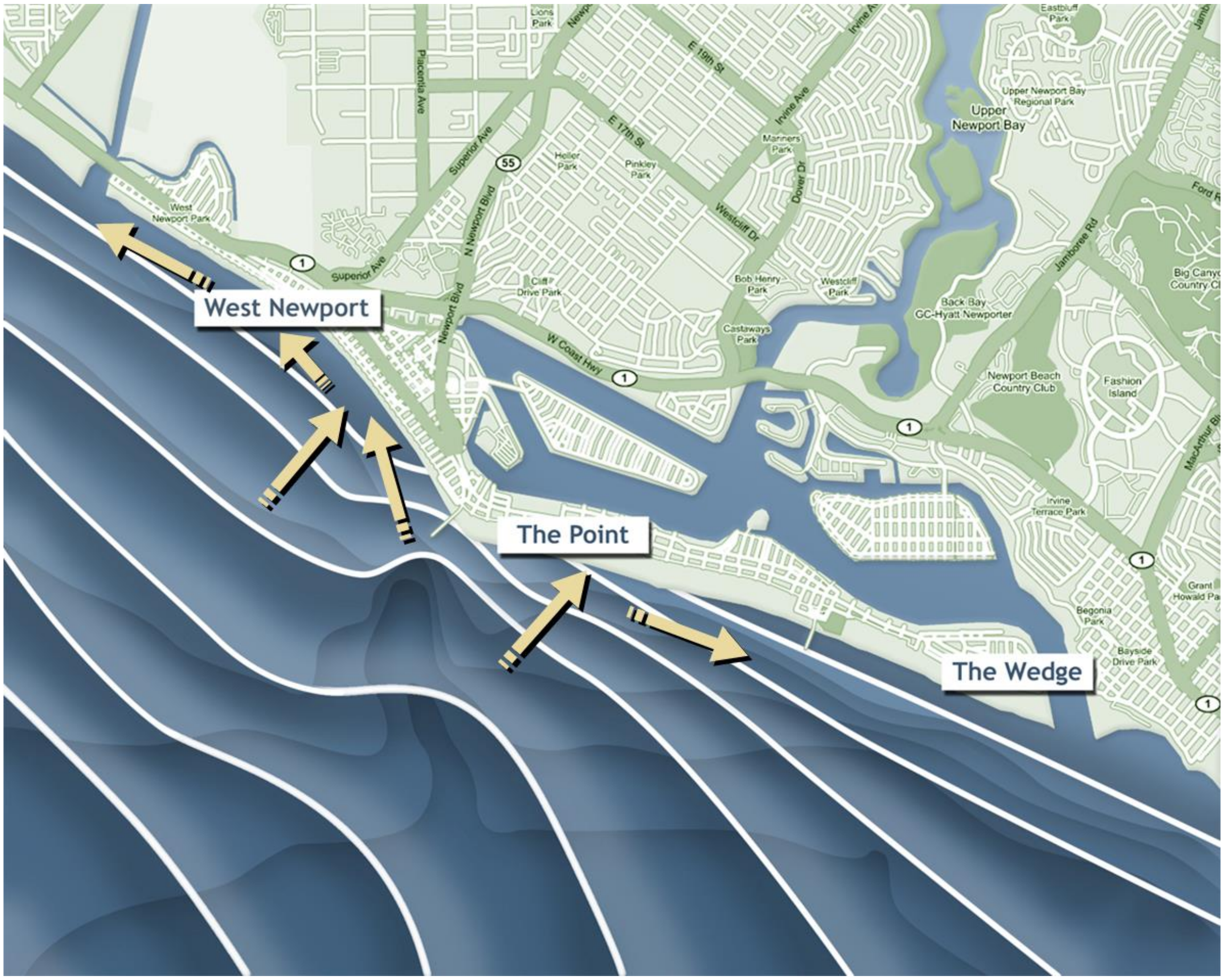


Figure 2-3: Wave Refraction during Southern Swell

2.6 Shoreline Change

In this section, a review of current shoreline conditions at Newport Beach is provided. Newport Beach is very dynamic as a result of the complicated interactions of the coastal processes described in the preceding sections. As described by M&N (2006a), sand is generally lost from West Newport Beach over time from within the narrow shoreline reach within the groin field between 30th Street and near 46th Street and, is generally gained between Prospect Street and the Santa Ana River mouth. Newport Point appears to shift in position from west to east, based on swell direction and season, but is relatively stable. While the shoreline at the Santa Ana River and Newport Point appears to be stable, the shoreline between Prospect Street and Newport Point recedes and forms an embayment that varies in its position over time. The shoreline generally lies farther landward during southern swell erosion events and shifts seaward during accretional western swell periods. The amplitude of the curvature of the shoreline planform (viewed from above) is greatest during periods of erosion (M&N 2006a).

An estimate of long-term shoreline change rates was provided in *The State of the Newport Coast Final Report* (M&N 2006a), based on an aggregate of data collected by the USACE (USACE 2002) and the City's ongoing beach profile monitoring program. The results indicate a long-term trend of erosion at West

Newport Beach profiles near the groin field and along Balboa Peninsula between Island Street and 18th Street. The mean shoreline change rate at West Newport Beach is -1.6 ft/yr. The highest rate of erosion (-16.3 ft/yr) was measured at 32nd and 40th Streets. The shoreline change rate at Balboa Peninsula varies between -4.3 ft/yr and -5.2 ft/yr. The highest rate of erosion (-9.2 ft/yr) was measured at 18th Street (M&N 2006a).

No historic shoreline measurements of Big Corona Beach were identified from either the USACE or the City. However, beach profiles were taken at Big Corona by the City in 2004 and 2005. Aerial photographs and the profiles were examined to determine the condition of Big Corona, along with data from the USACE sediment budget. Big Corona is approximately 300 feet wide on average and varies depending on season and year. Beach retreat does not appear to be occurring at the west portion of this site, but the east end of the beach is retreating, as observed by City staff and local residents, and presently encroaches on the main pedestrian coastal accessway at Inspiration Point (M&N 2006a).

Long-term shoreline changes are often related to sediment supply (described in Section 2.1), coastal storm conditions, and SLR. Long-term trends of erosion may be difficult to discern over short time scales (months to years), but over longer time scales (decades), shoreline change trends can have a significant impact on beaches. The Newport Beach shoreline is also sensitive to wave energy, which results in seasonal shoreline change patterns and storm-induced erosion. Seasonal shoreline change is driven by differences in wave height and direction between summer and winter months. Typically, smaller waves during the summer months allow the beach to advance seaward, resulting in a relatively wide beach that is popular with locals and visitors for the recreational opportunities available. Larger waves during the winter months cut back (erode) the beach, resulting in a narrower beach width. A schematic of the typical seasonal changes is illustrated in Figure 2-4. Note, however, that in Newport Beach the seasonal beach profile is reversed, i.e., the beach is typically wider in winter than summer.

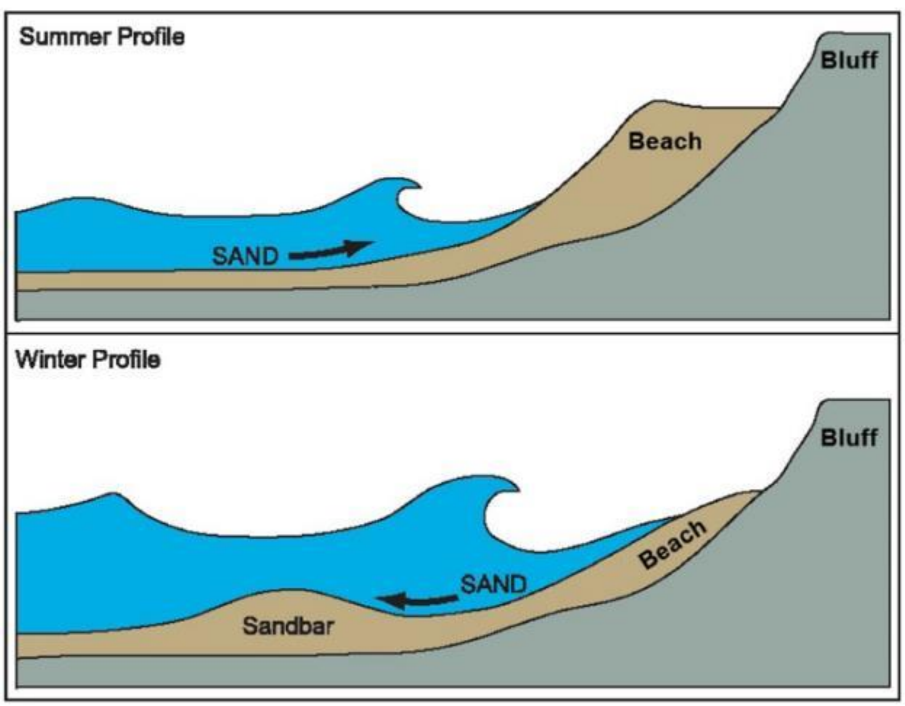


Figure 2-4: Schematic of Seasonal Shoreline Change (Patsch and Griggs 2007)

2.7 History of Coastal Storm Damage

The City of Newport Beach has a long history of battling coastal erosion and the resulting threat to infrastructure. Balboa Peninsula experienced coastal flooding in the early 1900s on occasions of high tides and storm waves. Figure 2-5 shows Balboa Peninsula in 1912 with waves breaking against a seawall in front of homes; Figure 2-6 shows "The Point" along the Peninsula with seawalls being constructed in the same year. West Newport experienced significant erosion and damage to homes in 1934, 1939, and 1968. Figure 2-7 shows the beach at West Newport in October of 1934 retreating landward of homes west of 36th Street where a groin existed at that time. Figure 2-8 shows a picture in the LA Times of West Newport near 43rd Street in August of 1968 and Figure 2-9 from the Daily Bulletin shows emergency rock protection being placed with a crane at West Newport (M&N 2006a).

Historically, the most acute problems of documented erosion have occurred at West Newport. However, coastal flooding still has the high potential to occur within the lower West Newport Beach area from 20th Street to 46th Street during severe storm wave events. In January 1988, coastal flooding occurred at 20th Street and 36th Street, as shown in Figure 2-10 and Figure 2-11. During an extremely severe (El Niño) winter storm event, wave runup overtopped the beach backshore and flooded the parking lot. The threat from flooding can still occur and could increase over time if sea level rises relative to land and if the sand volume within this beach declines over time (M&N 2006a).

Newport Beach has clearly been vulnerable in the past to serious beach erosion problems. Fortunately, the City has experienced successful reduced coastal erosion and flooding since the late 1960s due in part to protective actions taken by the Federal government. These actions have included ongoing beach nourishment at Surfside Colony/Sunset Beach, placing sand at West Newport, and installing groins to retain sand. As a result, upper West Newport (northwest of 56th Street) has widened and stabilized over the past 40 years. However, lower West Newport (southeast of 46th Street) remains narrow, and recent studies indicate it may still be eroding. The cause of the erosion is not clearly understood but can be inferred as related to the complex interaction of the Submarine Canyon off Newport Pier, the orientation of the coast relative to approaching waves, effects of offshore islands on sheltering waves, and other factors (M&N 2006a).

Newport Beach has historically relied upon beach nourishment from nearby sources to offset erosion. The greatest direct beach nourishment opportunities arise when maintenance dredging of the lower Santa Ana River is required. Maintenance dredging of the river has typically been done by the United States Army Corps of Engineers (USACE) or Orange County Public Works (OCPW) every 10-15 years. The last USACE project was in 1992 to channelize the river, and the County was given the responsibility to maintain the river since 2005. In 2016/2017, the County placed approximately 600,000 cy sand in the nearshore and on West Newport Beach to nourish the shoreline. The sandy material came from maintenance dredging of the Santa Ana River and, as a receiver site, the shoreline at West Newport Beach benefitted from that project. Sand dredged from the Santa Ana River in 2016/2017 was also placed along the shoreline of Balboa Island and China Cove.

Figure 2-5: 300 E. Block of Balboa Boulevard in 1912

Figure 2-6: Peninsula Point in 1912 (Images courtesy of the City Public Works Department)

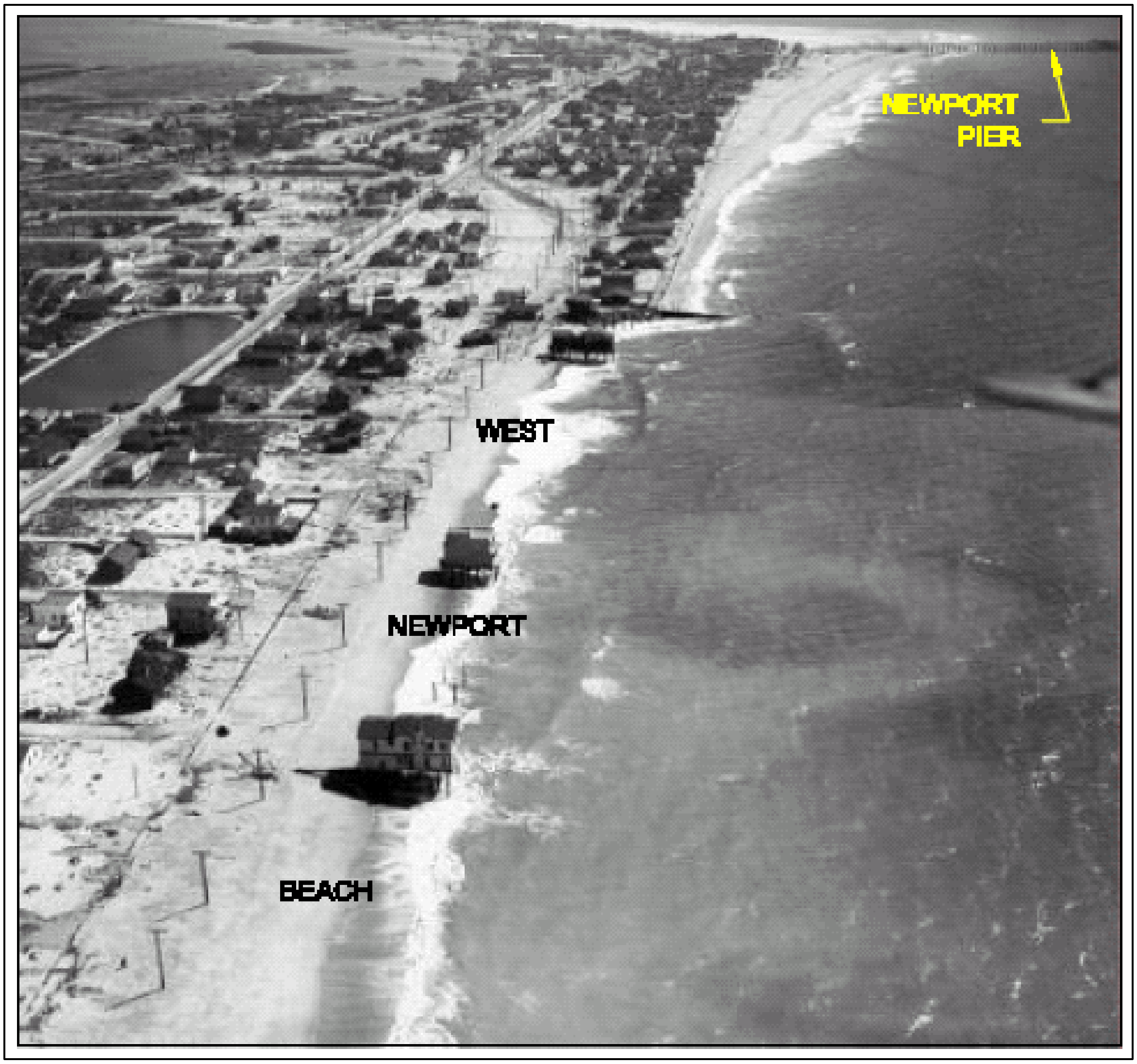
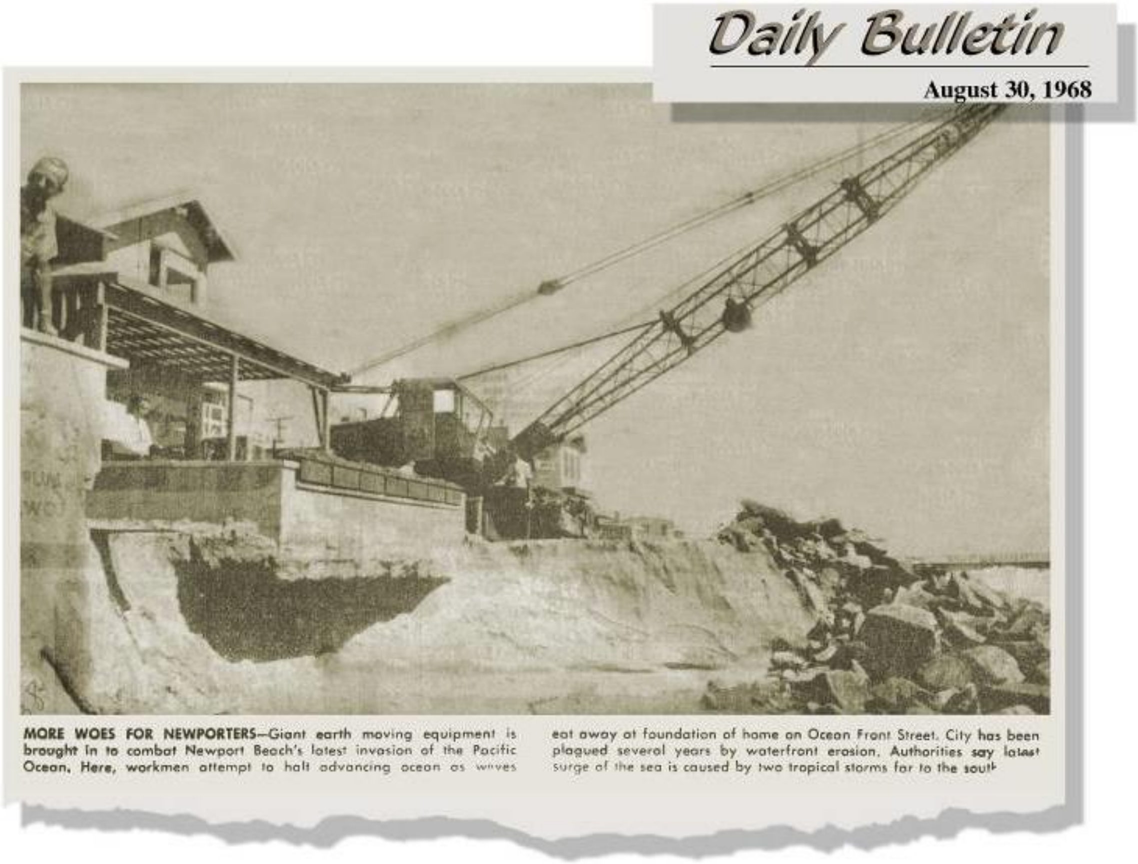


Figure 2-7: West Newport on October 10, 1934 (Source: USACE 2002)

Figure 2-8: West Newport Beach in Summer 1968


Daily Bulletin

August 30, 1968

MORE WOES FOR NEWPORTERS—Giant earth moving equipment is brought in to combat Newport Beach's latest invasion of the Pacific Ocean. Here, workmen attempt to halt advancing ocean as waves eat away at foundation of home on Ocean Front Street. City has been plagued several years by waterfront erosion. Authorities say latest surge of the sea is caused by two tropical storms far to the south

Figure 2-9: Emergency Rip Rap Being Placed at West Newport in August of 1968

Figure 2-10: West Newport on January 18, 1988 at 36th Street (Image courtesy of the City Public Works Department)

Figure 2-11: Newport Pier Parking Lot on January 18, 1988 (Image courtesy of the City Public Works Department)

3. Sea Level Rise

The NOAA provides monthly MSL data to track SLR rates for the US coasts. Figure 3-1 illustrates the monthly averaged MSL, recorded at LA Outer Harbor tide gauge with removal of seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The MSL shown in this figure is relative to the averaged MSL of the years between 1923 to 2017. Based on this data, the SLR rate is about 0.04 inches/year (4 inches/century) at LA Outer Harbor (NOAA 2018).

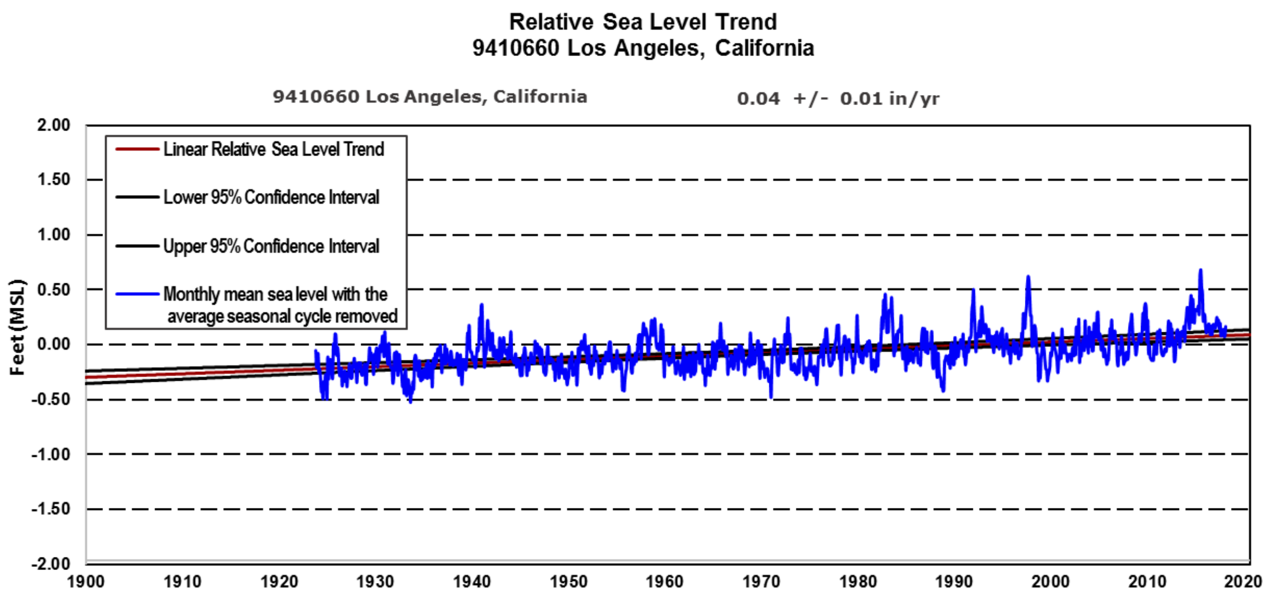


Figure 3-1: Relative Sea Level Trend

Sea level is predicted to rise as the result of general global warming that melts ice caps and warms (expands) seawater. The global average rate of SLR is also known as the eustatic rate. The pace and severity of SLR will depend on several factors, including – most importantly –the pace and scale of global greenhouse gas (GHG) emissions and the success of subsequent reduction measures over this century (OPC 2018). Future projections of SLR over time vary greatly, and particularly in the latter decades of this century. A range of scenarios exist for the future global average rate and it is valuable to understand the range of scenarios.

SLR science involves both global and local physical processes. Models are created based on science's best understanding of these processes from global to local scales and, therefore, are dynamic and periodically updated to reflect these changes. On a global level, the most recent predictions come from the Inter-governmental Panel on Climate Change's (IPCC) 5th assessment report released in 2014. The IPCC is an aggregator of peer reviewed scientific literature and provides estimates of global SLR every five or six years in detailed assessment reports. The IPCC reports provide updated SLR assessments and adaptation guidelines, which, in turn prompts local governments to update their planning policies and guidelines. The 5th assessment projections for SLR were 50% higher than the previous assessment (released 2007) due to the addition of ice sheet dynamics on SLR.

At the state level, the California Coastal Commission (CCC) presently recommends the *State of California Sea Level Rise Guidance (OPC 2018)* that was adopted in March 2018. The updated SLR Guidance was produced by the California OPC and reflects the most current understanding of SLR science. The document addresses the needs of state agencies *and* local governments as they incorporate SLR into their planning, permitting, and investment decisions.

3.1 Sea Level Rise Projections

This report predicts SLR based on the OPC's probabilistic projections for multiple emissions scenarios with the likely (67% probability) overall range between these scenarios being 13.2 to 43.2 inches (33.5 to 110 cm) by year 2100. Another study, done by others, reports an extreme scenario (named H++ [Extreme SLR scenario due to rapid Antarctic ice sheet mass loss – OPC 2018]) where all ice sheets melt and SLR increases dramatically worldwide. It should be noted the H++ scenario is a single scenario – not a probabilistic projection. The H++ scenario predicts 9.9 feet (302 cm) by year 2100. The likelihood of this scenario is unknown and is recommended by the OPC to only be considered for long-term, high-stakes decisions (OPC 2018).

Climate science is a constantly changing field, often with high degrees of uncertainty about Representative Concentration Pathways (RCP), which are four GHG concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment Report in 2014. The four RCP scenarios are 2.6, 4.5, 6.0, and 8.5. RCP 2.6 is the low emissions trajectory and RCP 8.5 is the "business-as-usual" fossil-fuel intensive emission trajectory. The intermediate scenarios represent mid-range levels of emissions reductions. RCP 8.5 represents high emissions and is the upper bound of SLR projections. It is the RCP most commonly used for conservative predictions of SLR. Per OPC guidance, this report includes the RCP 8.5 trajectory because, to date, GHG emissions worldwide have followed the business-as-usual trajectory (OPC 2018).

SLR scenarios were selected based on an initial screening of coastal resource vulnerabilities. Note: The flood mapping tool (Our Coast, Our Future [OCOF] online tool) and CoSMoS SLR data from the USGS is available in 25 cm (<10 inches) increments. Therefore, the SLR increments that were used for this study are more conservative than the 67% probability and align more with a probability of occurrence that ranges between 0.5% and 5% for the time horizons analyzed herein. The specific SLR scenarios depicted in Table 3-1 will provide a basis for understanding how hazards and vulnerabilities change with each increment of SLR. Table 3-1 also shows the CoSMoS SLR scenarios used in this study for each time horizon. In accordance with Assembly Bill 691 assessment criteria, vulnerability analysis must be done for SLR projected to year 2030, 2050, and 2100.

Table 3-1: Sea Level Rise Projections for Los Angeles

Year	CoSMoS SLR Scenario Selected	67% Probability SLR Scenario	5% Probability SLR Scenario	0.5% Probability SLR Scenario	H++ Scenario
2030	0.8 ft	0.5 ft	0.6 ft	0.7 ft	1.0 ft
2050	1.6 ft	1.0 ft	1.2 ft	1.8 ft	2.6 ft
2100	4.9 ft	3.2 ft	4.1 ft	6.7 ft	9.9 ft

(Source: OPC 2018, Table 28 values for high emissions trajectory)

SLR projections have varying levels of uncertainty. Generally, this uncertainty is less in the near term (before 2050). In the longer term, these projections diverge as uncertainty increases. Three SLR scenarios were selected that represent major thresholds for the coastline in Newport Beach. These thresholds are driven by coastal flooding and erosion that is expected to increase (progress inland) with SLR. The range of scenarios presented here capture important impact thresholds for coastal resources along Newport Beach regardless of when they occur.

4. Evaluation of Sea Level Rise Related Hazards

The effects of SLR on coastal processes, such as shoreline erosion, storm related flooding and bluff erosion, were evaluated using results of CoSMoS Version 3.0, Phase 2. CoSMoS is a software tool and multi-agency effort led by the USGS to make detailed predictions of coastal flooding and erosion based on existing and future climate scenarios for Southern California. The modeling system incorporates state-of-the-art physical process models to enable prediction of currents, wave height, wave runup, and total water levels (Barnard et al. 2009). The mapping results from CoSMoS provide predictions of shoreline erosion (storm and non-storm), coastal flooding during extreme events, and bluff erosion. The hazards depicted in this report are presented solely based on the assumptions and limitations accompanying the CoSMoS data available at the time of this study. No additional numerical modeling or independent verification of the CoSMoS data was performed.

4.1 CoSMoS Sea Level Rise Scenarios

A total of 10 SLR scenarios are available; these include 0.8 feet (0.25 m) increments from 0 to 6.6 feet (0 to 2 m), and an extreme SLR scenario of 16.4 feet (5 m). Each increment and the extreme SLR scenario of 16.4 feet is used as input in CoSMos. The inputs are modeled in CoSMoS, which then outputs the hazard results to a map interface. Note that CoSMoS models the increments independently of the rate at which they are predicted to occur and merely shows what coastal hazards will occur with increased water levels.

The SLR scenario of 16.4 feet in CoSMoS represents the worst-case scenario for many coastal communities. It differs from the H++ extreme water level of 9.9 feet in that no polar ice sheet melting is associated with it and the time frame for it to happen is based on a likelihood of occurrence well beyond the year 2150. The H++ scenario of 9.9 feet is predicted to occur by the year 2100 and is not based on any likelihood of occurrence (i.e., H++ is a single scenario). It should also be noted SLR continues beyond the year 2100. The OPC analyzes when SLR scenarios might occur by applying probabilistic projections (within the 0.5%, 5%, and 66% probability range) through the year 2150.

Table 4-1 summarizes the SLR scenarios that are available from CoSMoS Version 3.0, Phase 2. Shoreline erosion projections are available for each SLR scenario and four management scenarios. Management scenarios include with and without beach nourishment and coastal armoring (i.e., “Hold-the-Line” or not). Flood hazards are only available for the Hold-the-Line and No Beach Nourishment management scenario. All coastal hazard data from CoSMoS can be viewed from the OCOF web tool, which provides a useful map interface for the different scenarios (http://data.pointblue.org/apps/ocof/cms/).

Table 4-1: Summary of CoSMoS Version 3.0 Phase 2 Scenarios

Planning Horizon, Year	Management Scenario Description	Sea Level Rise, ft (m)	Available Data
Current – 2100	Hold-the-Line, Beach Nourishment	0-6.6, 16.4 ft (0-2, 5 m)	Shoreline erosion
Current – 2100	Hold-the-Line, No Beach Nourishment	0-6.6, 16.4 ft (0-2, 5 m)	Flood hazards and shoreline erosion
Current – 2100	No Hold-the-Line, Beach Nourishment	0-6.6, 16.4 ft (0-2, 5 m)	Shoreline erosion
Current – 2100	No Hold-the-Line, No Beach Nourishment	0-6.6, 16.4 ft (0-2, 5 m)	Shoreline erosion

4.2 Coastal Flooding

Coastal flooding predictions simulate the effects of erosion, wave runup, and overtopping during storm events. Future storm scenarios for typical conditions, 1-year (100% annual chance), 20-year (5% annual chance), and 100-year (1% annual chance), are available for each SLR scenario. Flooding extents are calculated and mapped at profiles spaced about 300 feet along the shoreline. The projected water levels used in the flood mapping consider future shoreline change, tides, sea level anomalies like El Niño, storm surge, and SLR. Future wave conditions used in the model are based on forecasted conditions out to year 2100.

Flooding results are available only for the Hold the Line, No Beach Nourishment management scenario. This assumption dictates that the morphology of the beach profiles used for flood mapping (i.e., allocating limits of flood extents) changes with time (and SLR) assuming no beach nourishment and a maximum retreat of the shoreline to the existing development line.

4.3 Shoreline Erosion Projections

CoSMoS results include long-term erosion resulting from SLR and projected wave conditions. Beach erosion was modeled with the CoSMoS Coastal One-line Assimilated Simulation Tool (CoSMoS-COAST), which comprises a suite of models that consider historic erosion trends, long-shore and cross-shore sediment transport, and changes due to SLR. These models were tuned with historic data to account for unresolved sediment transport processes and inputs, such as sediment loading from rivers and streams, regional sediment supply (beach nourishment and bypassing), and long-term erosion. Future shoreline positions predicted by CoSMoS-COAST include the four management scenarios in Table 4-1.

Hold-the-Line assumes that the existing boundary between sandy beach and development is maintained with coastal structures. No Hold-the-Line would allow erosion to propagate inland to the maximum potential erosion extents. Beach Nourishment assumes historical beach nourishment rates are carried forward. No Beach Nourishment assumes the beach is left in its existing state.

CoSMoS-COAST shoreline projections are based on an initial shoreline representing the MHW line position on year 1995. Therefore, the initial shoreline does not necessarily reflect current conditions along the coast of Newport Beach. The CoSMoS-COAST baseline is located seaward of the present day shoreline in some locations of Reach 2, and predominantly along the coast of Reach 1. This suggests that that future erosion predictions in Newport Beach are on the conservative side and, therefore, appropriate to assess future erosion hazards.

The No Hold-the-Line, No Beach Nourishment management scenario was used to evaluate shoreline change in Newport Beach under the different amounts of SLR associated with the three planning horizons considered in this report. This management scenario depicts future shoreline conditions assuming existing or future development does not restrict the natural evolution of the shoreline.

CoSMoS-COAST shoreline projections for the No Hold-the Line, No Beach Nourishment management scenario were used to develop estimates of beach loss due to long-term erosion for each planning horizon. Results are listed in Table 4-2.

Table 4-2 Projected Beach Loss Due to Long-term Erosion

SLR	Beach Loss							
	West Newport Beach (Reach 1)		Balboa Beach (Reach 2)		Corona del Mar State Beach* (Reach 3)		Little Corona del Mar Beach (Reach 3)	
	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)
0.0 ft	0	0%	0	0%	0	0%	0	0%
0.8 ft	0	0%	35.7	19%	0.1	0%	0.3	37%
1.6 ft	0.1	0%	42.9	23%	0.6	4%	0.5	61%
4.9 ft	9.9	19%	78.5	42%	3.8	22%	0.9	100%

** State Park designation. Park vulnerability to coastal erosion and flooding is accounted for in the overall vulnerability of parks summary (Table 5-6).*

4.4 Sea Level Rise Exposure – Reach 1

CoSMoS-COAST shoreline projections for a SLR of 0.8 feet on Reach 1 indicate that no significant erosion is anticipated in Reach 1 for the 2030 time horizon. The 2030 shoreline in the northwestern region of the reach (Figure 4-1*(a)*) is seaward of the baseline. This suggests an overall accretion of the coastline before the shoreline starts receding as a consequence of SLR. For the central region of Reach 1 (around 48th Street, Figure 4-1*(b)*), where the beaches are narrowest, the CoSMoS baseline remains in close proximity to the 2030 shoreline (indicating no net erosion or accretion). A beach width of about 160 feet at this location is sufficient to maintain public access and provide wide recreational opportunities. Meanwhile, for the southwestern region of Reach 1 (i.e., West of Newport Pier, Figure 4-1*(c)*) CoSMoS predicts some retreat with respect to the baseline. Although the Dory Fishing Fleet, which is a State Historical Monument, and the Newport Pier parking lot encroach onto the beach at this location, the beach is anticipated to be at least 100 feet wide. On average, CoSMoS projects that for the 2030 time horizon, the shoreline on Reach 1 will accrete about 40 feet with respect to the baseline.

CoSMoS predicts retreat of the shoreline for the 2050 time horizon (1.6 feet SLR) with respect to the 2030 shoreline to be about 30 feet on average. The largest retreat is anticipated around 48th Street on the central region of Reach 1 (Figure 4-1*(b)*). Coastal assets are not anticipated to become vulnerable to erosion for the 2050 time horizon, as infrastructure west of Newport Pier remains over 80 feet landward of the projected shoreline.

The projected shoreline for the 2100 time horizon (4.9 feet SLR) retreats significantly all along Reach 1. Average retreat with respect to the 2050 shoreline is about 130 feet (see also Table 4-2 for beach loss estimates). This results in exposure of infrastructure west of Newport Pier, where the shoreline is projected to have retreated landward of the Dory Fishing Fleet State Historical Monument (Figure 4-1*(b)*). The Newport Pier parking lot at this location is not directly impacted (undermined) by erosion; however, it becomes vulnerable to wave and water levels as well as to flooding during extreme storm events.

The eight rubble mound groins between 28th Street and 56th Street will continue to fulfill their role of maintaining beach widths and will probably delay the anticipated long-term shoreline erosion impacts for Reach 1 until the increase in MSL starts to compromise their ability to retain sand. Preliminary results from this Study suggest a SLR of 0.8 feet (2030 time horizon) will likely have negligible effects on the groin system. However, with greater amounts of SLR the functionality and integrity of these structures may need to be investigated further. Table 4-3 and Table 4-4 provide a comparison of CoSMoS projected water levels for each of the planning horizons with the Digital Elevation Model (DEM) of Newport Beach.

As shown in the tables, tide levels are comparable with the groin crest elevations for a SLR projection of 1.6 feet (2050 time horizon). However, during a 100-yr storm, tide levels exceed groin elevations and expose the coastal structures to more severe wave conditions. This could result in damage to the groins (i.e., displacement of rocks) and compromise the ability of the groin field to retain sand. Monitoring and maintenance of the structures, along with a routine sand replenishment program, will ensure the groin field functions as intended. With a SLR of 4.9 feet (2100 time horizon) the structural integrity of the groin system will likely become more compromised and perform at a level less than optimal. As the groins are federal structures, the City will need to work with USACE to find and implement adequate mitigation strategies that ensure the structural integrity and functionality of the groin system is maintained with future SLR.

Table 4-3: CoSMoS Projected Water Levels

Still Water Level (ft, NAVD88)			
Year	SLR	No Storm	100-yr Storm
2030	0.8 ft	7.55	8.20
2050	1.6 ft	8.53	9.51
2100	4.9 ft	11.81	12.80

Table 4-4: Groin Crest Elevations

Groin Crest Elevation* (ft, NAVD88)							
Groin 1	Groin 2	Groin 3	Groin 4	Groin 5	Groin 6	Groin 7	Groin 8
8.53	8.53	8.86	7.55	8.20	7.87	7.55	8.10

**Crest elevation measured at offshore end of each structure from Groin 1 (56th Street) to Groin 8 (28th Street)*

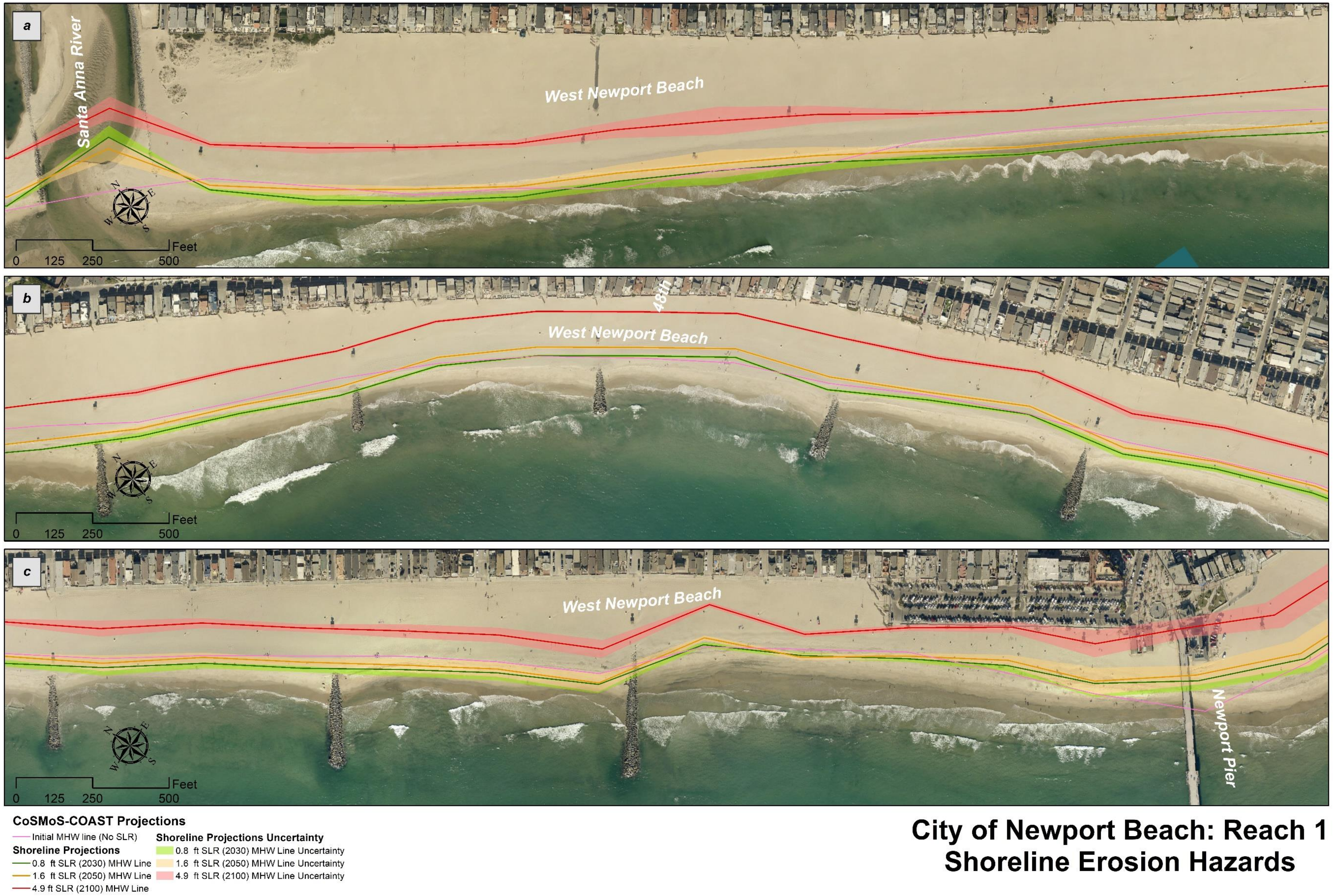


Figure 4-1: Shoreline Erosion Hazards – Reach 1

4.5 Sea Level Rise Exposure – Reach 2

Overall, Reach 2 comprises wide sandy beaches that provide the backland with a large horizontal buffer against SLR related hazards. Shoreline projections for a SLR of 0.8 feet (2030 time horizon) indicate that beach widths along this reach will be over 300 feet wide with a few exceptions. These exceptions are: the beach East of Newport Pier (about 60 feet wide, Figure 4-2*(a)*), the beach fronting the Newport Elementary School Playground (about 160 feet wide, Figure 4-2*(a)*), and the beach fronting the park and parking lot around Balboa Pier (about 160 feet, Figure 4-2*(b)*). This beach width allows for continuous recreation and access opportunities along the reach.

With respect to the CoSMoS-COAST baseline, the largest retreat for 2030 is projected east of Newport Pier (Figure 4-2*(a)*), and for the eastern-most stretch of the Reach (Figure 4-3*(d)*) close to the Entrance Channel Jetty. Meanwhile, minimal to no retreat is anticipated for the beach fronting Island Avenue (Figure 4-2*(b)*). On average, the projected retreat for Reach 2 is around 30 feet. No assets are anticipated to be exposed to coastal erosion for this time horizon.

A similar shoreline retreat is anticipated for the 2050 timeframe (1.6 feet SLR) with a more pronounced retreat on the eastern stretch near the Entrance Jetty, and a nearly negligible retreat around Island Avenue. The average retreat of Reach 2 for this time horizon (with respect to 2030) is around 30 feet. Beach widths are still adequate to provide public access and recreation opportunities, and no assets are exposed to coastal erosion for this time horizon.

CoSMoS projections indicate a shoreline retreat of about 100 feet on average along Reach 2 for the 2100 time horizon (4.9 feet SLR). This amount of retreat would place the Lifeguard Headquarters Building, east of Newport Pier, seaward of the shoreline (Figure 4-2*(a)*). However, no other assets are anticipated to become exposed to coastal erosion for this timeframe, as beaches will remain over 50 feet wide for all other locations in the Reach (see Table 4-2 for beach loss estimates).

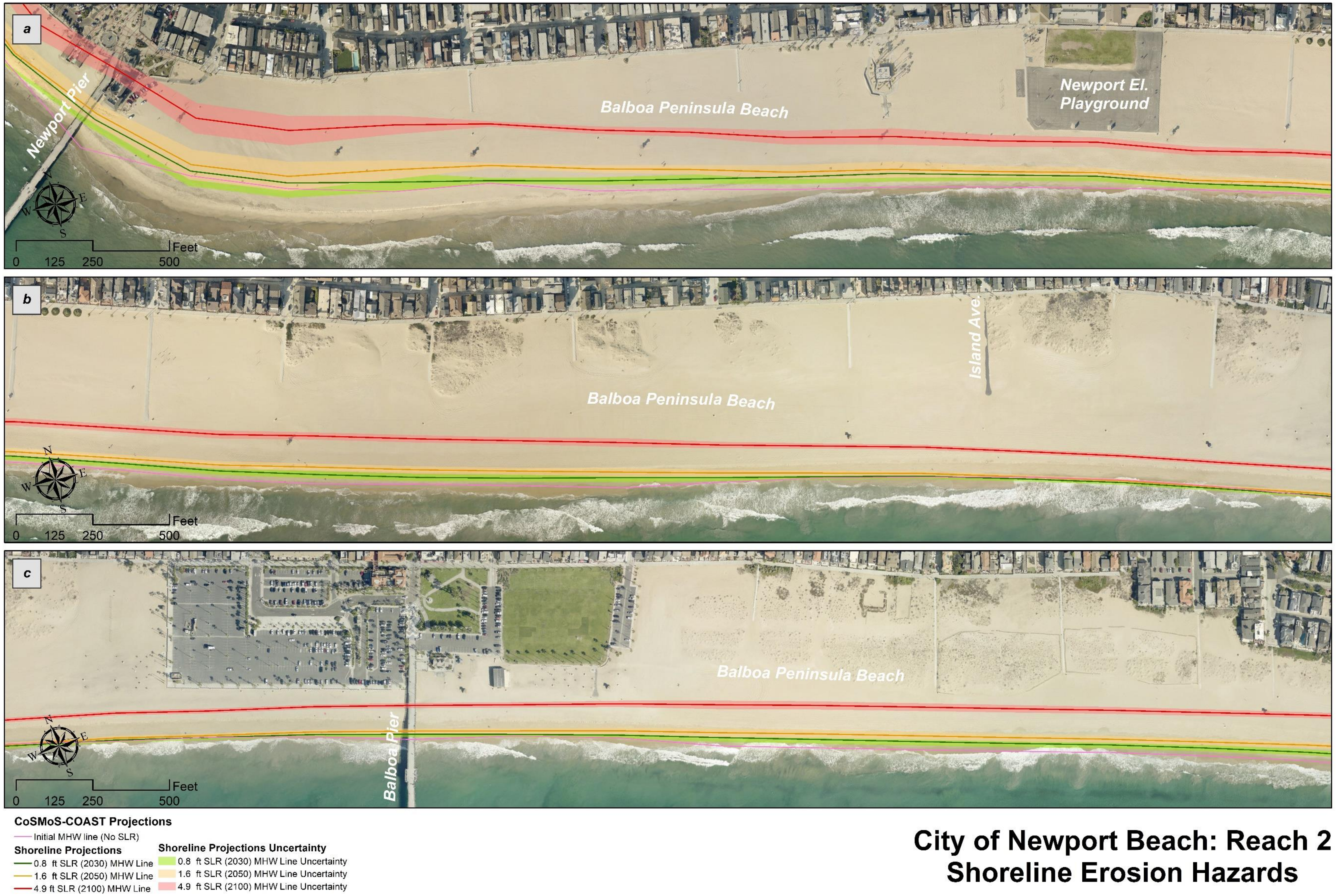


Figure 4-2: Shoreline Erosion Hazards – Reach 2 (1 of 2)

Figure 4-3: Shoreline Erosion Hazards – Reach 2 (2 of 2)

4.6 Sea Level Rise Exposure – Reach 3

CoSMoS-COAST includes long-term erosion projections for the sandy beach areas of Big Corona del Mar (State Park) and Little Corona del Mar in Reach 3 (rocky shoreline stretches are excluded from simulations). Overall, Big Corona del Mar is projected to remain relatively stable for the short-term planning horizons. As depicted in Figure 4-4*(a)*, a SLR of 0.8 feet (2030 time horizon) is not anticipated to promote coastal erosion along most of its coast; shoreline retreat with respect to the baseline is projected only close to the Entrance Channel Jetty. With a SLR of 1.6 feet (2050 time horizon), CoSMoS-COAST projects a constant, but moderate retreat (about 20 feet), which would place the shoreline at least 130 feet seaward of the parking lot and other amenities within the park, allowing to maintain public access and a wide recreational use of the beach. Finally, with a SLR of 4.9 feet, projected erosion increases significantly (see Table 4-2 for beach loss estimates). A shoreline retreat of about 90 feet on average is anticipated in Big Corona del Mar, resulting in beach widths of about 20 feet at its narrowest locations. While no other assets are projected to become directly exposed to coastal erosion, public access and recreation might become limited, as the beach commences to become squeezed between the ocean and the upland infrastructure.

Due to its geographic setting, and limited sand availability, the small pocket beach at Little Corona del Mar (Figure 4-4*(b)*) will be more vulnerable to SLR and its resulting long-term erosion. The projected shoreline for a SLR of 0.8 feet (2030 time horizon) nearly reaches the toe of the bluffs on the north side of the beach (average shoreline retreat of about 20 feet). These bluffs are projected to be impacted by erosion (shoreline retreat of about 30 feet) with a SLR of 1.6 feet (2050 time horizon). No impacts from coastal erosion are projected to the adjacent upland infrastructure; however, it is likely that recreation and public access to the beach will become limited for these time horizons. CoSMoS-COAST projects that the shoreline at Little Corona del Mar will retreat about 90 feet on average when SLR reaches 4.9 feet (2100). This projected erosion will result in total loss of the beach (see Table 4-2) area and coastal bluffs and undermining of the existing infrastructure that currently backs the beach (outside of the tidelands).

Figure 4-4: Shoreline Erosion Hazards, Reach 3

5. SLR Vulnerability Assessment

The purpose of this assessment is to identify impacts that SLR and coastal hazards may have on the existing resources and assets within the City. For this purpose, a numerical rating system was developed to assess the vulnerability of assets at the 2030, 2050, and 2100 planning horizons. As described in Table 5-1, a resource's vulnerability to SLR is the combination of its exposure to hazards, its sensitivity to said hazards (potential damage or loss of function), and its adaptive capacity (ability to restore function or avoid damage). The sum of these ratings indicates if a resource has low (3-4), moderate (5-7), or high (8-9) vulnerability to SLR.

Table 5-1: Vulnerability Rating System

Exposure is the degree to which an asset or resource is susceptible to coastal hazards such as flooding, inundation and bluff erosion for a given sea level rise scenario.		
Category	**Rating**	**Explanation**
Exposure	Low (1)	Asset or resource partially exposed to flooding, inundation, or bluff/dune erosion.
	Moderate (2)	Asset or resource moderately exposed to flooding, inundation, or bluff/dune erosion.
	High (3)	The majority of the asset or resource is exposed to flooding, inundation, or bluff/dune erosion.
Sensitivity is the degree to which the function of an asset or resource would be impaired (i.e., weakened, compromised or damaged) by the impacts of sea level rise.		
Category	**Rating**	**Explanation**
Sensitivity	Low (1)	Asset or resource is not affected or minimally affected by coastal hazards at a given SLR scenario.
	Moderate (2)	A moderately sensitive asset or resource may experience minor damage or temporary service interruption due to coastal hazard impacts but can recover relatively easily.
	High (3)	A highly sensitive asset or resource would experience major damage or long-term service interruptions due to coastal hazard impacts, requiring significant effort to restore/rebuild to original condition.
Adaptive capacity is the inherent ability of an asset or resource to adjust to sea level rise impacts without the need for significant intervention or modification.		
Category	**Rating**	**Explanation**
Adaptive Capacity	High (1)	Asset or resource can easily be adapted or has the ability and conditions to adapt naturally.
	Moderate (2)	Asset or resource can be adapted with minor additional effort.
	Low (3)	Asset or resource has limited ability to adapt without significant changes.
Vulnerability Scoring (Exposure + Sensitivity + Adaptive Capacity): Low (3-4), Moderate (5-7), High (8-9)		

To identify exposure of assets, vulnerability maps were created by overlaying SLR hazards information to tidelands resources from the four categories introduced in Section 1.4 of this report. Exposure of particular assets was quantified and rated in terms of the source of exposure (i.e., the hazard type) and quantity (%) of assets impacted for each planning horizon. Sources of exposure to SLR hazards are described below:

- Coastal Erosion (Erosion): Long-term shoreline change will impact resources and assets if the shoreline retreats far and/or close enough to assets and resources located in the coastal zone.

- Tidal Inundation (Inundation): Resources and assets impacted by inundation will be subject to daily wetting and drying associated with tides. Boating and navigation infrastructure assets might become obsolete or fail due to the increase in tidal elevations as a result of SLR.

- Extreme Flooding (Flooding): Resources and assets impacted by flooding will be subject to temporary (i.e., hours) flooding occurring episodically in association with extreme wave and precipitation events (e.g., 100-yr return period storm event). Boating and navigation infrastructure assets might become obsolete or fail due to extreme high water levels in combination with SLR.

Table 5-2 provides water surface elevations in Newport Bay as projected by CoSMoS for the 2030, 2050, and 2100 time horizons. The *No Storm* condition represents future high water elevations during spring tides, but without the influence of major storm events. The *100-yr Condition* combines future spring high water elevations with the effects of an extreme storm event with a recurrence period of 100 years. Water elevations provided in this table were used in the vulnerability assessment to identify the SLR threshold for which particular resources would become exposed or vulnerable.

Table 5-2: CoSMoS Projected Water Levels in Newport Bay

Projected Water Levels (feet, NAVD88)			
Time Horizon (SLR)	2030 (0.8 ft SLR)	2050 (1.6 ft SLR)	2100 (4.9 ft SLR)
High tide (No Storm)	+7.7	+8.6	+11.8
100-yr Storm	+8.4	+9.2	+12.6

Projected tidal inundation and extreme flooding in Newport Beach tidelands is depicted in Figure 5-1 and Figure 5-2. As a first remark, it is noted that these figures, along with those presented in subsequent sections, depict inundation and flood coverage over tideland areas only. These maps are intended to assess projected hazards over these areas exclusively; these maps do not apply to the remaining areas of Newport Beach.

As a reference, present day (i.e., no SLR) inundation and flood extents are depicted with light blue shades in Figure 5-1 and Figure 5-2. For clarification, areas indicated as flooded under present day conditions, or a shorter-term time horizon, will also be subject to flooding under subsequent time horizons. As an example, areas depicted in green on Reach 1 (Figure 5-1) are areas that will be subject to tidal inundation on the 2030, 2050, and 2100 time horizons, whereas areas depicted in red will only be inundated by tides around year 2100.

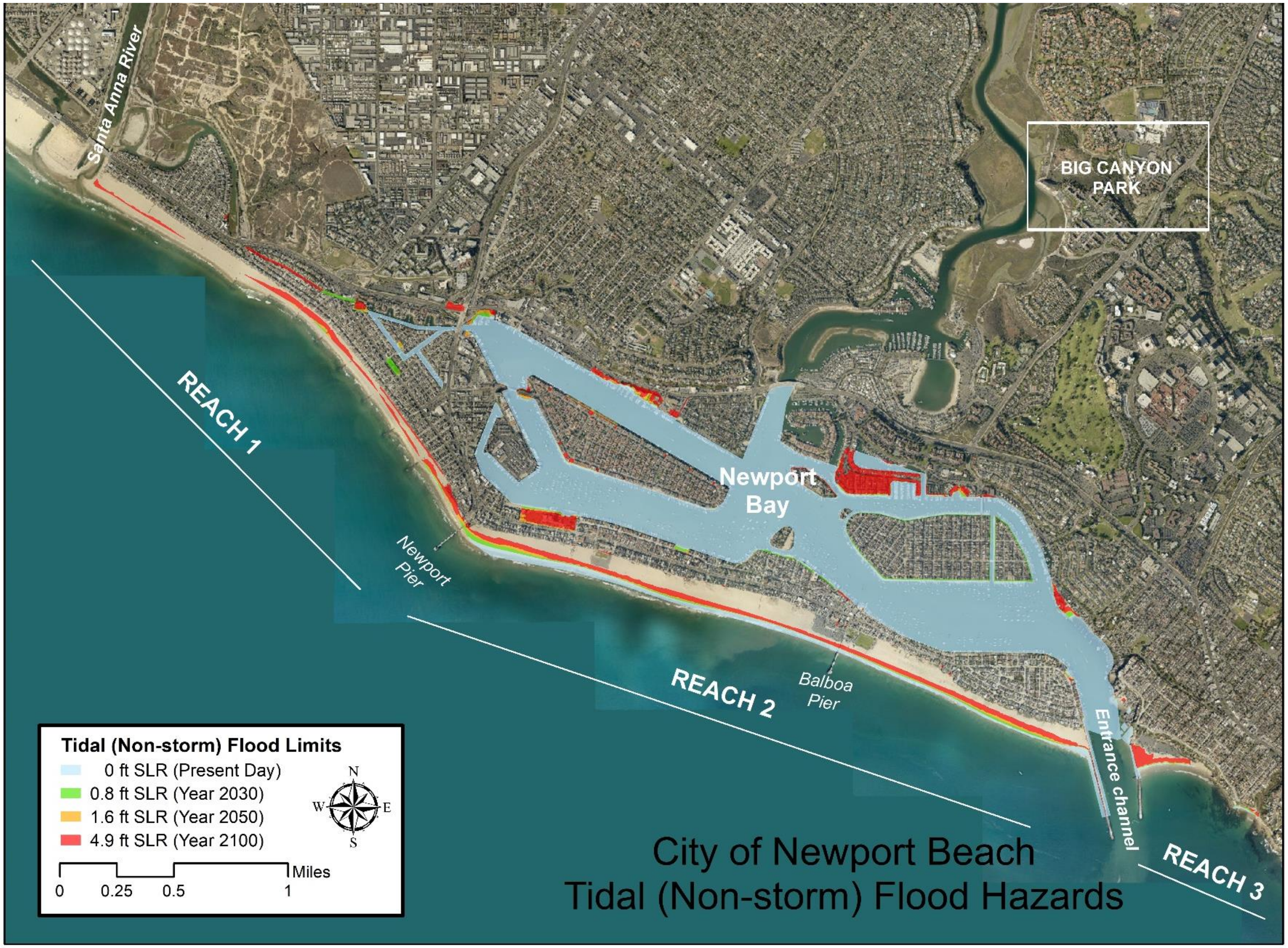


Figure 5-1: Projected Extent of Tidal Inundation on Newport Beach Tideland Areas for the 2030, 2050, and 2100 Planning Horizons

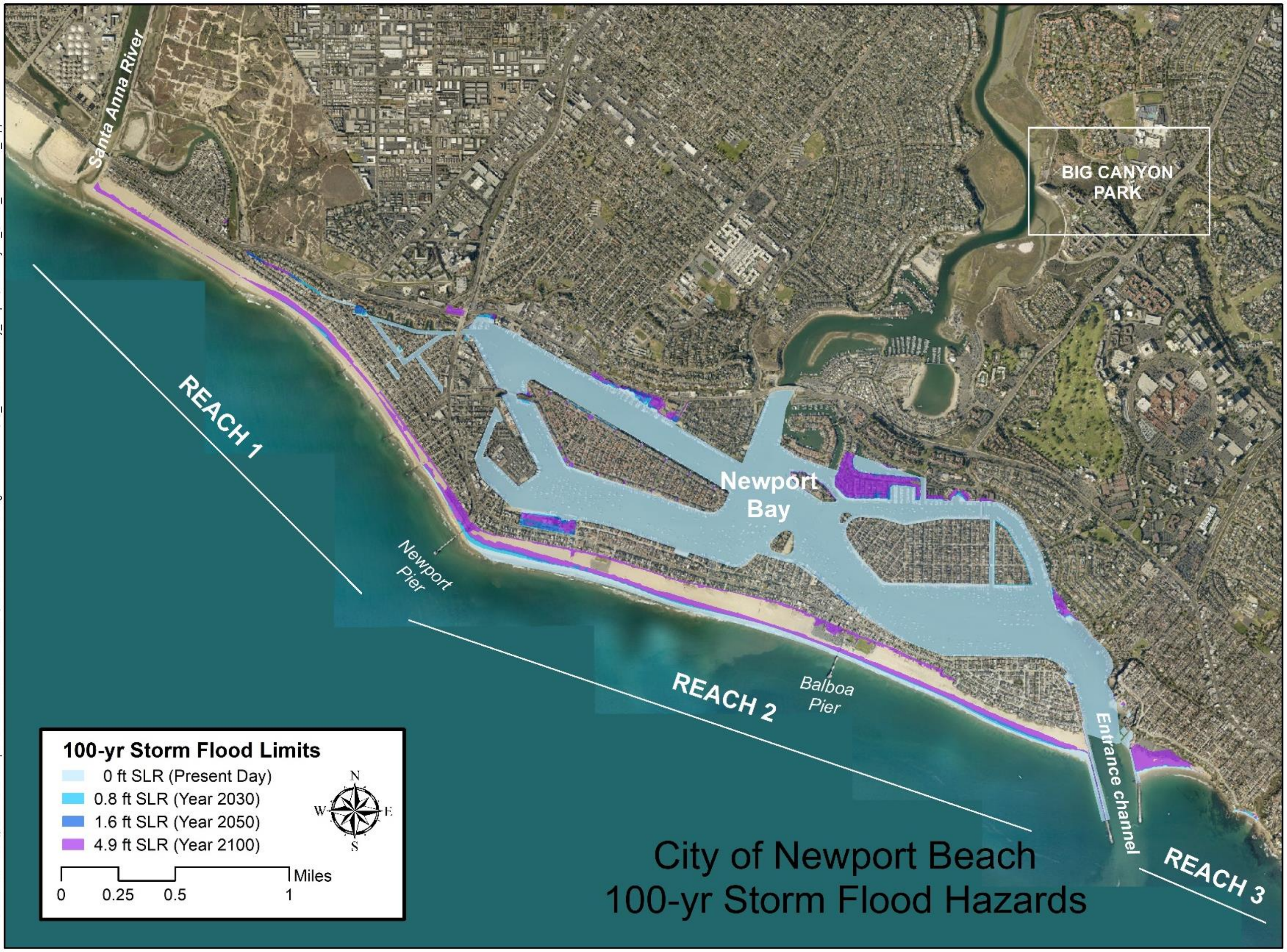


Figure 5-2: Projected Extent of Extreme Flooding on Newport Beach Tideland Areas for the 2030, 2050, and 2100 Planning Horizons

Vulnerability of tideland assets to SLR is assessed in the following sections. Vulnerability rating matrices, which follow criteria in Table 5-1, are presented and discussed for each resource category. Additionally, inventory summaries of the identified vulnerable tideland assets through the different planning horizons (including present day conditions for reference) are provided in Table 5-8. The summaries provide quantities for each asset type affected by SLR. Figure 5-3 to Figure 5-26 show vulnerability maps for the 2030, 2050, and 2100 planning horizons. It is again noted that these maps represent resources and hazards that are exclusively within tideland areas of Newport Beach.

5.1 Parks and Beaches

Table 5-3 shows the vulnerability rating for parks and beaches. Parks are recognized as important assets to recreation as they provide low cost visitor-serving amenities. Out of the 17 parks in Newport Beach tidelands, 16 are located on sensitive low-lying areas of Newport Beach. Although impacts to the physical structures (e.g., asphalt paving, restrooms, and some utilities) within the affected parks would be relatively low (i.e., low sensitivity), loss of these amenities would be significant since space for these features to move inland is not available (i.e., low adaptive capacity).

Exposure of sandy beaches to SLR impacts, primarily coastal erosion, is anticipated with any SLR scenario. In a natural setting, beaches can be thought to have a high adaptive capacity because they will naturally adjust to a rising sea level if adequate sand exists in the system. However, the adaptive capacity of beaches can be low in areas where beaches are backed by hard infrastructure and/or where insufficient sand exists in the system.

Table 5-3: Vulnerability Rating for Parks and Beaches

Asset	Time Horizon	Exposure Rating	Sensitivity Rating	Adaptive Capacity	Vulnerability Rating (Score)
Beaches	2030	1	1	1	3
	2050	1	1	1	3
	2100	3	2	3	8
Parks	2030	1	1	2	4
	2050	1	1	2	4
	2100	3	2	3	8

5.1.1 Vulnerability of Parks

Table 5-4 provides a breakdown of projected flooding areas for Parks in Newport Beach tidelands. Overall, minor impacts to parks are anticipated for the 2030 time horizon. For Reaches 1 and 2, parks around Newport Island (i.e., Newport Island Park, Lake Street Park, Channel Place Park, and 38th Street Park) and in close proximity to the Bay (i.e., Marina Park and Veterans Memorial Park) are projected to experience partial inundation during high tides (projected flooding through time can be observed in Figure 5-3 through Figure 5-14 as darker shades of green overlaying park areas). During the 100-year storm, temporary flooding is anticipated over the same parks, but over a larger area, with flooding over the entire 38th Street Park and Lake Street Park, in Reach 1. Overall, only 5% of the total park areas will be affected for the 2030 time horizon. Vulnerability of parks for this time horizon is, therefore, ranked as low.

Projected water levels at the 2050 time horizon and during the 100-year storm will result in flooding over 14 parks. This represents impacts on about 12% of the total park areas and includes flooding along the western fringes of Big Canyon park. Overall vulnerability of parks is ranked low for this time horizon.

The significant increase in coastal erosion projected for the 2100 timeframe is projected to impact Big Corona del Mar State Park (Reach 3, Figure 5-13). Additionally, with the exception of West Newport Park (Reach 1), Peninsula Park (Reach 2), and Big Canyon Park (Figure 5-14), the rest of the parks will be entirely or nearly entirely flooded under the 100-year storm event (38% of park areas impacted). With a limited ability to relocate or adapt to the projected conditions, the overall vulnerability for parks is ranked high for the 2100 timeframe. Similar to the 2050 time horizon, minimal impacts associated with inundation or flooding are anticipated for Big Canyon Park for the 2100 time horizon. As depicted in Figure 5-14, the 100-year flood in combination with 4.9 feet of SLR reaches only the fringe western limits of the park.

Table 5-4 Projected Inundation (No-Storm) and Flooding (100-yr Storm) in Newport Beach Parks.

Park Name	Reach	Park Area (sq ft)	0 ft SLR		0.8 ft SLR		1.6 ft SLR		4.9 ft SLR	
			No-Storm	100-yr Storm	No-Storm	100-yr Storm	No-Storm	100-yr Storm	No-Storm	100-yr Storm
Lookout Point	3	37,867	0%	0%	0%	1%	1%	1%	1%	1%
West Newport Park	1	279,184	0%	0%	0%	0%	0%	0%	35%	82%
Channel Place Park	1	53,228	3%	12%	11%	28%	23%	95%	100%	100%
38th Street Park	1	34,391	0%	98%	84%	99%	99%	100%	100%	100%
Newport Shores Park	1	8,886	0%	0%	0%	0%	0%	0%	100%	100%
Veterans Memorial Park	2	60,833	2%	3%	3%	5%	7%	23%	100%	100%
Corona Del Mar State Beach**	3	745,797	4%	7%	5%	9%	7%	11%	40%	70%
Rhine Wharf Park	1	667	74%	100%	81%	100%	100%	100%	100%	100%
Peninsula Park	2	199,676	0%	0%	0%	0%	0%	0%	0%	6%
Newport Island Park	1	14,285	22%	53%	30%	90%	94%	100%	100%	100%
West Jetty View Park	2	36,074	38%	40%	39%	41%	41%	43%	51%	62%
Lido Park	1	6,936	0%	0%	0%	0%	0%	0%	20%	38%
Myrtle Park	2	1,998	1%	1%	1%	1%	2%	22%	100%	100%
Big Canyon Park	NA	1,705,899	0%	0%	0%	0%	0%	0%	0%	0%
Lake Street Park	1	2,882	47%	100%	97%	100%	100%	100%	100%	100%
Marina Park	2	314,587	1%	6%	7%	13%	19%	51%	99%	100%
Marina Park (Docks)	2	75,080	42%	48%	49%	53%	54%	62%	100%	100%
Total	-	3,578,271	2%	5%	4%	6%	7%	12%	27%	38%

5.1.2 Vulnerability of Beaches

Approximately 17% of sandy beach area is anticipated to be impacted by coastal erosion and tidal inundation by year 2030. Most of the coast along Reach 1 (Figure 5-3) is projected to remain wide enough (around 500 feet on its northwestern end to about 200 feet on its narrowest point) to allow for recreation opportunities and provide a horizontal buffer against storms. Beaches around Newport Pier, which are narrower due to encroachment of hard infrastructure (parking lot, fish market, and Lifeguard Headquarters Building), will also remain wide enough (around 130 feet wide) to allow for public access and recreation.

Beaches on Reach 2 (Figure 5-4) are generally wider than those in Reach 1, and are, therefore, less vulnerable to SLR hazards. Typical beach widths range from about 500 feet to about 300 feet (with the exception of beaches around Balboa Pier and Newport Elementary, which are about 160 feet wide). On the harbor side, the tideland beaches at 10th Street and China Cove show vulnerability to coastal inundation (see Figure 5-4 and Figure 5-5) and these areas get incrementally worse as sea level rises. At Reach 3, the projected beach width for Little Corona del Mar ranges from a few feet, where the beach is backed by a coastal bluff to about 90 feet, where the beach is backed by a paved pathway (see Figure 5-6).

During a 100-year major storm event, 19% of the beach is projected to be subject to flooding. This condition might result in a temporary public access disruption around Newport Pier (Figure 5-3), where flood limits are within a few feet of hard infrastructure and upland development. The Little Corona del Mar Pocket Beach (Figure 5-6) might also be almost entirely flooded during this condition.

Beach vulnerability for the 2030 time horizon is low at West Newport Beach and Peninsula Beach, as impacts are only anticipated for less than 20% of the total beach area. Both West Newport Beach and Peninsula Beach benefit from the wide sandy beach conditions. The beaches at 10th Street, China Cove, and Little Corona, however, do show tidal inundation impacts and loss of beach area (see Figure 5-4 and Figure 5-5).

For the 2050 time horizon, beach vulnerability to SLR-related hazards is not significantly aggravated at West Newport Beach and Peninsula Beach. Approximately 20% of sandy beach area will be impacted by coastal erosion and tidal inundation; however, beach widths will still allow for recreation and public access. Retreat of the MHW line for Reach 1 is largest around the center of the reach (beach width of about 175 feet, Figure 5-7), while beaches around Newport Pier exhibit the smallest retreat. Coastal erosion on Reach 2 is largest at its northwest and southeast ends, and is relatively uniform along the rest of the reach. Nevertheless, beaches are still 300 feet and 400 feet wide, respectively. Retreat of the MHW line is negligible fronting Newport Elementary School and around Balboa Pier, i.e., the beaches are likely to remain over 150 feet wide for this time horizon. No impacts to public access or recreation are, therefore, expected for this time horizon. On the harbor side however, the tideland beaches at 10th Street and China Cove show vulnerability to coastal inundation (see Figure 5-8 and Figure 5-9). Meanwhile, for the Little Corona del Mar Beach in Reach 3 (Figure 5-9), the projected MHW line has reached the bluffs and, it is likely that only the southern portion (backed by paved pathway) of the beach is accessible for recreation by this time horizon.

Under the 100-year storm, about 22% of sandy beach area will be subject to flooding. High water levels are anticipated to reach the fish market and lifeguard buildings adjacent to the Newport Pier (Figure 5-7);

therefore, public access will be temporarily disrupted. The vulnerability of beaches is also rated low for the 2050 time horizon, as, no significant increase in impacts are anticipated.

Beach vulnerability to SLR hazards increases significantly for the 2100 time horizon. Approximately 40% of sandy beach area is projected to be impacted by long-term coastal erosion and tidal inundation. Typical retreat of the MHW line is around 100 feet under this scenario. This will affect beaches in Reaches 1, 2, and 3 (Figure 5-11, Figure 5-12, and Figure 5-13).

In Reach 1, the highest exposure to coastal erosion and tidal inundation is anticipated around Newport Pier, where the MHW is projected to have retreated past the fish market and Lifeguard Headquarters Building (*No-hold the Line, No Nourishment scenario*). Note that a rock revetment was constructed around the base of the Lifeguard Headquarters Building. The revetment may serve to protect the building during this SLR scenario. This Study recommends the revetment be assessed to determine if it provides sufficient protection in 2100 or needs augmentation. Another sensitive, but less critical, area is the central region of Reach 1, where beaches are projected to be approximately 50 feet wide. At Reach 2 on the harbor side the beach at 10th Street is completely submerged in place. Other sensitive areas in Reach 2 (Figure 5-12) are the beaches fronting Newport Elementary School and the beaches around Balboa Pier, which are projected to be around 50 feet and 80 feet wide, respectively. The remaining beaches in Reach 2 are less vulnerable and remain relatively wide (about 170 feet on the narrower southeastern stretch). Little Corona del Mar Beach in Reach 3 is projected to be completely lost due to long-term coastal erosion (*No-hold the Line, No Nourishment scenario*), and the MHW line is projected to reach the hard infrastructure backing the existing beach and bluffs.

During the 100-year storm (year 2100), high water levels from the bay (which inundate low lying areas in Newport Island) reach most of the beaches on Reach 1. This, in combination with high water levels and wave action from the ocean, results in flooding of almost the entire southwestern beach of Reach 1. Beaches on Reach 2 are also flooded from the bay and ocean sides. However, the majority of the beach area is projected to remain dry under this event. Little Corona Beach on Reach 3 is projected to be completely flooded during the 100-year storm condition.

Beach vulnerability is high for the 2100 timeframe, as impacts from erosion are anticipated for approximately 46% percent of the beach area. With increased erosion, the beaches will be squeezed between the ocean and hard infrastructure, limiting the beach's natural ability to maintain its elevation relative to sea level by migrating upward and landward. Loss of beach due to coastal erosion also translates to a reduction on the natural buffer against storm waves. A potentially major effort might be required to effectively mitigate for the anticipated SLR impacts to beaches in Reaches 1, 2, and 3 by this time horizon.

The narrow, bluff-backed beach of Little Corona is sensitive to changes in sediment supply. By 2100, SLR will likely move breaking waves closer to the bluffs, which will increase bluff erosion rates and potentially threaten property as the bluffs gradually retreat. Depending on the rate and volume of sediment supplied by bluff erosion, the beach at Little Corona may not be able to keep up with SLR. The vertical access to Little Corona from Ocean Boulevard/Poppy Avenue will also be threatened if this access is undercut by bluff erosion. Erosion from storm waves will be a concern for this area. An increase in coastal storm magnitude or frequency would increase coastal bluff retreat. Wave heights are generally greater during El Niño months. Large storms arriving at times of high tides could be particularly destructive to this pocket beach area.

5.2 Submerged Waterways

5.2.1 Navigation Channel

Table 5-5 shows the vulnerability rating for boating infrastructure. Vessel traffic on navigation channels might be impacted by SLR in the case of increased shoaling, requiring additional efforts to maintain design depths and avoid navigational hazards. Pending further investigations, no drastic changes in the hydrodynamics and sediment input to Newport Bay are anticipated as a result of SLR; therefore, this type of impact is assumed negligible. Further, without the presence of road or pedestrian bridges above the navigation channel (Figure 5-11 and Figure 5-12) there is no bridge clearance issue and no foreseen impact to vessel traffic as a result of SLR.

5.3 Boating Infrastructure

Resources in this category generally have a high adaptive capacity to changes in sea levels. However, these assets can also be highly vulnerable if they are not designed to accommodate some amount of SLR. To adequately and accurately quantify exposure of assets in this category, field inspections. in combination with a review of the design of existing structures, in Newport Bay is required. For this vulnerability assessment, it is assumed that the totality of the structures is designed according to standards and will, therefore, become exposed at the same threshold of SLR.

Table 5-5: Vulnerability Rating for Boating Infrastructure

Asset	Time Horizon	Exposure Rating	Sensitivity Rating	Adaptive Capacity	Vulnerability Rating (Score)
Docks	2030	0	0	0	0
	2050	3	3	3	9
	2100	3	3	3	9
Mooring Sites	2030	0	0	0	0
	2050	0	0	0	0
	2100	0	0	0	0

5.3.1 Vulnerability of Docks

The boat slips and docks in Newport Harbor are floating docks and are designed to rise and fall with the tides. However, some important aspects to consider when assessing exposure of dock infrastructure to SLR hazards include elevations on guide-piles, bulkhead walls, and increasing loads that these assets, along with other mooring hardware, could be subject to as a result of a higher water column and increased environmental loading on moored vessels. Per the 2008 City of Newport Beach Waterfront Project Guidelines and Standards, the minimum allowable pile cut off elevation is +12.8 feet NAVD88, and this implies that the existing docks could accommodate up to 4.9 feet of SLR without being at risk of floating above the existing guide piles. However, per the 2008 guidance, bulkhead seawalls are to be constructed with a top elevation of not less than +8.8 feet NAVD88 (9.0 feet MLLW), which was the assumed elevation for this report. Assuming docks become obsolete when access via gangways no longer maintains negative slopes towards the docks, impacts to docks are anticipated by year 2050, when high tides (+8.6 feet NAVD88, Table 5-2) are projected to nearly reach the assumed crest elevation for the bulkhead seawall

(+8.8 feet NAVD88). A detailed assessment of increased environmental loadings is recommended to ensure that boat docks do not become vulnerable prior to the established threshold (2050 time horizon).

No vulnerability for docks is identified for the 2030 time horizon. Meanwhile, major changes and significant updates in the boating infrastructure of Newport Bay would be required to adapt to rising sea levels at subsequent time horizons. Overall vulnerability for the 2050 and 2100 time horizons is, therefore, ranked as high.

5.3.2 Vulnerability of Mooring Sites

Important aspects to consider when assessing exposure of mooring sites to SLR hazards include length of tether lines and increasing loads that these assets, along with anchorage and mooring hardware, could be subject to as a result of a higher water column and increased environmental loading on moored vessels. For this assessment, it is assumed that existing infrastructure on mooring sites is adequate to accommodate for the anticipated SLR up to the 2100 time horizon (i.e., these assets are not vulnerable). A detailed assessment of increased environmental loadings is recommended to confirm the conclusion above.

Table 5-6: Parks and Beaches, Boating Infrastructure and Submerged Tidelands Vulnerable Resources

Resources			Vulnerable Resources (Quantities)								Vulnerable Resources (%)							
			Year 2018 0.0 feet SLR		Year 2030 0.8 feet SLR		Year 2050 1.6 feet SLR		Year 2100 4.9 feet SLR		Year 2018 0.0 feet SLR		Year 2030 0.8 feet SLR		Year 2050 1.6 feet SLR		Year 2100 4.9 feet SLR	
Category	Asset Type (Unit)	Total	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm
Parks and Beaches	Parks (Acres) (Erosion)	82	NA		0		1		4		NA		0%		1%		5%	
	Parks (Acre) (Flooding)	82	2	4	4	5	5	10	23	31	4%	4%	4%	6%	7%	12%	27%	38%
Parks and Beaches	Beach (Acre) (Erosion)	245	NA		36		44		89		NA		15%		18%		36%	
	Beach (Acre) (Flooding)	245	33	39	43	48	51	55	100	115	13%	16%	17%	19%	21%	23%	41%	47%
Boating Infrastructure	Docks (Count)	1,136	0	0	0	0	1136	1136	1136	1136	0%	0%	0%	0%	100%	100%	100%	100%
Boating Infrastructure	Mooring Sites (Count)	13	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%	0%	0%
Submerged Tidelands	Navigation Channel	1	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%	0%	0%

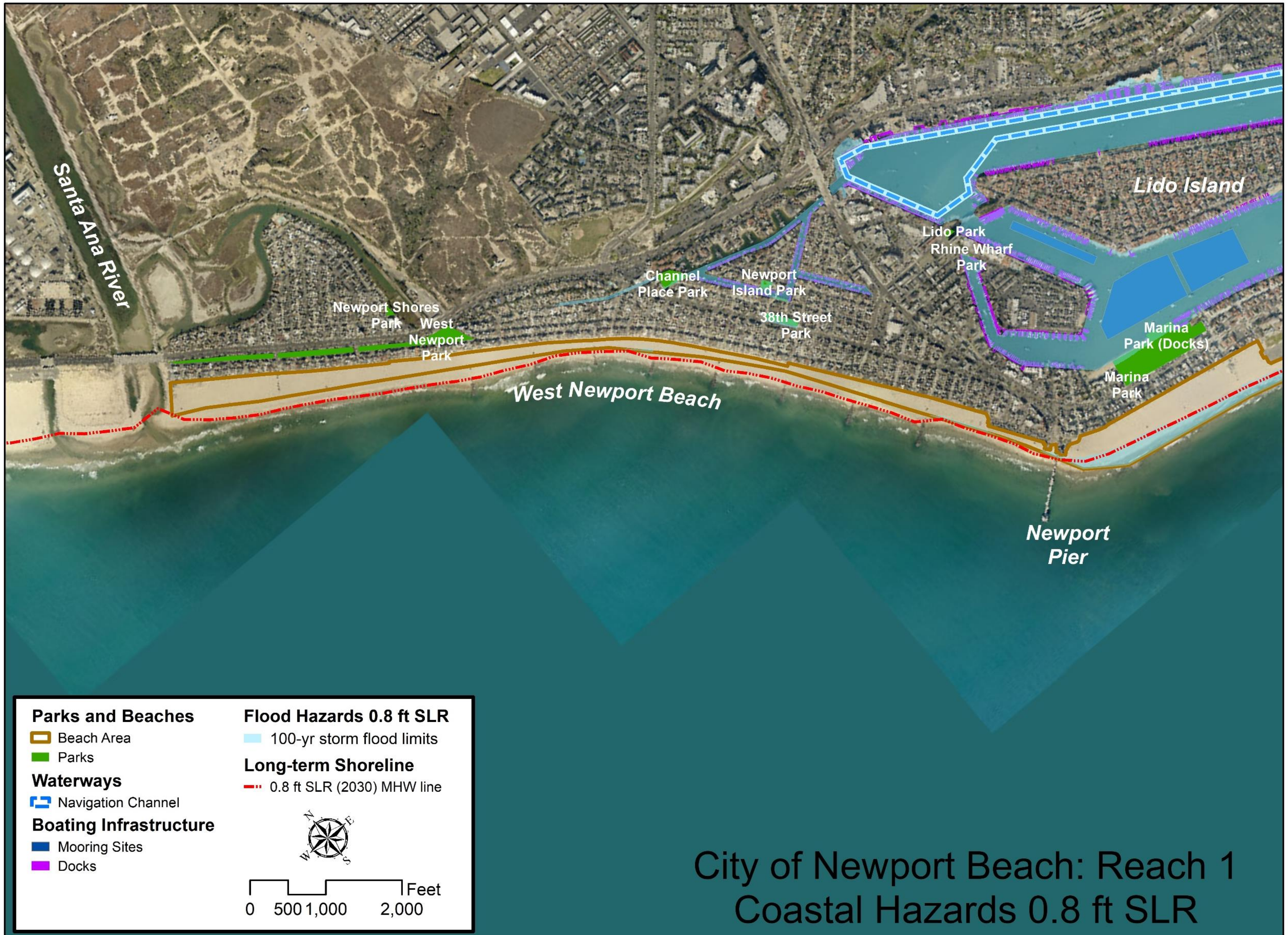


Figure 5-3: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 1

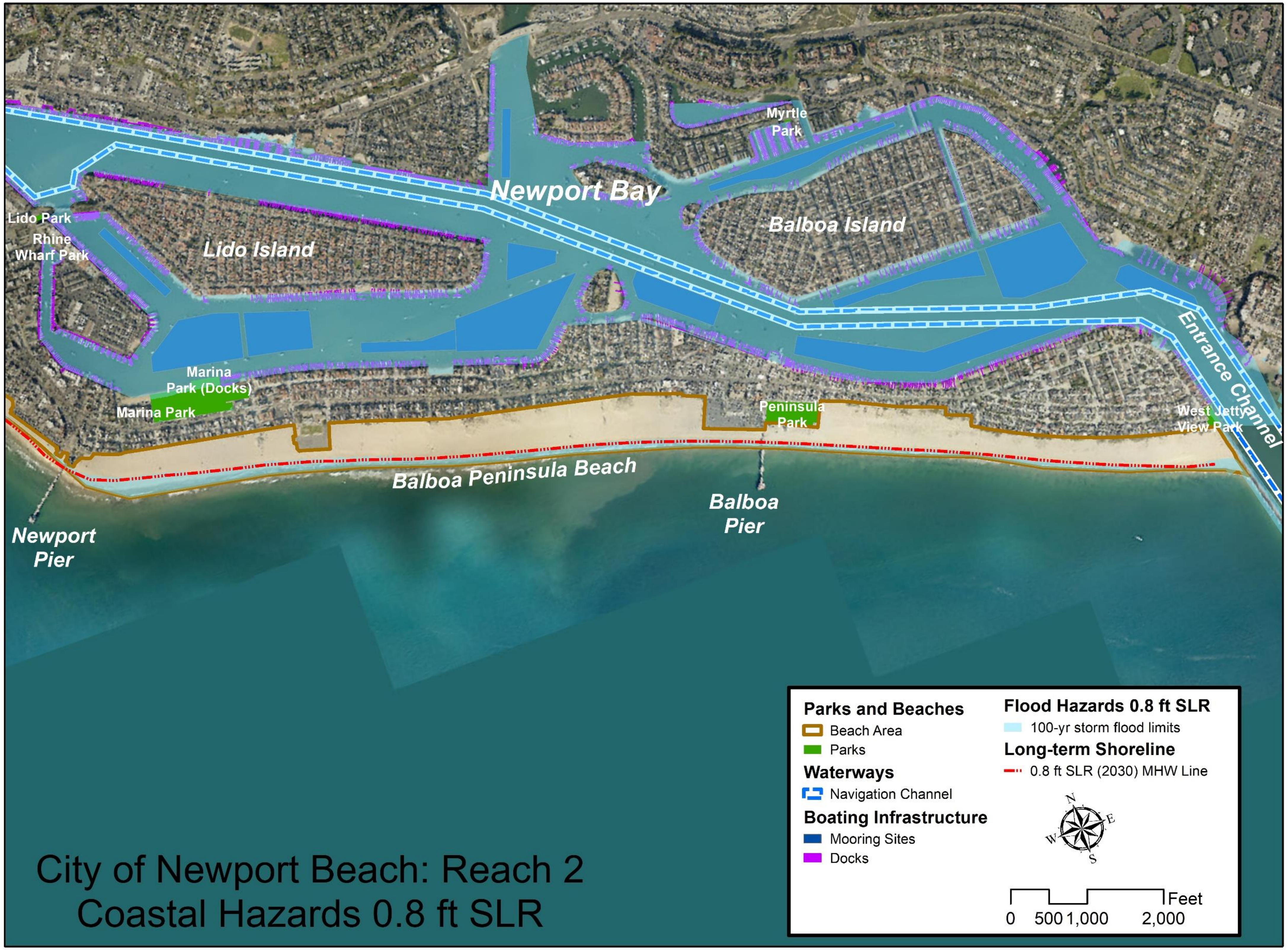


Figure 5-4: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 2

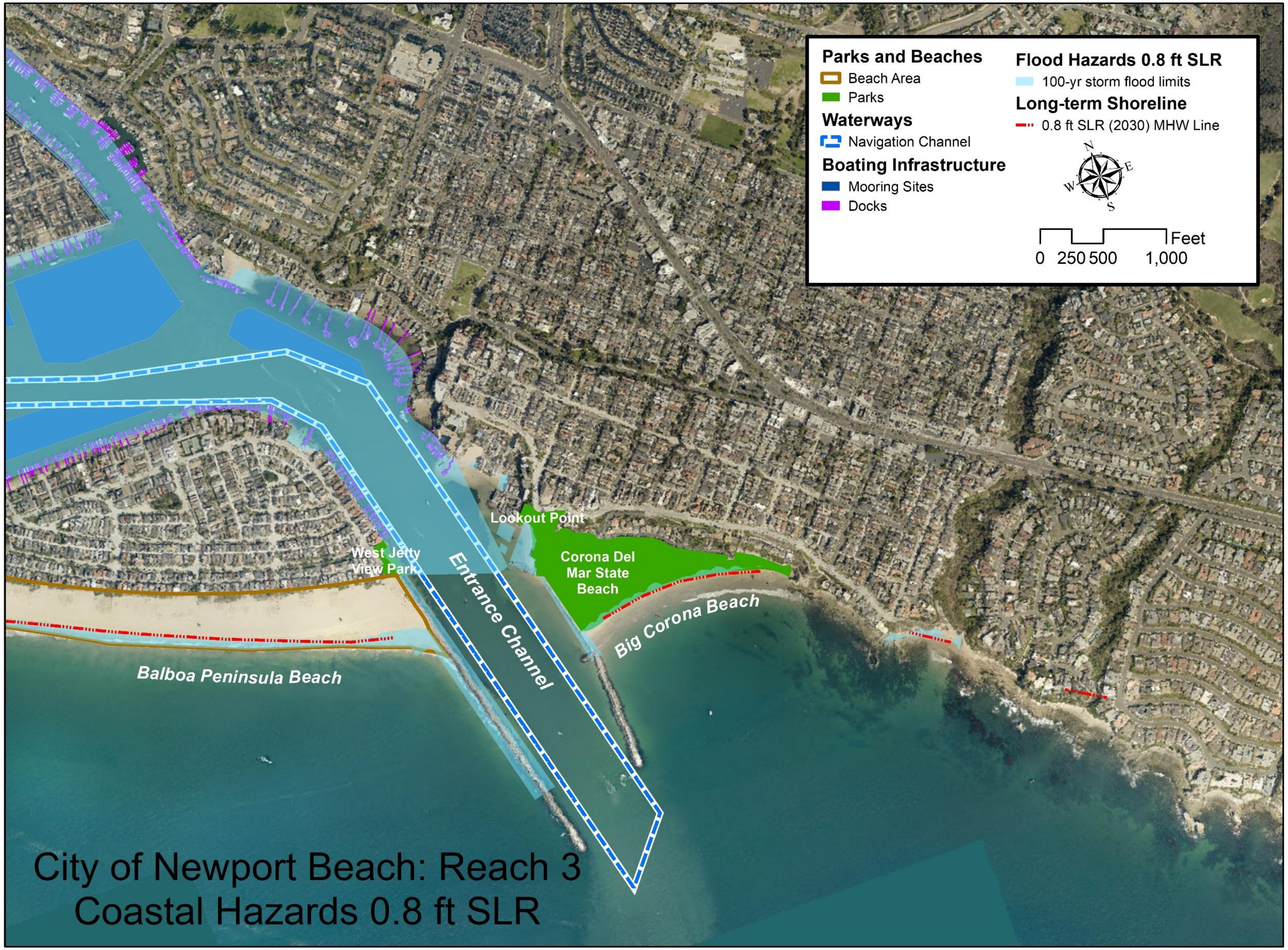


Figure 5-5: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 3

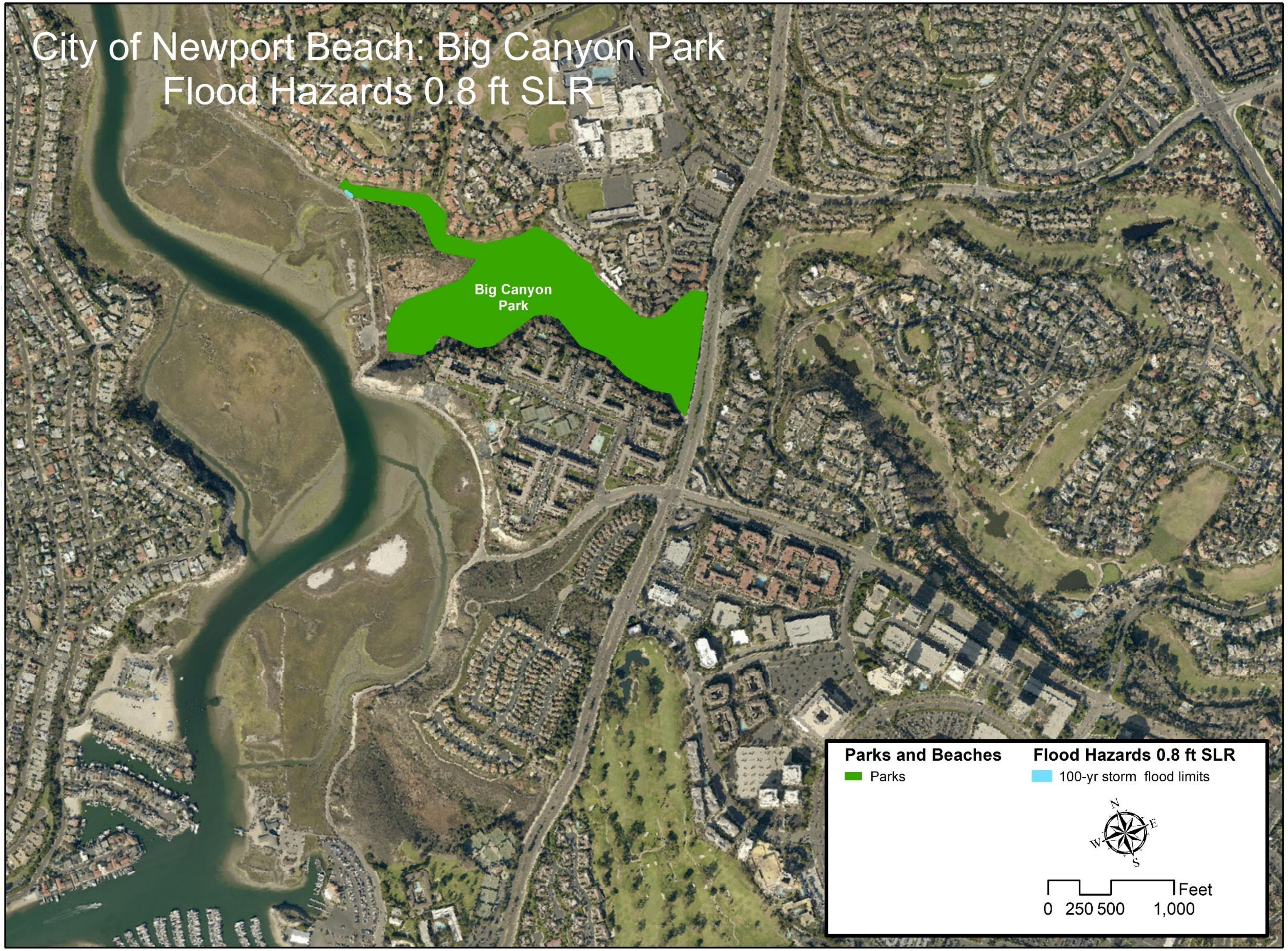


Figure 5-6: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 0.8 Feet SLR (Year 2030) Hazards – Big Canyon Park

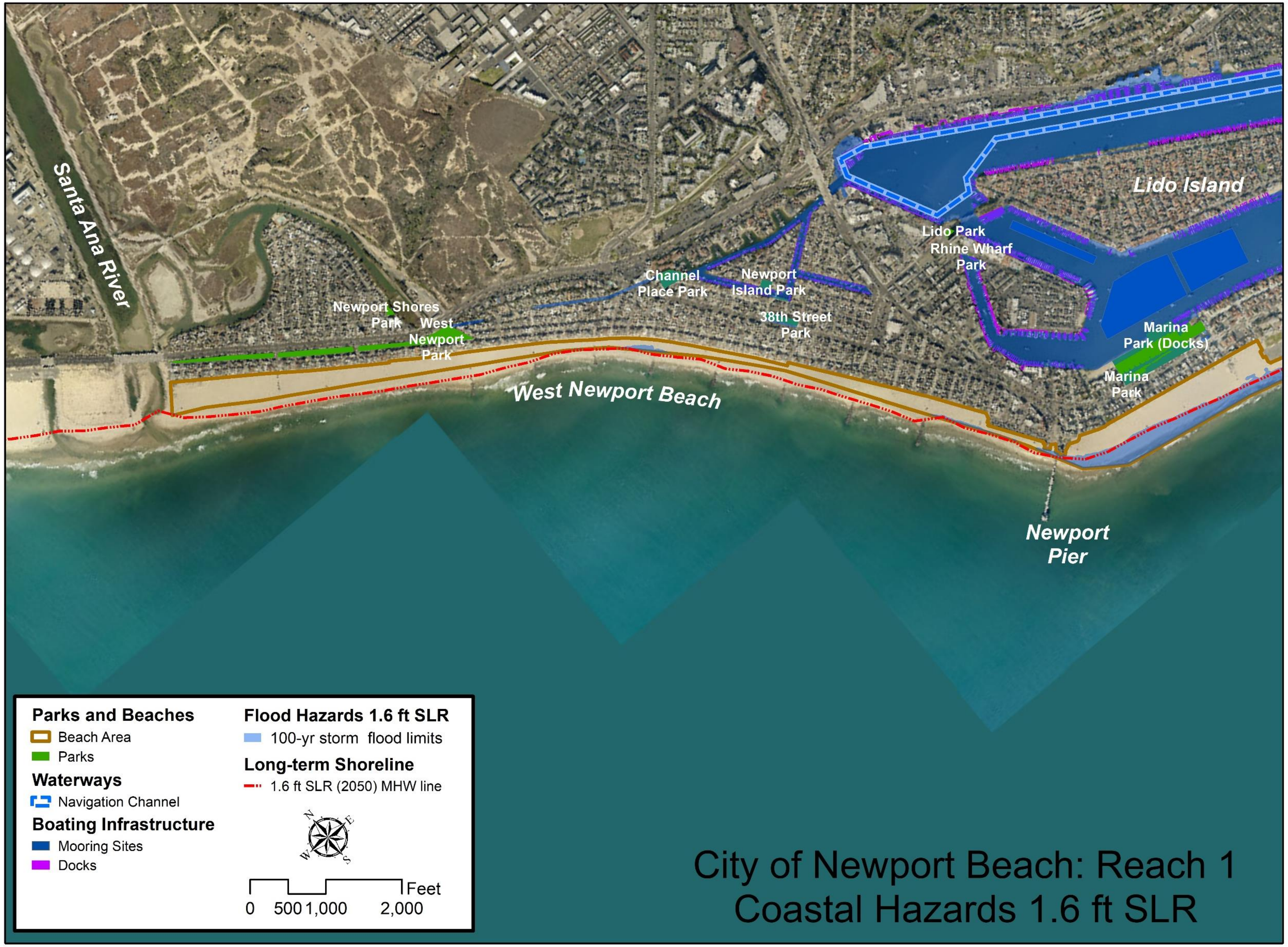


Figure 5-7: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 1

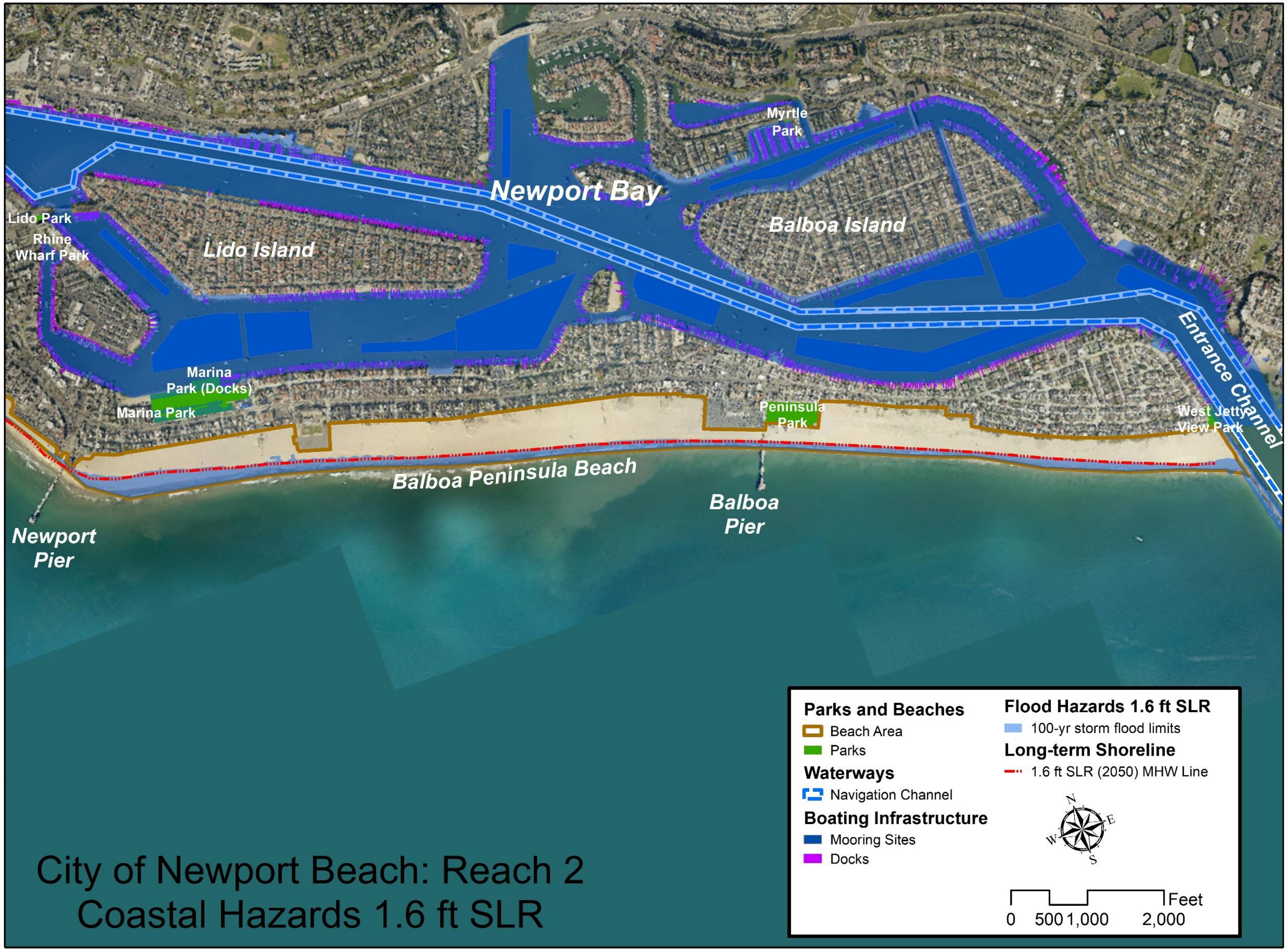


Figure 5-8: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 2

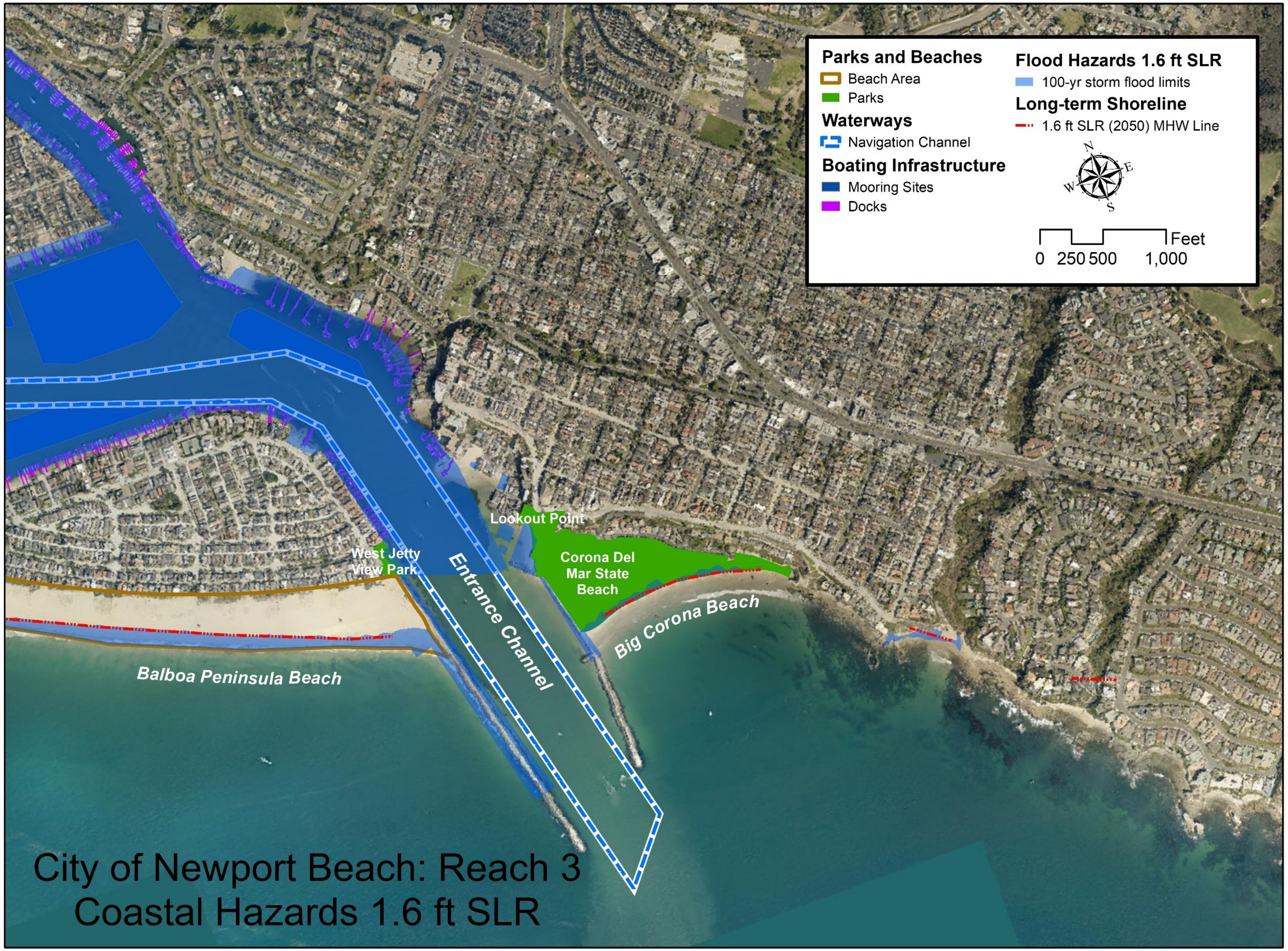


Figure 5-9: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 3

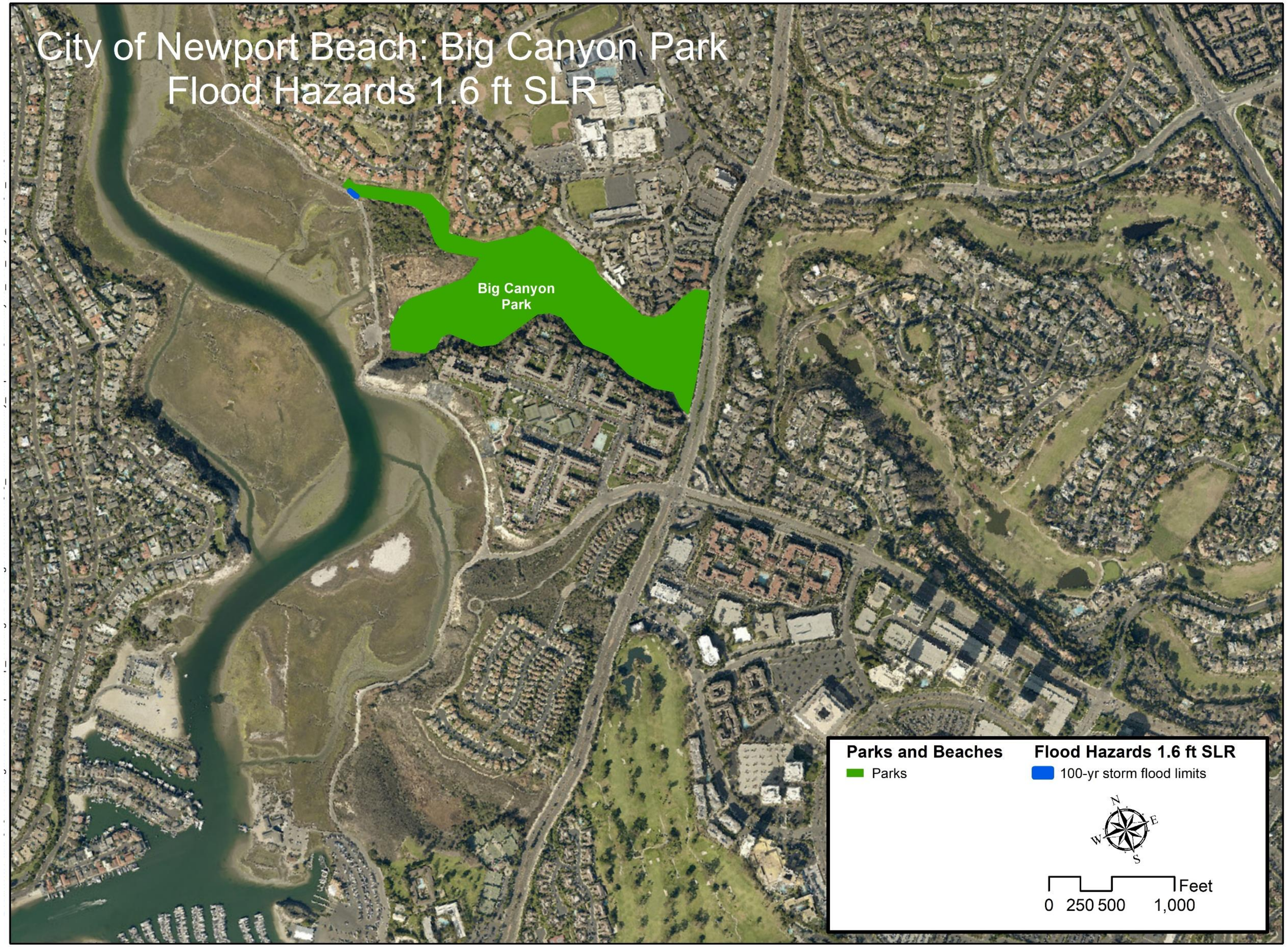


Figure 5-10: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 1.6 Feet SLR (Year 2050) Hazards – Big Canyon Park

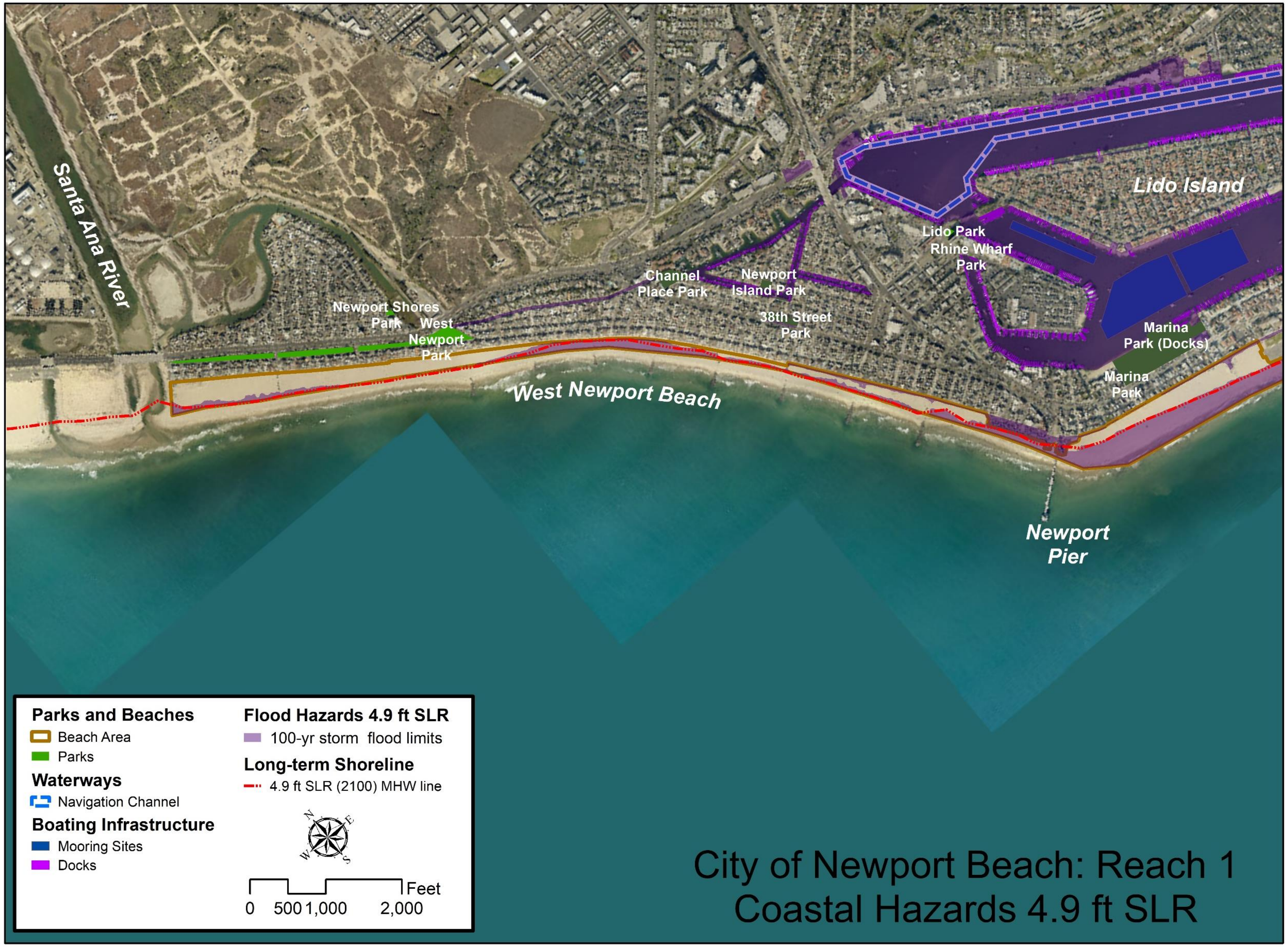


Figure 5-11: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 1

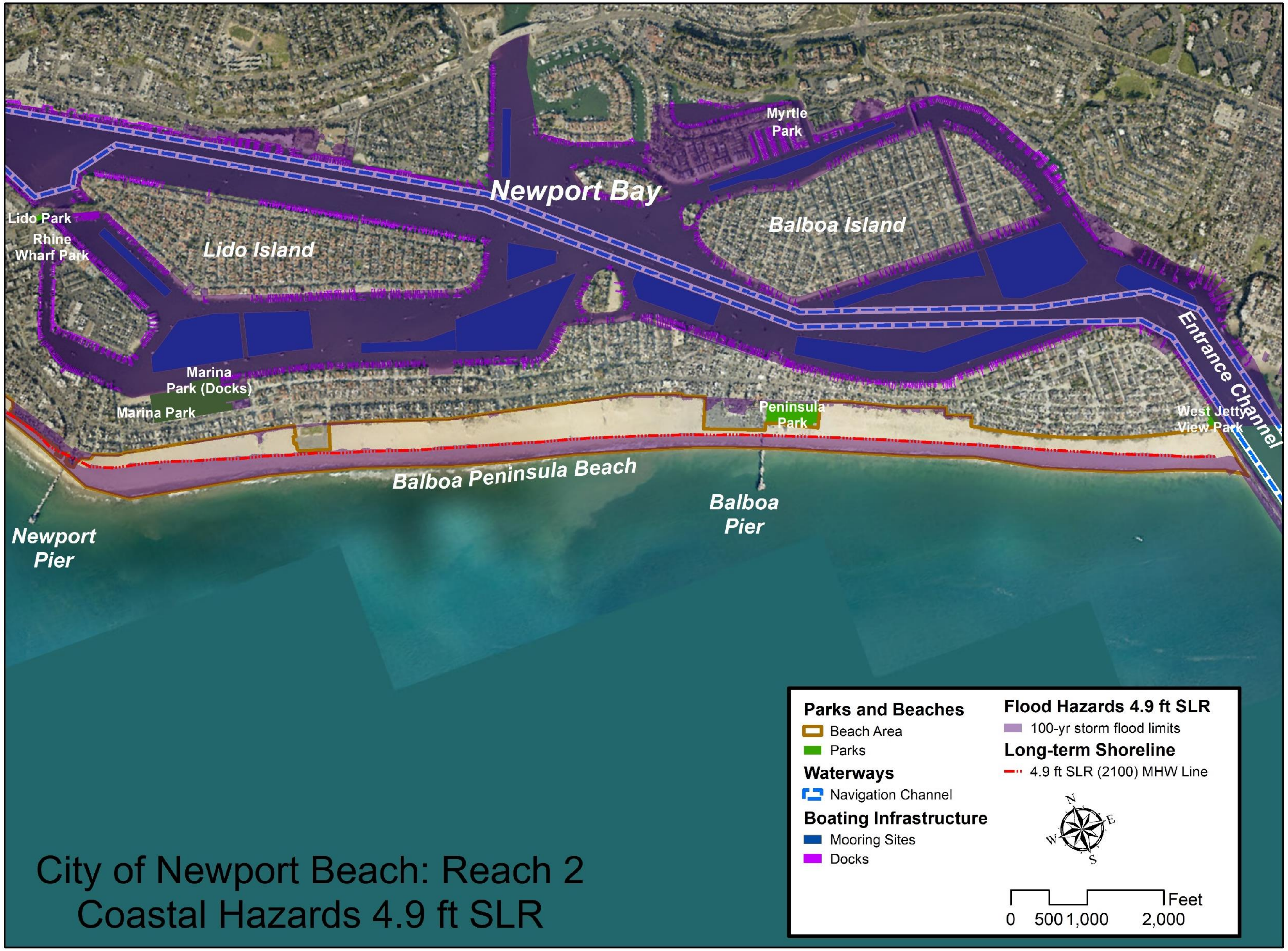


Figure 5-12: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 2

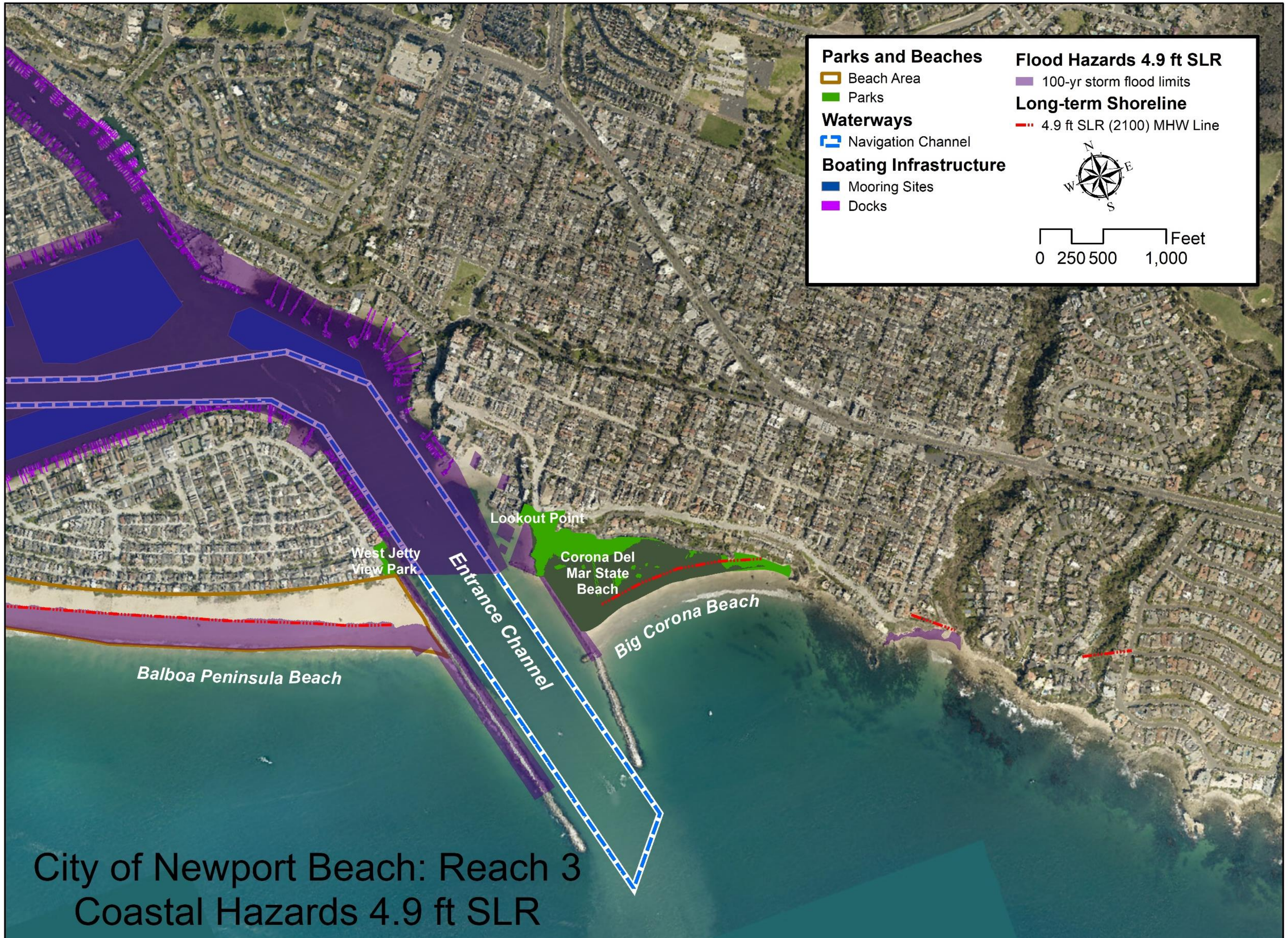


Figure 5-13: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 3

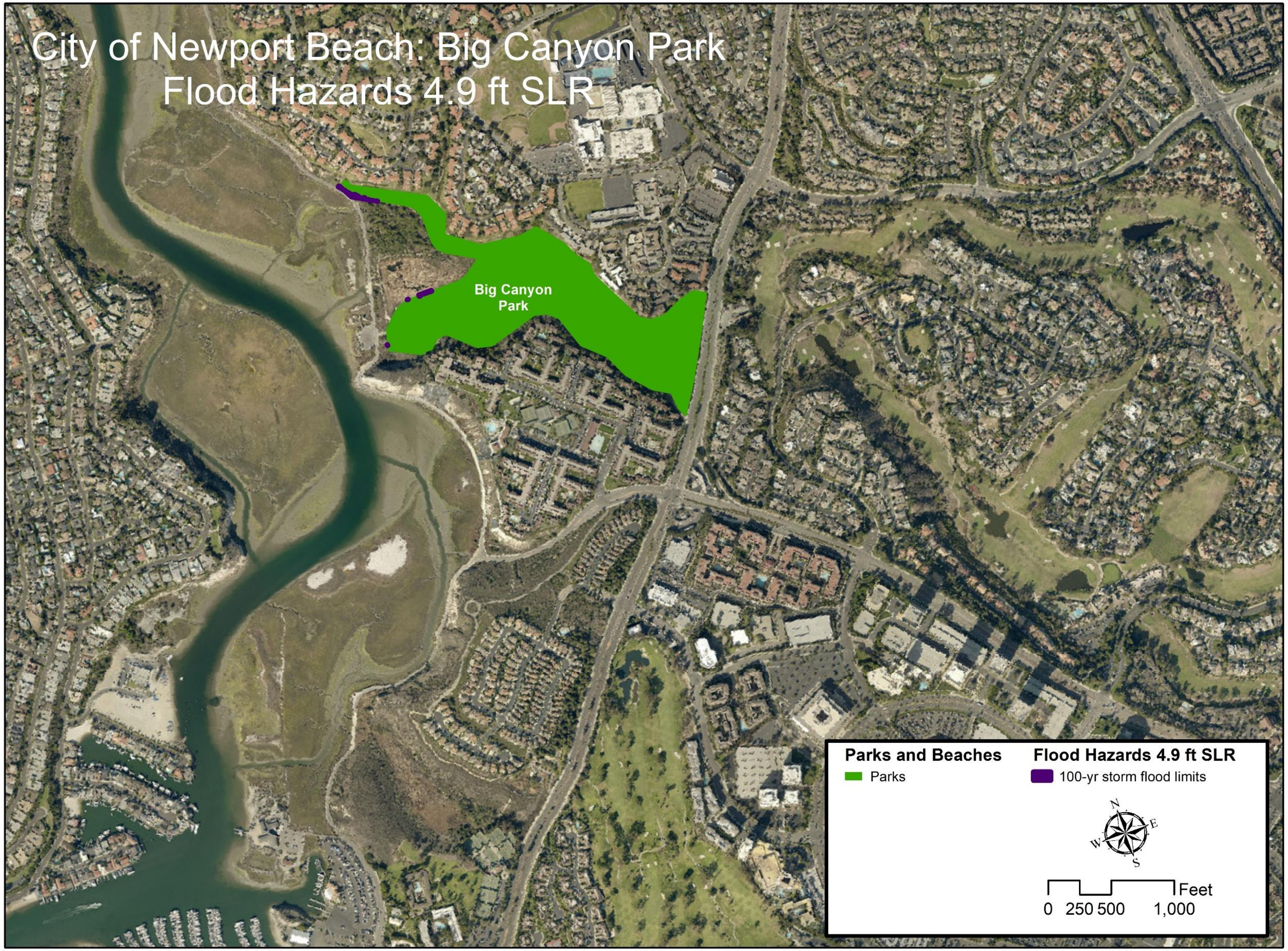


Figure 5-14: Parks, Beaches, Boating Infrastructure, and Submerged Tidelands Assets with 4.9 Feet SLR (Year 2100) Hazards – Big Canyon Park

5.4 Upland Development

Table 5-7 shows the vulnerability rating for upland development. The overall exposure of upland development resources to SLR hazards in Newport Beach is high. A predominantly low-lying relief promotes inundation and flooding even for non-storm conditions under moderate SLR. Under present day conditions, the bulkhead wall running along most of the perimeter of the bay provides some protection against flooding. Gaps in the bulkhead wall on many pocket beaches around the bay give entry to high water levels and make the backland vulnerable to flooding. This, along with SLR, will progressively make the bulkhead obsolete. The low-lying relief in Newport Beach also limits the capacity of many resources to adapt to changing conditions.

Table 5-7: Vulnerability Rating for Upland Development

Asset	Time Horizon	Exposure Rating	Sensitivity Rating	Adaptive Capacity	Vulnerability Rating (Score)
Buildings	2030	1	3	3	7
	2050	2	3	3	8
	2100	3	3	3	9
Streets	2030	2	2	1	5
	2050	2	2	3	7
	2100	3	3	3	9
Commercial Areas	2030	2	3	3	8
	2050	2	3	3	8
	2100	3	3	3	9
Bulkhead Wall	2030	0	0	0	0
	2050	2	3	3	8
	2100	3	3	3	9
Parking Lots	2030	2	1	2	5
	2050	2	1	2	5
	2100	3	1	2	6
Restrooms	2030	1	2	3	6
	2050	1	2	3	6
	2100	3	2	3	8
Utilities (Stormdrain System)	2030	3	3	3	9
	2050	3	3	3	9
	2100	3	3	3	9
Utilities (Wastewater System)	2030	2	3	3	8
	2050	2	3	3	8
	2100t	3	3	3	9

5.4.1 Vulnerability of Buildings

Buildings are sensitive assets that provide for homes, goods and services, public facilities, and education. Adaptive capacity for buildings could potentially be moderate if located inland and have finished floors on elevated building pads, which is not the case for buildings in Newport Beach. Exposure of buildings to tidal inundation and extreme flooding is low for the 2030 time horizon (11% exposed). Most buildings impacted by this time horizon are in the inland area north of Lido Isle and in the Balboa Peninsula Area (Reach 2, Figure 5-16). Exposure increases (18% exposed) for the 2050 time horizon, when potential flooding due to extreme storm events is projected to impact the Lifeguard Headquarters Building and adjacent buildings in Reach 1. Exposure of buildings for the 2100 time horizon increases drastically (about 77% impacted). By this time, the Lifeguard Headquarters Building and adjacent buildings in Reach 1 are also projected to be exposed to coastal erosion. Tidal inundation and extreme flooding are projected to significantly impact Newport Elementary School recreational facilities, the Community Center and the adjacent buildings in Marina Park (Reach 2). Due to the high sensitivity and low adaptive capacity of buildings in Newport Beach tidelands, vulnerability is rated moderate for the 2030 time horizon and high for the 2050 and 2100 time horizons.

5.4.2 Vulnerability of Streets

Streets mapped in Figure 5-15 to Figure 5-25 include vehicle and pedestrian pathways as well as trails providing public access to and from the tidelands. Streets are generally thought to have moderate to high sensitivity to flood hazards as even minor amounts of flooding on roads can cause significant traffic delays and potentially disrupt emergency service vehicles and evacuation routes. Streets typically have a low adaptive capacity due to the significant costs associated with relocation or raising of these structures. Vulnerability of streets for the 2030 time horizon is ranked moderate, as it is mainly public access to the tidelands, which will be temporarily interrupted (low sensitivity). For the mid- and long-term time horizons (2050 and 2100), inundation and flooding of roadways not only pose interruption of traffic, but also roads and pedestrian ways start to become pathways for high water levels to intrude inland and cause greater flooding impacts. Vulnerability of streets to SLR, therefore, increases from moderate at the 2030 time horizon, to high at the 2100 horizon.

5.4.3 Vulnerability of Commercial Areas

Commercial areas in Newport Bay have a high sensitivity to flooding and limited adaptive capacity to relocate or adapt to changing conditions. Moderate exposure to inundation and flooding is anticipated for 2030 and 2050 (28% and 38% of areas flooded, respectively) in commercial areas located inland, north of Lido Isle and Balboa Island, as well as on Lido Peninsula (Reach 2, Figure 5-16). For the 2100 time horizon, about 73% (high exposure) of the commercial areas will be subject to flooding during the 100-year storm (Figure 5-23 and Figure 5-24). Vulnerability of commercial areas is rated high for all time horizons.

5.4.4 Vulnerability of Bulkhead Walls

As discussed above, the bulkhead walls represent a critical asset as they provide protection against flooding to the rest of the upland development resources. For this vulnerability assessment, the top of the bulkhead wall is assumed constant at +8.8 feet NAVD88. This implies that functionality of the bulkhead wall will start to become limited around the 2050 time horizon, when high tides (+8.6 feet NAVD88, Table

5-2) have nearly reached this elevation. Also for this time horizon, the elevation of the bulkhead walls could be exceeded by ocean water levels under an extreme storm condition. Vulnerability of the bulkhead wall is rated high for both the 2050 and 2100 timeframes due to its high sensitivity and the major effort required to maintain or enhance its level of flood protection.

5.4.5 Vulnerability of Parking Lots

Parking lots are thought of as low sensitivity assets to flooding as few significant damages or impacts result from temporary interruption in their services (other than sand cover needing to be removed, and water needing to be drained). They have a moderate adaptive capacity to flooding since the cost of raising or relocating these assets might be substantial. For the 2030 and 2050 time horizons, there is moderate exposure (36% to 52% impacted) of the parking lots immediately adjacent to the bay, especially for those located inland in the areas north of Lido and Balboa Island. For the 2100 time horizon, exposure increases to high as the extreme flood reaches all of the parking lots. The overall vulnerability of parking lots remains moderate for all time horizons.

5.4.6 Vulnerability of Restrooms

Restrooms are high sensitivity assets that have a low to moderate adaptive capacity to SLR hazards as their relocation could represent major efforts. Exposure to tidal inundation remains low for the 2030 and 2050 time horizons, as the majority of the restrooms remain out of the inundation and flooding zones (about 15% and 23% impacted, respectively). Vulnerability is ranked moderate for these time horizons. However, exposure increases abruptly (88% impacted) for the 2100 time horizon, when the overall vulnerability is ranked high.

5.4.7 Vulnerability of Utilities (Wastewater and Storm Drain Systems)

Utility assets, such as the wastewater and storm drain systems, are highly sensitive assets as they are necessary to run the City effectively and interruption of these utilities would significantly disrupt quality of life for residents. This infrastructure typically has a high sensitivity and low adaptive capacity.

Vulnerability of the wastewater system is assessed in terms of exposure of the pump station facilities to SLR hazards. Tidal inundation is projected to impact one of the two pump stations facilities (central region of Reach 2, Figure 5-16) during the 2030 and 2050 time horizons. The remaining pump station, located close to the Community Center in Reach 2, is anticipated to be affected by tides and extreme water levels during the 2100 time horizon (Figure 5-24). Vulnerability is rated high for all time horizons.

Vulnerability of the storm drain system is assessed in terms of exposure of catch basins and outlets to high water levels, which will compromise the drainage function. With the exception of outlet structures located at higher grounds on Big Canyon Park (Figure 5-18), the majority of the outlet structures are exceeded by high tides by year 2030 and 2050 (Figure 5-19 and Figure 5-20). Catch basins are less exposed to inundation and flooding during this time horizon, but become almost completely exposed by 2100. Nevertheless, without functionality of outlet structures, the system becomes obsolete at earlier time horizons. Vulnerability for both resources is rated high for all time horizons.

Table 5-8: Upland Development Vulnerable Resources

Resources			Vulnerable Resources (Quantities)								Vulnerable Resources (%)							
			Year 2018 0 feet SLR		Year 2030 0.8 feet SLR		Year 2050 1.6 feet SLR		Year 2100 4.9 feet SLR		Year 2018 0 feet SLR		Year 2030 0.8 feet SLR		Year 2050 1.6 feet SLR		Year 2100 4.9 feet SLR	
Category	Asset Type (Unit)	Total	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm	No Storm	100-yr Storm
Upland Development	Parcels (Acres) (Erosion)	695	NA		20		34		100		NA		3%		5%		15%	
	Parcels (Acres) (Flooding)	666	95	139	144	182	186	223	367	421	14%	21%	22%	27%	28%	34%	55%	63%
	Buildings (Count) (Erosion)	260	NA		0		0		3		NA		0%		0%		1%	
	Buildings (Count) (Flooding)	260	19	25	25	29	33	46	195	199	7%	10%	10%	11%	13%	18%	75%	77%
	Lifeguard Headquarters (Count)	1	0	0	0	0	1	1	1	1	0%	0%	0%	0%	100%	100%	100%	100%
	School Playground (Count)	1	0	0	0	0	0	0	0	1	0%	0%	0%	0%	0%	0%	0%	100%
	Community Center (Count)	1	0	0	0	0	0	0	1	1	0%	0%	0%	0%	0%	0%	100%	100%
	Commercial Areas (Acres)	29	4	6	6	8	8	11	17	21	13%	21%	21%	28%	29%	39%	60%	72%
	Bulkhead (LF)	90,988	0	0	0	0	0	90,988	90,988	90,988	0%	0%	0%	0%	0%	100%	100%	100%
	Streets (LF)	68,919	18,142	30,263	29,273	29,942	30,272	32,387	47,534	61,866	26%	44%	42%	43%	44%	47%	69%	90%
	Parking Lots (Count)	25	7	9	9	11	12	13	20	25	28%	36%	36%	44%	48%	52%	80%	100%
	Restrooms (Count)	13	1	2	2	2	2	3	8	12	8%	15%	15%	15%	15%	23%	62%	92%
	Wastewater Pump Station (Count)	2	0	1	1	1	1	1	2	2	0%	50%	50%	50%	50%	50%	100%	100%
	Stormdrain Catch Basins (Count)	52	0	9	9	11	11	26	41	46	6%	19%	17%	21%	21%	50%	79%	88%
	Stormdrain Outlets (Count)	17	3	10	9	12	12	12	12	12	18%	59%	53%	71%	71%	71%	71%	71%

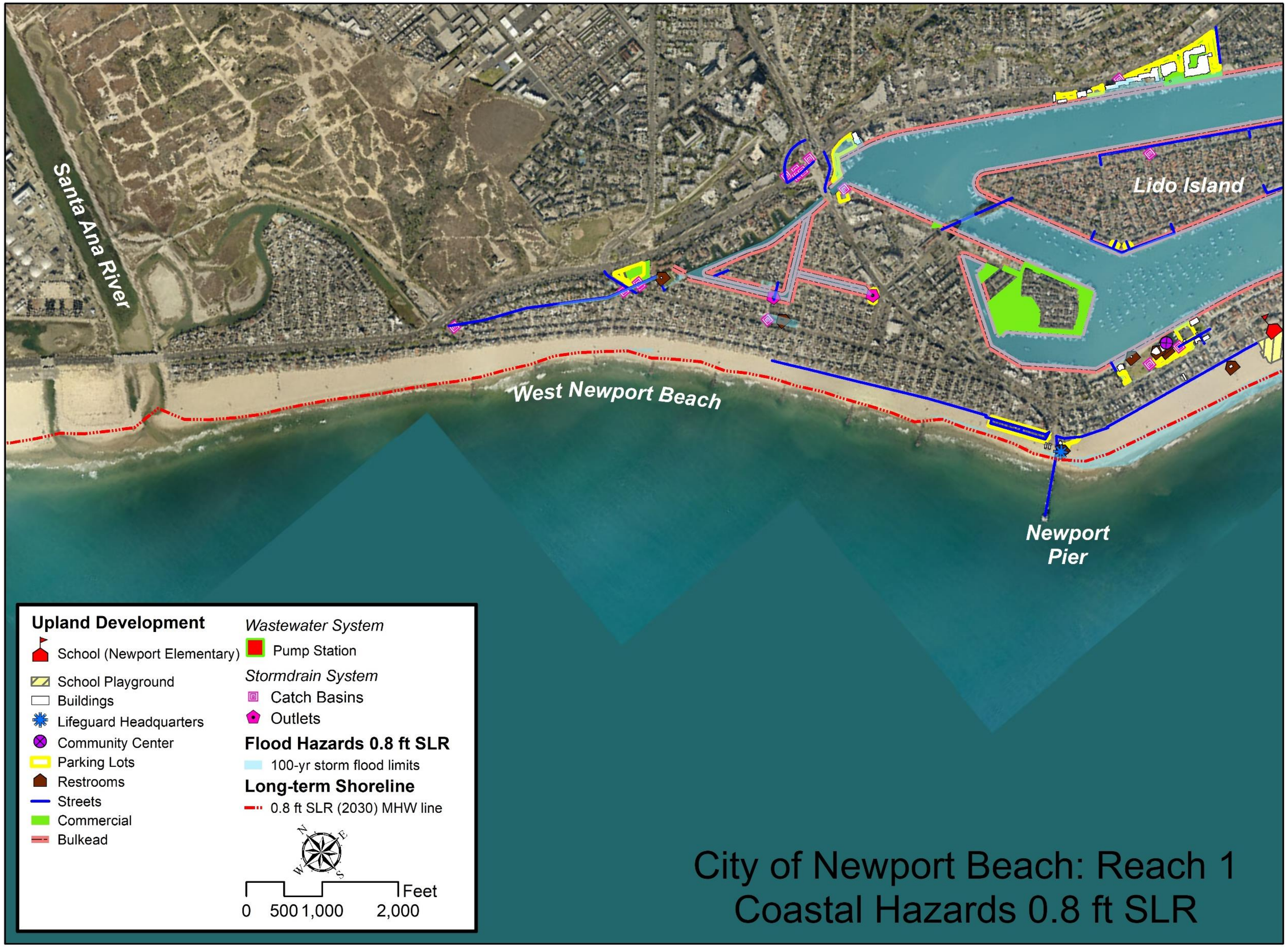


Figure 5-15: Upland Development Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 1

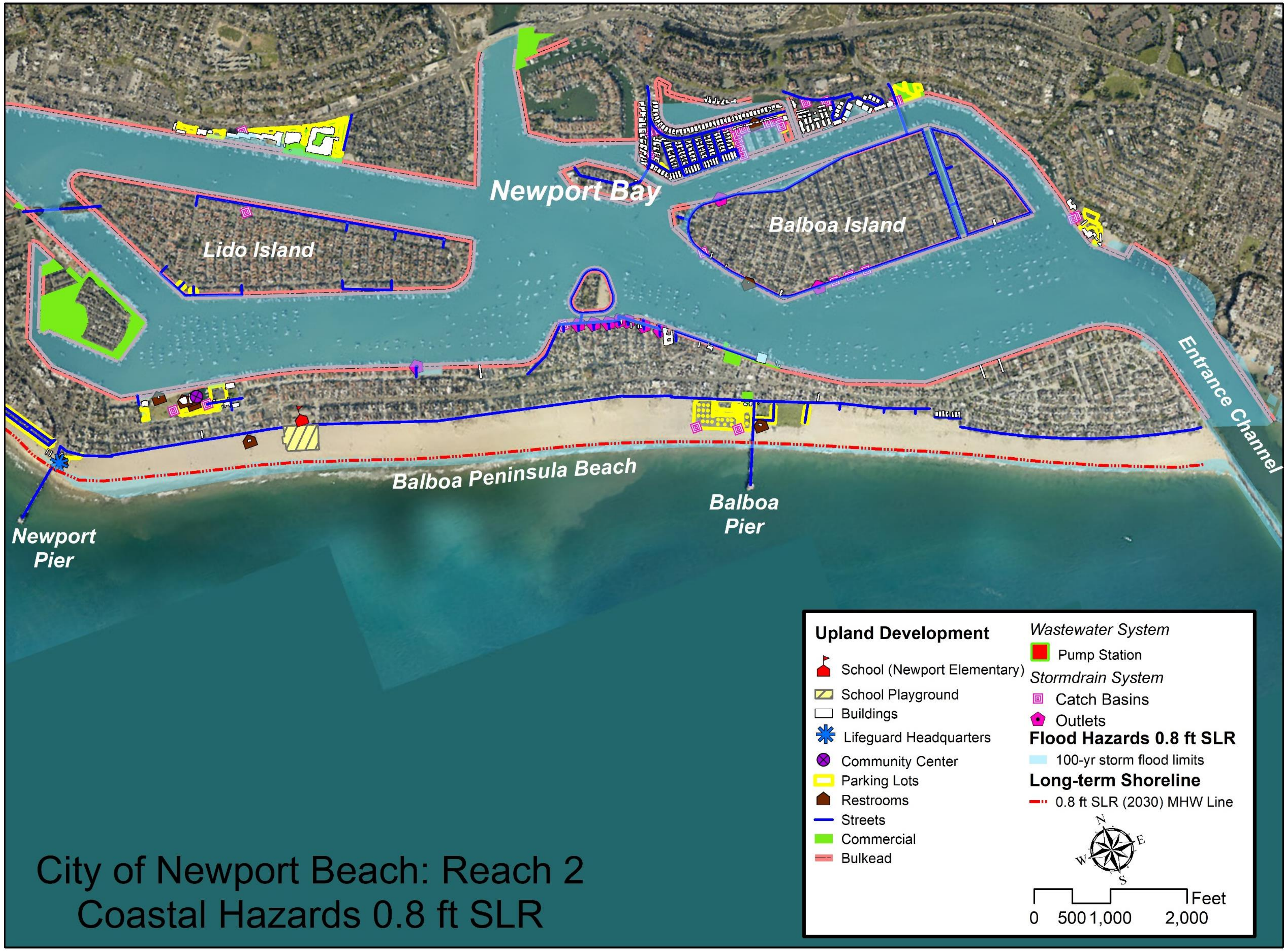


Figure 5-16: Upland Development Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 2

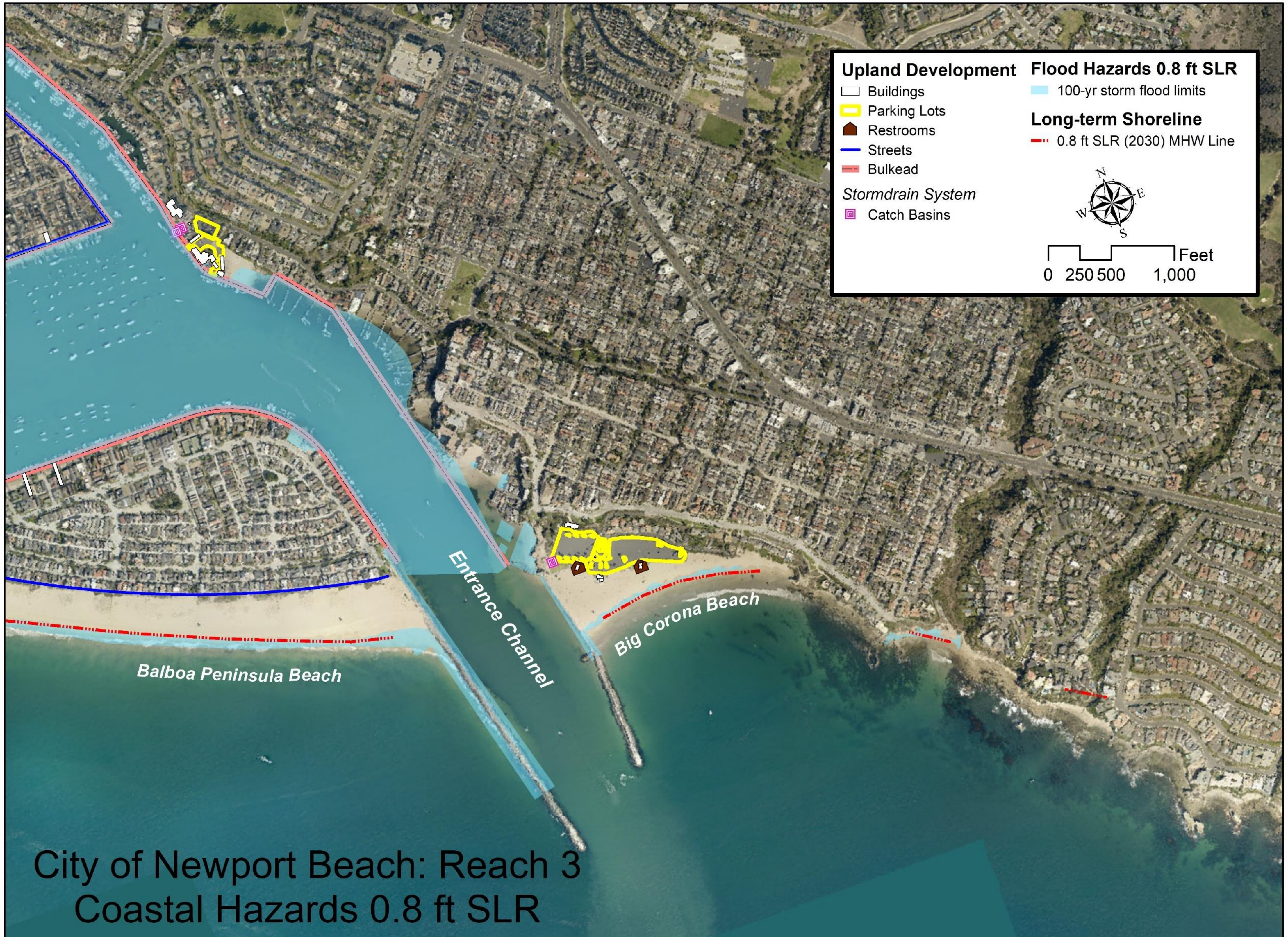


Figure 5-17: Upland Development Assets with 0.8 Feet SLR (Year 2030) Hazards – Reach 3

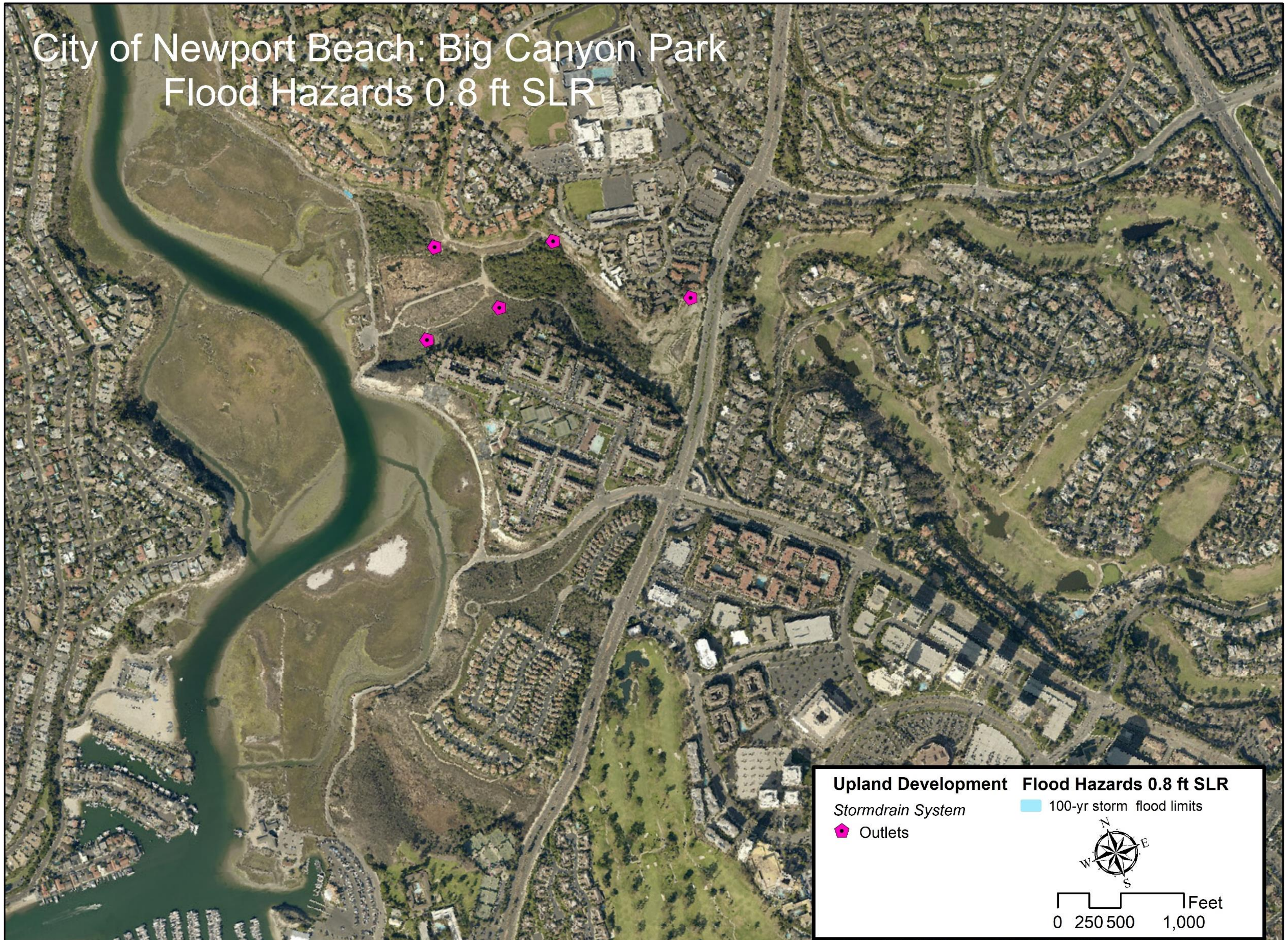


Figure 5-18: Upland Development Assets with 0.8 Feet SLR (Year 2030) Hazards – Big Canyon Park

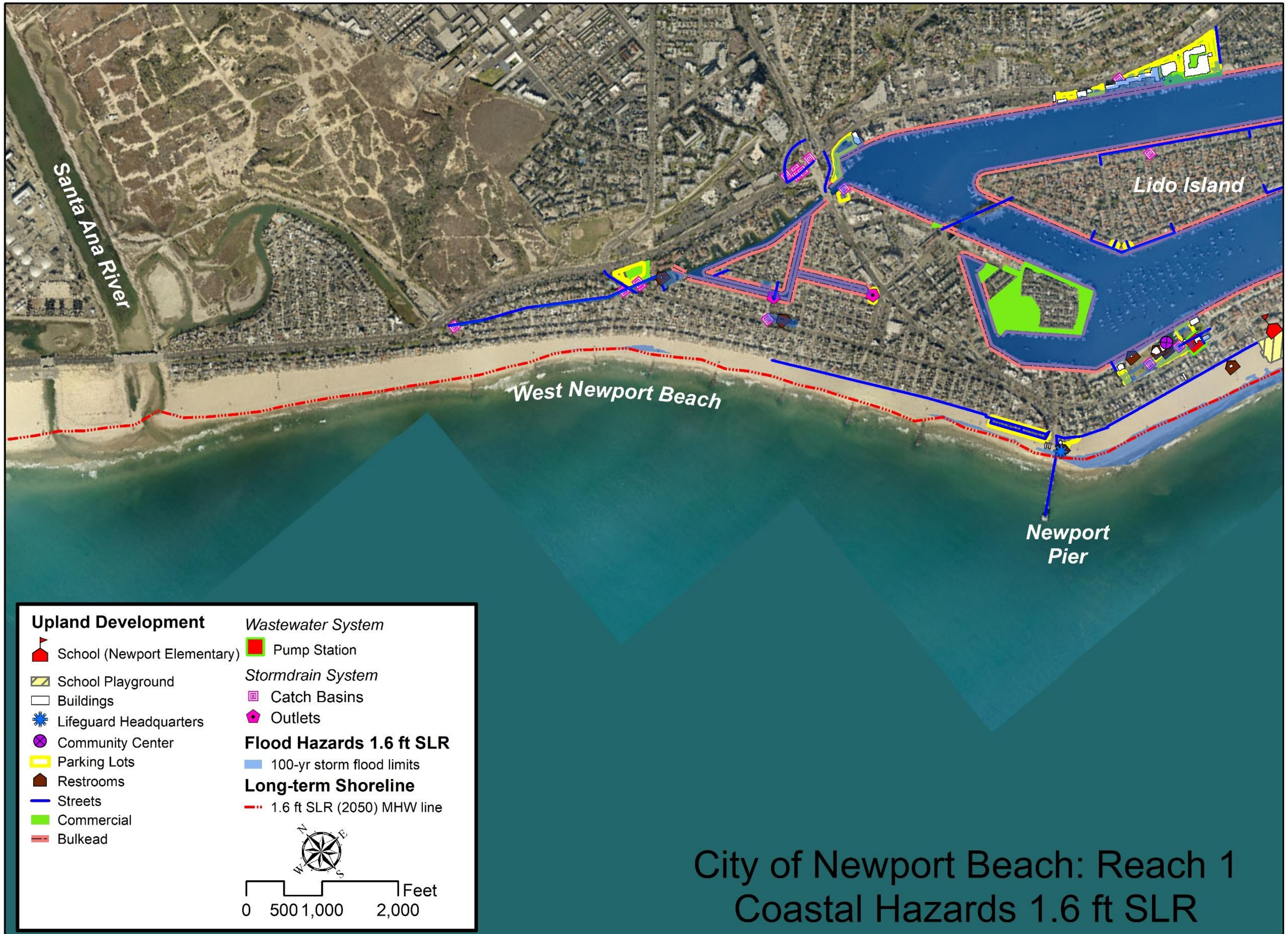


Figure 5-19: Upland Development Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 1

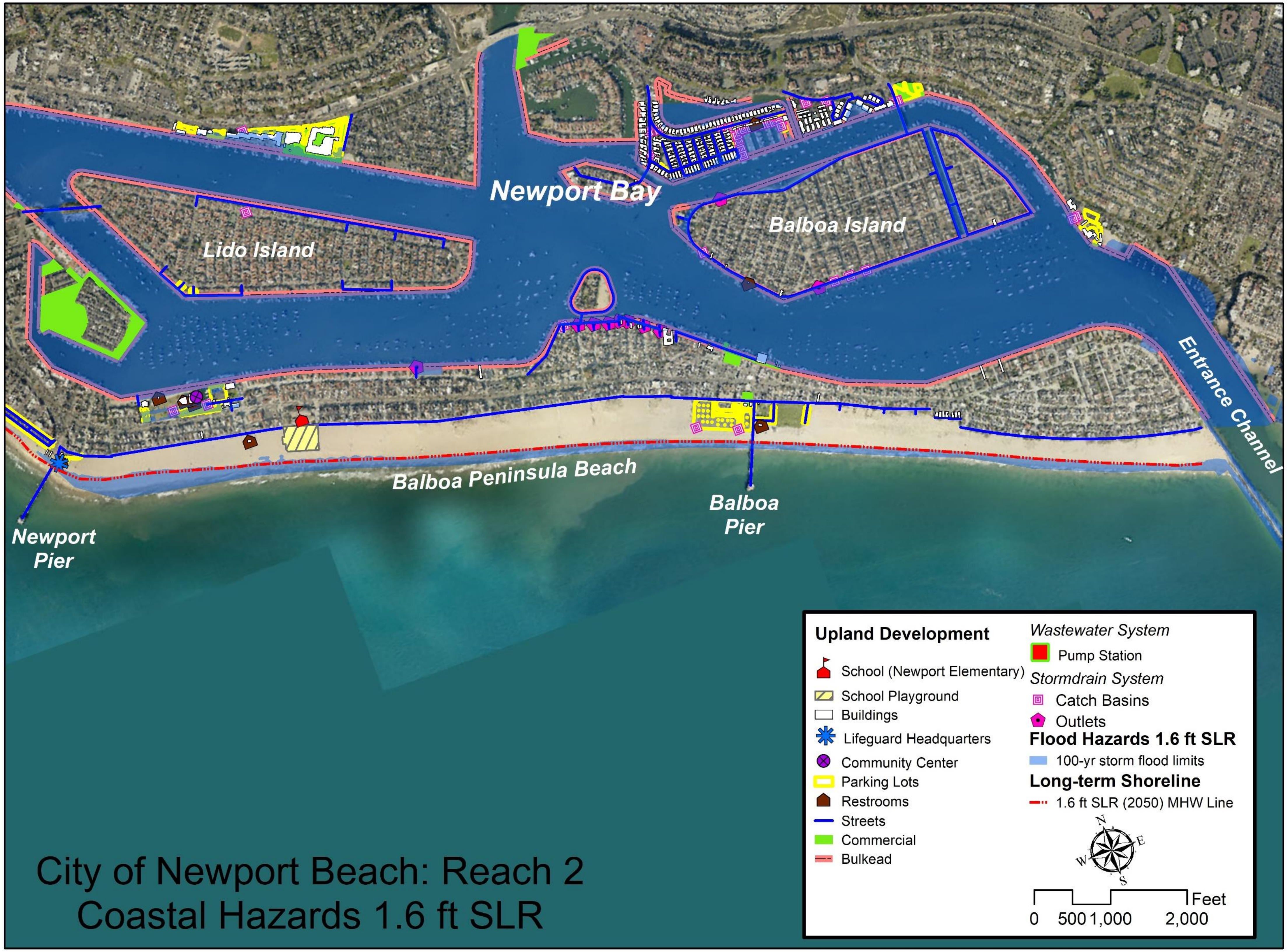


Figure 5-20: Upland Development Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 2

Figure 5-21: Upland Development Assets with 1.6 Feet SLR (Year 2050) Hazards – Reach 3

Figure 5-22: Upland Development Assets with 1.6 Feet SLR (Year 2050) Hazards – Big Canyon Park

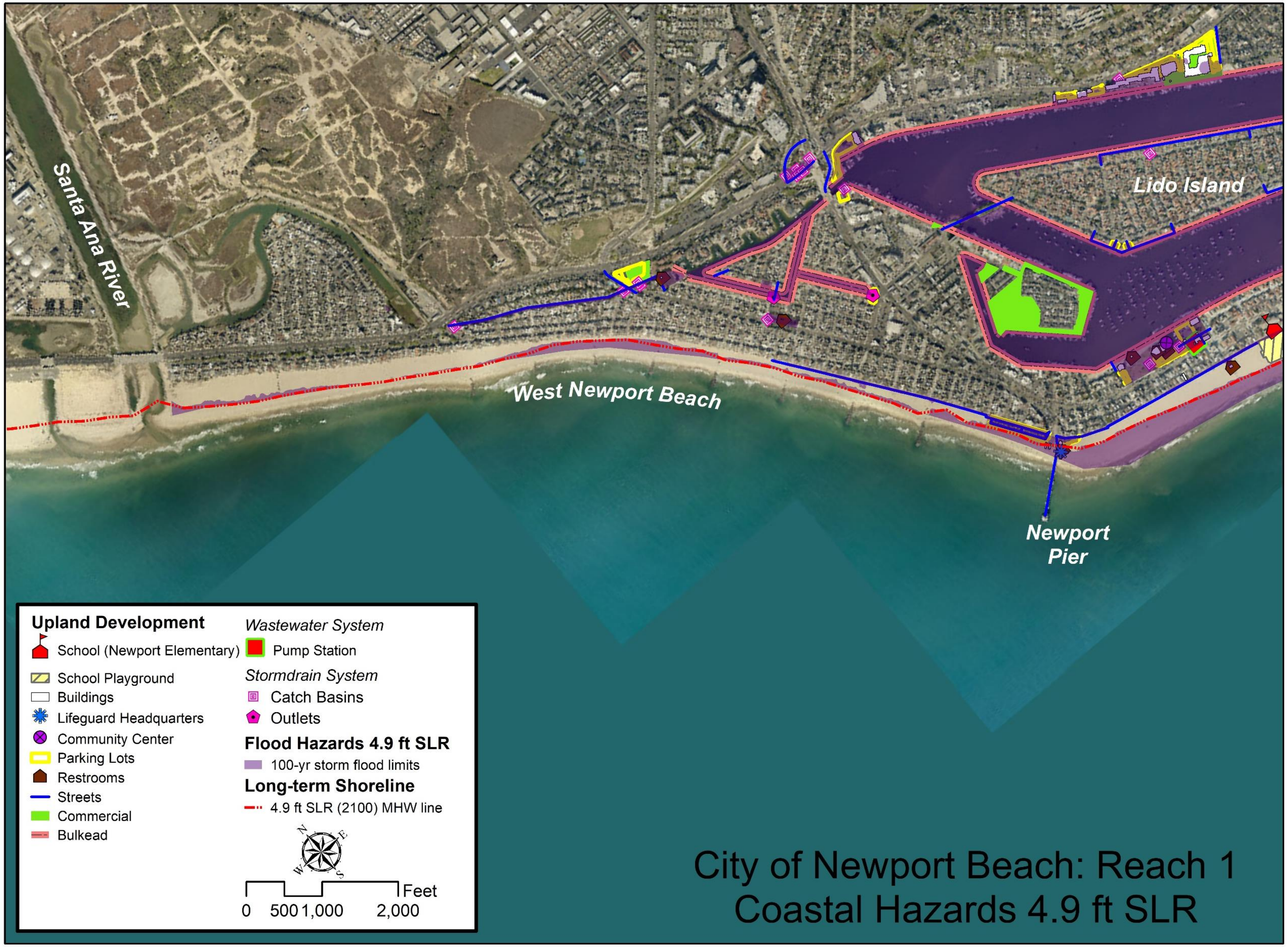


Figure 5-23: Upland Development Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 1

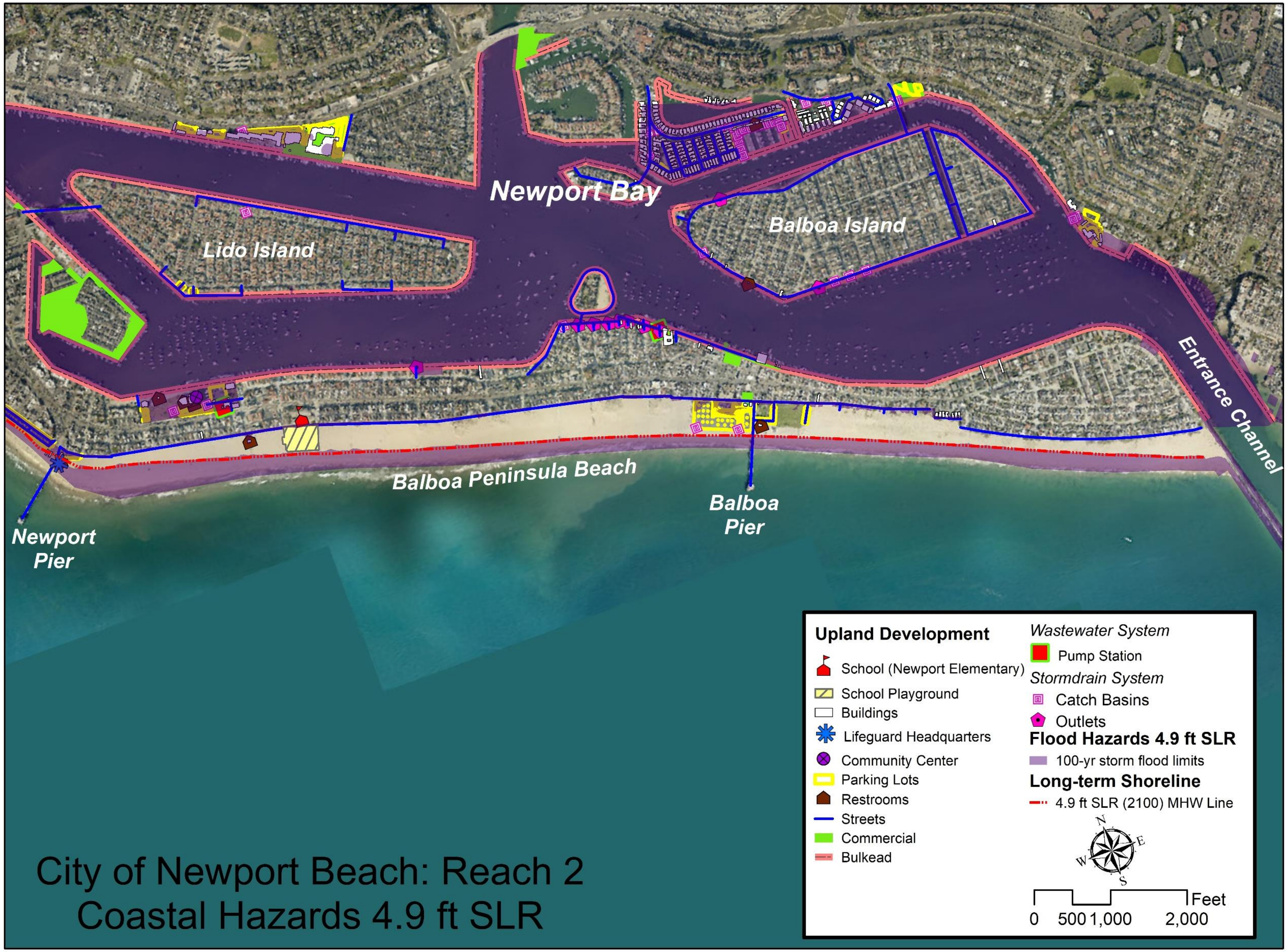


Figure 5-24: Upland Development Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 2

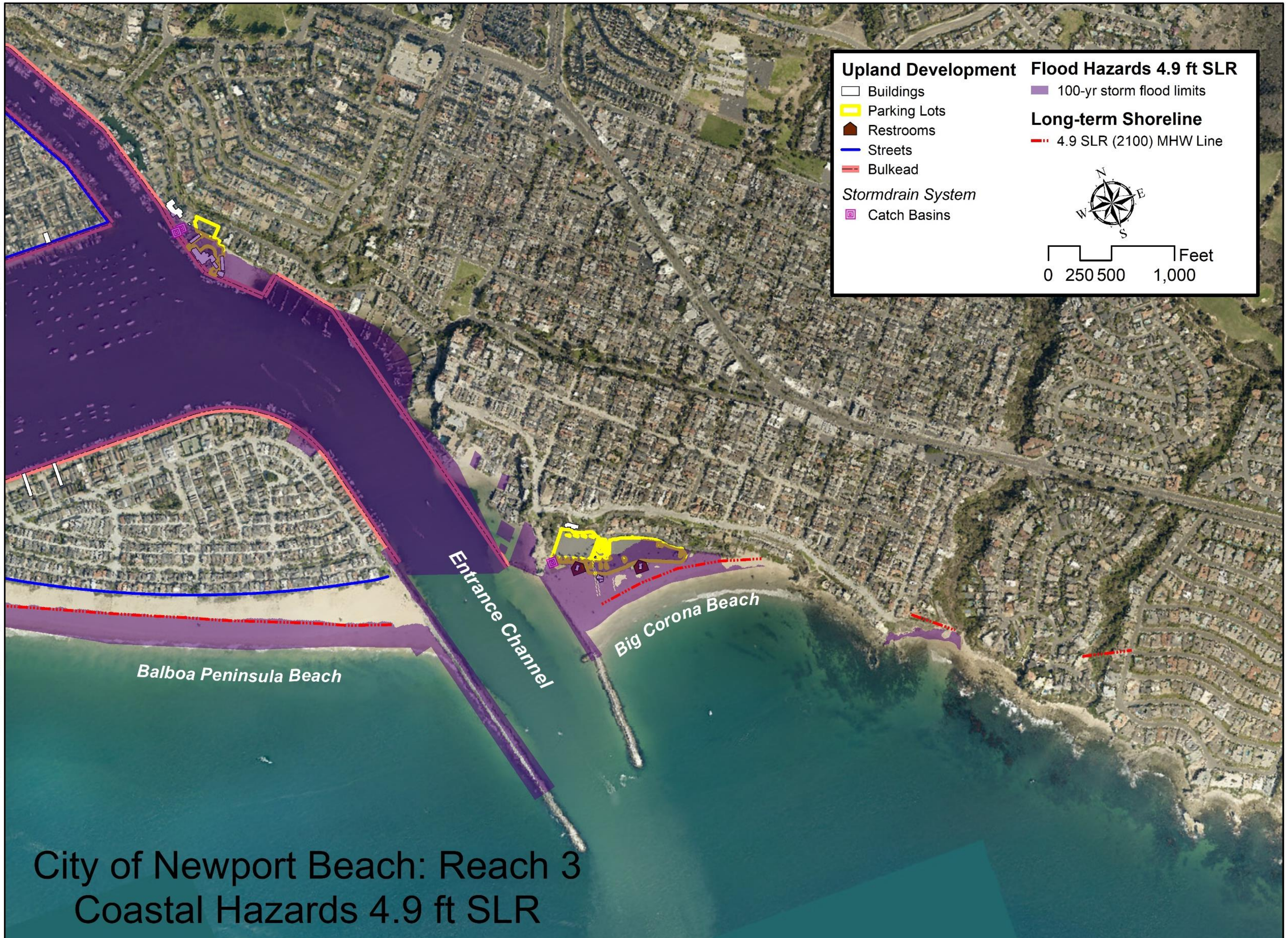


Figure 5-25: Upland Development Assets with 4.9 Feet SLR (Year 2100) Hazards – Reach 3

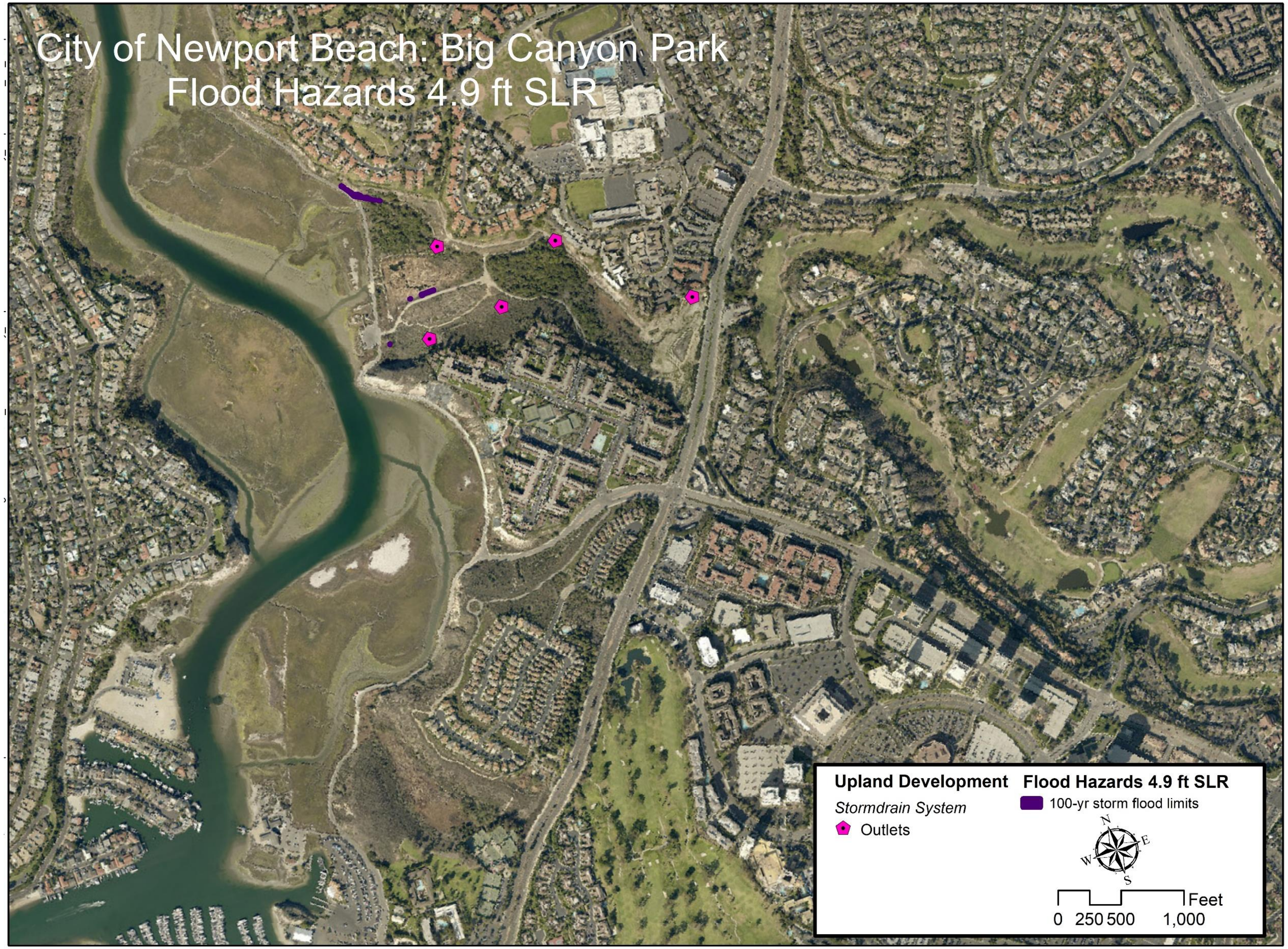


Figure 5-26: Upland Development Assets with 4.9 Feet SLR (Year 2100) Hazards – Big Canyon Park

5.5 Public Access

With SLR of 0.8 feet and a 100-year storm, access and roadways along the harbor side of the Peninsula are vulnerable to coastal flooding, including the Bay Front Boardwalk on Balboa Island and the Edgewater Avenue Boardwalk on the Peninsula. With SLR of 1.6 feet and a 100-year storm, coastal flooding is exacerbated in these areas. With a SLR of 4.9 feet and a 100-year storm, flooding extends inland on the Peninsula and impacts the Oceanfront Boardwalk. In fact, with a SLR of 4.9 feet and a 100-year storm, most all public access routes in and outside of the study area could be affected due to future sea levels and shoreline conditions if no mitigation and adaptation measures are taken into consideration. This includes access along West and East Oceanfront in Reach 1 and 2, Breakers Drive and the public parking lot at Big Corona, as well as public access and roadways along the harbor side of the Peninsula, and several portions of Pacific Coast Highway (for flood mapping of areas outside the tidelands refer to the OCOF website http://data.pointblue.org/apps/ocof/cms/index.php?page=flood-map). Beach access to Little Corona from Poppy Avenue in Reach 3 will be limited due to beach erosion and the possibility of bluff erosion. Big Corona Beach will be eroded with only a small percentage of beach remaining and the vertical beach access from Ocean Boulevard will be limited.

5.6 Recreation

A variety of recreational activities occur within Newport Beach Tidelands and the surrounding region. The study area is used by surfers, fishermen, boaters, birdwatchers, and other passive recreational users. Future sea levels and shoreline condition will impact recreation through the public access issues mentioned before. Also, without any adaptation and mitigation measures (e.g., beach nourishment), the narrow beach in front of 10th Street and West Bay Avenue (Reach 2) will be flooded with SLR at 0.8 feet combined with a 100-year storm. At Big Corona and Little Corona, the recreational beaches are subject to being significantly diminished with a SLR of 4.9 feet. This will happen mainly due to shoreline retreat and higher flood potential considering future sea levels combined with major storms, as well as lack of room for retreat due to the existence of coastal bluffs.

5.7 Coastal Habitat

The coastal habitat within the project area that will be affected by future sea levels is the coastal stretch of beach along West Newport Beach, Peninsula Beach, Corona del Mar, and to a minor degree Big Canyon. The low-lying beaches along 10th Street and Bay Avenue, China Cove, and Little Corona are the areas that will experience more frequent flooding in the future if protective measures are not taken. By 2050, all beaches along Reach 1, 2, and 3 will experience some effects of coastal flooding and shoreline erosion. The 2100 SLR scenario in combination with a 100-year storm poses the greatest threat to beach habitat. Due to its topographic relief, Big Canyon appears relatively free from the threat of SLR. However, as SLR increases, saltwater intrusion could begin to pose a threat to the riparian vegetation and should be monitored.

6. Estimate of Financial Cost

6.1 Replacement and Repair Costs

This section provides estimates of the replacement and repair costs of property at risk due to SLR. The economic analysis provided for this study is based on geospatial data. All of the land, structures, and infrastructure analyzed have specific geospatial references, which were overlaid with the hazard zones to assess impacts from coastal flooding, inundation, and erosion.

The economic analysis used Orange County Assessor's parcel data and City land use data to identify property boundaries, location, and size of the parcel, along with other information such as zoning and current use. The use of geospatial analysis also allows one to incorporate the length and width of beaches, coastal trails, access points, and other pertinent information about coastal recreation.

Flood damages to structures were estimated by applying the USACE's depth damage curves (USACE 2003), which estimates damages as a percent of the total value of the structure. The USACE method also allows one to estimate the average damage to the contents of the structure (e.g., furniture, inventory, etc.). These curves translate flood depth into a percentage loss as a function of the total value of the structure.

In the State of California, most private property (except for some non-profit organizations) is assessed for property tax purposes and the assessed value of each is included in the parcel data along with geospatial references that include the location, shape, and size of the parcel. Further, this parcel data generally includes an assessed valuation for both land and "improvements" – the assessed value of the structure(s) on the land. Unfortunately, the assessed value of property often differs markedly from the actual market value, especially in California where Proposition 13 limits any increase in value to 2 percent a year. Since the inflation rate for houses and other property has been significantly higher than 2 percent for many years, using assessed value may lead to significant underestimates of the market price of a property today.

To adjust for the inherent bias in assessed data, this analysis used the best available housing price data to construct a housing priced index (HPI) for the City that converts the original sales price into current market prices. Since Newport Beach's housing market is unique, this study employed a local index based on data from Zillow (2018). In California, parcels owned by government entities (federal, state and local, including school district property) and non-profit organizations (e.g., churches) are not subject to property taxes and hence not assessed. This report worked with the City of Newport Beach to obtain value for municipal land and structures; in addition, it used recent transactions for coastal property by governmental and non-governmental agencies to value other non-assessed land.

Land zoned for residential use will have a different market price than land zoned for commercial or other uses. Since zoning could change in the future as a result of SLR and climate change, these values could change. Similarly, the threat of coastal erosion and flooding may also lower the value of property at-risk in the future, and possibly increase the value of property not at-risk. These possibilities are beyond the scope of this analysis. Infrastructure was valued at replacement cost using engineering estimates from the contributing engineer.

The economic analysis below estimates flood and erosion losses under three SLR scenarios (0.8 ft., 1.6 ft., and 4.9 ft.) with a 100-year storm event including shoreline retreat. Table 6-1 summarizes the main findings of the economic analysis.

Table 6-1: Cost and Impact Categorization

Impact Level	Cost to Repair / Adaptation Costs (asset damage)	Value of Lost Use / Adaptation Benefit (cargo damage and operation disruptions)
Low	Significant potential flood damages to private and public property, including residential property and the Balboa Bay Yacht Club.	Potential disruption to residents and businesses, as well as some recreational facilities.
Medium	Increased flood damages, especially to single-family residences. Balboa Bay Resort subject to flooding.	Increased disruption to residents and visitors to Balboa Bay Resort.
High	Increased flood damages compared to medium impact, especially to single-family residences. Fire station vulnerable.	Increased disruption to residents compared to medium impact.

Over 90 buildings and structures could be impacted by flooding with 0.8 feet of SLR, with numerous single-family residential structures located at Beacon Bay and Harbor Island and multi-family residential structures at the Balboa Bay Yacht Basin. With 1.6 feet of SLR, more residential structures are vulnerable (discussed below), as well as a school playground and the Lifeguard Headquarters. With 4.9 feet of SLR, more private property is subject to flooding and erosion. In addition, a school is subject to flooding.

Table 6-2 provides a list of vulnerable facilities. Note that most of the vulnerabilities are due to flood damages, not erosion. A number of public and private facilities are at risk to damages from a 100-year storm, and these damages generally increase over time. The most critical facility at risk to flooding (with 4.9 feet of SLR) is a fire station. Since this parcel is not subject to property taxes, estimated repair costs cannot be determined. However, the potential loss of service from a fire station, particularly during a coastal storm when first responders are needed, is likely to be significant to the community

A significant amount of private property is also subject to flooding. As indicated in Table 6-2, many single-family and multi-family units in Reaches 1 and 2 are subject to flooding, and this vulnerability increases over time. In addition, many commercial properties will be impacted, notably the Balboa Bay Yacht Club and Resort. The Lifeguard Headquarters at Newport Pier, on the border between reach 1 and reach 2 could be threatened by periodic flooding with 1.6 feet of SLR, though the fact that most of the headquarters is elevated should be a mitigating factor. With 4.9 feet of SLR, flooding will get worse for the lifeguard tower and threaten the fire station, near the lifeguard headquarters. The Newport elementary school in Reach 2 may face flood damages with 1.6 feet of SLR or higher, including the playground; this could lead to school closings.

Table 6-2: Private and Public Property Subject to Flood Damages

Facility	Reach	Sea Level Rise		
		0.82 ft (25 cm)	1.64 ft (50 cm)	4.9 ft (150 cm)
Fire Station	1/2	No impact	No impact	Potential Flooding Impact: Unable to determine cost of repair.
Single-Family Residences	1/2	21 residences subject to flooding. Impact: Estimated $6 million in repair costs.	49 residences subject to flooding. Impact: Estimated $16 million in repair costs.	78 residences subject to flooding. Impact: Estimated $24 million in repair costs.
Multi-Family Residences	1/2	17 units subject to flooding. Impact: Estimated $4.5 million in repair costs.	22 units subject to flooding. Impact: Estimated $4.6 million in repair costs.	25 units subject to flooding. Impact: Estimated $4.8 million in repair costs.
Commercial Property	1 and 2	6 properties subject to flooding. Impact: Estimated $2.9 million in repair costs.	7 properties subject to flooding. Impact: Estimated $6.4 million in repair costs.	8 properties subject to flooding. Impact: Estimated $8.3 million in repair costs.
School	2	No impact	School subject to flood damages. Impact: Unable to estimate repair costs.	School and playground subject to flood damages. Impact: Unable to estimate repair costs.
Lifeguard Headquarters	1/2	No impact	HQ subject to flood damages. Impact: Unable to estimate repair costs.	HQ subject to flood damages. Impact: Unable to estimate repair costs.

Table 6-3 and Table 6-4 below summarize this study's estimates for flooding and erosion costs for the three SLR levels. Table 6-5 provides estimates of the number of units subject to flooding by category. This study was not able to obtain accurate information for flooding costs to several government properties, including the fire station, the lifeguard headquarters and Newport elementary school. Since the fire station and Lifeguard Headquarters involve first responders, further assessment of the potential losses or adaptation costs is likely warranted. As indicated below, single-family residential homes represent the largest potential financial/economic losses, with over half of the total estimated losses at all SLR levels. At the City's request, this study also examined whether losses occurred to property located on long-term leaseholds owned by the City of Newport Beach. As indicated in Table 6-3 below, most of the commercial property impacted by flooding is on leased land. However, none of the residential property impacted is on leased land. None of the property (residential or commercial) subject to erosion is on leased land.

Table 6-3: Flood Repair Costs Due to SLR and a 100-Year Event

Facility Type	Sea Level Rise			
	0.0 ft.	0.8 ft.	1.6 ft.	4.9 ft.
Single Family Residential	$5,500,000	$5,900,000	$16,000,000	$24,000,000
Multi-Family Residential	$3,400,000	$4,500,000	$4,600,000	$4,800,000
Commercial—On Leased Land	2,200,000	2,200,000	5,700,000	$5,700,000
Commercial-Not Leased	$300,000	$$700,000	$700,000	$2,600,000
Total	**$11,400,000**	**$13,300,000**	**$27,000,000**	**$37,100,000**

Table 6-4: Property Losses Due to Erosion from a 100-Year Event

Facility Type	Sea Level Rise			
	0.0 ft.	0.8 ft.	1.6 ft.	4.9 ft.
Single Family Residential	$0	$400,000	$400,000	$1,400,000
Parks and Recreation	$0	$1,800,000	$4,000,000	$23,100,000
Total	**$0**	**$2,200,000**	**$4,400,000**	**$24,500,000**

Table 6-5: Number of Units Subject to Flood Losses from a 100-year Event

Facility Type	Sea Level Rise			
	0.0 ft.	0.8 ft.	1.6 ft.	4.9 ft.
Commercial	19	21	49	78
Misc. Wholly Exempt	10	17	22	25
Residential Condo	5	6	7	8
Multiple Residential	17	26	39	122
Single Family	19	21	49	78
Total	**70**	**91**	**166**	**311**

6.2 Non-Market Loss Value

In this section, potential non-market losses due to SLR are estimated for recreational and ecosystem services, as well as public trust resources that could be impacted by future sea levels and shoreline conditions. Economists classify recreation and ecosystem services as non-market. The non-market value cannot be determined from a market price, which is for services and goods that can be bought and sold.

To determine the non-market values, economists suggest using the concept of willingness to pay (WTP), 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 (e.g., see Raheem et al. 2009 and Barbier et. al. 2011). The analysis below relies on numerous studies of non-market value discussed below. The analysis of future sea levels and shoreline retreat provided in the previous chapter indicated that all three reaches (West Newport, Balboa Peninsula, and Corona del Mar beaches) are subject to erosion from a 100-year storm.

Beaches provide services with different non-market economic values. These services include recreational value, storm-buffering capacity, and provision of biological and ecological diversity (CDBW 2011 and Barbier et. al. 2011). In California, beaches below the high water line are in public trust, and there is no market value for them. One of the recommended methods to determine the non-market value of a beach is to divide its value into use and non-use values. The use values include, but are not limited to, direct use benefits such as recreation (boating, birding, fishing, etc.) and indirect use benefits including flood control, shoreline protection, and groundwater discharge. The non-use values include biodiversity, cultural, and heritage existence benefits.

Although in practice it is challenging to measure or determine non-market values, there are several theoretical methods to determine non-market beach value. Beaches provide a number of different ecological functions, goods, and services (Barbier et. al. 2011). In practice, it is often difficult to quantify these values or how they diminish with beach width. For example, a very wide (> 500 feet) beach may have adequate recreational capacity and diminishing beach width may have little impact on recreational value, whereas a narrower beach (e.g., Little Corona) could lose most of its recreational value.

In addition to recreational value, disturbance control is also a significant non-market benefit for beaches. The analysis in Section 6.1 (Replacement and Repair Costs) incorporates the value of this disturbance control; as the beach erodes, flood and inland erosion losses will increase. Consequently, adding in another disturbance control term would constitute double counting. There is insufficient information to evaluate other losses in Ecological Functions Goods and Services (EFGS) as the beach erodes.

The recreational value of beaches in California has been studied extensively. This non-market value is typically measured in terms of WTP for a trip to the beach. Economists can measure WTP by estimating the travel cost to and from the site (revealed preference) or by asking visitors how much they would be willing to pay (stated choice). Most of the studies cited in Table 6-6 are travel cost models (e.g., see Parsons 2003). This WTP is typically expressed as a “day-use value.”

As indicated in the table below, estimates of day-use value vary by study and by beach with valuations ranging from $15 to $116 per consumer surplus per day (2018 dollars). As indicated in Table 6-6 above, the average is $50.13 (2018 dollars). However, following Pendleton and Kildow (2006) this study used the median value of $41.87 per visitor per day (in 2015 dollars) rounded to $40 per person per day. This method is also consistent with a recent CCC decision in Solana Beach (CCC 2017).

Table 6-6: Estimates of Day-Use Value for California Beaches

Region	Counties	Usage Level*	Studies	CS Values ($2018)
Southern	San Diego Orange Los Angeles Ventura Santa Barbara	High	12	$15.66[1]
				$22.63[2]
				$25.39[3]
				$29.06[2]
				$31.81[2]
				$35.24[1]
				$36.42[4]
				$39.88[2]
				$47.31[5]
				$99.67[1]
				$109.98[6]
				$116.67[6]
		Low	0	
Central	San Luis Obispo Monterey Santa Cruz San Mateo San Francisco	High	1	$50.29[6]
		Low	0	
Northern	Marin Sonoma Mendocino Humboldt Del Norte	High	0	
		Low	0	
CA Average		N/A		$50.13
Midpoint Pendleton & Kildow (2006)		N/A		$41.87[7]
[1] ***Leeworthy & Wiley (1993)***				
[2] ***King (2001) – midpoint between two methods***				
[3] ***Chapman and Hanemann (2001) – corrected for inflation using CPI***				
[4] ***Lew and Larson (2005)***				
[5] ***Lew (2002)***				
[6] ***Leeworthy (1995)***				
[7] ***Midpoint of** Pendleton & **Kildow (2006) adjusted for inflation ($2015)***				

This study relied on lifeguard estimates made by the City at the three reaches. Lifeguards working for the City take detailed attendance counts of the three reaches every day. The City provided this study with daily estimates of beach attendance from 2015 to 2017. Table 6-7 below presents the City's attendance estimates for all three reaches within the City.

Table 6-7: City of Newport Beach Attendance Estimates 2015-2017

Year	Attendance
2015 Estimate	9,954,345
2016 Estimate	11,060,626
2017 Estimate	10,604,530
Average	10,539,834

The City breaks down attendance at Reach 3 (Corona State Beach) by assuming that 18.6% of total beach visitors attend Corona State Beach. Based on counts from the Orange County California Regional Sediment Master Plan (CRSMP) (2013), this study assumed that 25% of beach visitors attend Reach 1. Table 6-8 below presents average attendance estimates (2015-2017) at each reach.

Table 6-8: Breakdown of Average Attendance Estimates (2015-2017) by Reach

Reach	Average Attendance (2015-2017)
1 West Newport	2,634,958
2 Balboa Peninsula	5,944,466
3 Big Corona	1,960,409

To estimate the loss in non-market value, one must also estimate the loss in attendance due to beach erosion. This study follows the USACE (2002) and assumes a "carrying capacity" of 100 square feet per person per day. Since attendance is not uniform, the carrying capacity constraint will limit attendance first on the busiest days (e.g., weekends in July and August and, the 4th of July, etc.); and, as the beach shrinks, more and more days will be impacted by limited carrying capacity. For each reach and for each SLR scenario, this study estimated the carrying capacity assuming 100 square feet per person.

This analysis also assumes a very modest (0.37%) increase in average attendance per year, consistent with the California Department of Finance's projections (2018) for population growth in Orange County. Table 6-9 through Table 6-11 estimate the loss in non-market value for each reach and SLR scenario; Table 6-12 provides estimates for the total loss.

Table 6-9: Annual Loss in Non-Market Value at Reach 1 (Newport West)

SLR (Feet)	Loss in Area (Acres)	Loss in Non-Market Value
0.8	0.0	0
1.6	0.1	$6,241,428.74
4.9	10	$20,724,178.71

Table 6-10: Annual Loss in Non-Market Value at Reach 2 Balboa Peninsula)

SLR (Feet)	Loss in Area (Acres)	Loss in Non-Market Value
0.8	36	$899,164.97
1.6	43	$3,742,651.58
4.9	79	$31,634,807.39

Table 6-11: Annual Loss in Non-Market Value at Reach 3 (Corona)

SLR (Feet)	Loss in Area (Acres)	Loss in Non-Market Value
0.8	0.4	$21,811,423.76
1.6	1.1	$29,975,997.17
4.9	4.6	$52,481,760.72

Table 6-12: Annual Loss in Non-Market Value at All Three Reaches

SLR (Feet)	Loss in Area (Acres)	Loss in Non-Market Value
0.8	36	$22,710,588.72
1.6	44	$39,960,077.49
4.9	93	$104,840,746.82

As indicated above, the losses in non-market value are significant and will increase substantially over time. By 2030, the total loss is $22.7 million; it increases to $40 million with 1.6 feet of SLR, and $105 million with 4.9 feet of SLR. Also, note that even though Corona State Beach is smaller and has lower attendance, the impacts are much greater since erosion is more significant relative to carrying capacity. With 4.9 feet of SLR, the Corona State Beach is projected to disappear. Note that the method used here, a loss in recreational value, only occurs when a beach/reach does not have sufficient carrying capacity. Consequently, although Reach 2 (Balboa Peninsula Beach) will face large losses in beach area, it currently has sufficient carrying capacity. As Reach 2 erodes, some carrying capacity will be lost on peak days (e.g., Fourth of July, busy July and August weekends), which leads to the losses in recreational value estimated above.

7. Discussion of Adaptation Strategies

This section considers two options from each end of the adaptation planning spectrum. One option assumes a Hold-the-Line strategy is implemented to protect coastal resources within tidelands with a seawall or bulkhead wall. The other option represents a Managed Retreat approach and assumes relocation or removal of vulnerable and sensitive resources, which subsequently allows the beach to migrate landward in response to SLR and changing coastal dynamics. This simple comparison is intended to facilitate a more in-depth discussion and analysis of the potential impacts and trade-offs resulting from adaptation strategies designed to mitigate SLR impacts.

7.1 Hold the Line (Protect)

With a hard line along East and West Oceanfront throughout most of West Newport Beach and Balboa Peninsula, the first impacts that tideland beaches will experience with SLR can be characterized as "coastal squeeze." As sea level rises, coastal squeeze can be defined as the gradual loss of area between the sea and structures designed to protect communities from flooding, such as seawalls and bulkhead walls. A beach, for example, is prevented from natural landward migration due to a protected or non-erodible structure and its area is reduced, or squeezed, until the sea completely drowns the beach in place. For Newport Beach, the dry beach and intertidal zone (and assets dependent on these areas) are at risk of permanent loss due to coastal squeeze in several tideland areas, including at Corona del Mar, China Cove, and 10th Street (bay side).

Figure 7-1 depicts the narrowing and eventual loss of the dry beach and intertidal zones with progressive amounts of SLR assuming the tideland areas will be protected in place to Hold-the-Line. In addition to loss of beach habitat, there would be significant impacts to beach access, recreation opportunities, surfing conditions, and the beach-centered tourism economy. The SLR threshold for these impacts to occur varies along the coast. At the bay side pocket beach located at 10th Street, the effects of coastal squeeze are visible today with the shoreline up against the backbeach wall during king tides. A Hold the Line approach is only effective in so far as sufficient dry beach is present between the sea and the tidelands asset being protected. As coastal squeeze occurs, other adaptation strategies may need to be employed, such as importing beach sand to raise the beach profile and maintain a sandy beach area.

The eight rubble mound groins between 28th Street and 56th Street should continue to perform reasonably well in retaining sand and minimizing the erosion that occurs at this location. However, preliminary analysis suggests a SLR of 1.6 feet (2050) and greater in conjunction with large storm events could become an issue if these structures become damaged and begin to operate at a reduced benefit to the City. As the groins are federal assets, the City should work with the USACE to implement adaptive measures such as increasing the crest elevation of the structures. Numerical modeling could be employed to provide a detailed analysis of how the structures perform under various SLR scenarios.

7.2 Managed Retreat

If the shoreline retreats landward as the beach profile migrates upward and landward in response to SLR, some coastal assets along the Peninsula may need to be relocated. Beach migration landward has implications for the Lifeguard Headquarters Building and other coastal amenities (restrooms and school playground, for example). Essentially, those facilities would need site-specific adaptation measures to remain functional. If inland space is available, it would present an opportunity for relocation of these facilities (although the Lifeguard Building needs to remain along the beach to function effectively). Relocating the facilities inland also provides an additional 50-100 feet of beach area, which would make the sandy beach more resilient to storm-induced erosion and littoral sediment supply deficits in the near term. An option for the Lifeguard Building would be to elevate it on Newport Pier as an extension of the pier on piles. An illustration of the beach profile evolution under a managed retreat approach is also provided in Figure 7-1.

Higher projections of SLR indicate that the negative effects of "coastal squeeze" would be a concern at Big Corona and Little Corona under the 4.9-foot SLR scenario. Under this scenario the active shoreline would reach the parking lot at Big Corona and all the way to the bluffs at Little Corona, increasing the potential for bluff erosion and undermining of bluff top development. Per OPC's recent SLR projections, a SLR increase of 4.9 feet could occur as soon as the year 2100 (low probability) or several decades later in the year 2140 (median probability). Given this longer time horizon and the uncertainty surrounding many variables that affect shoreline position, the timing of when the bluffs would be subject to consistent wave action under a managed retreat approach is much more difficult to predict. The long-term effect of changes in greenhouse gas emissions, glacial melt, littoral sediment supply, El Niño patterns, and adaptation strategies (i.e., beach nourishment) implemented over this time horizon will have significant impacts on the future rate of shoreline retreat.

A managed retreat approach that involves relocation of vulnerable resources would offer benefits to the community by mitigating impacts of coastal squeeze (beach loss) for SLR scenarios of 4.9 feet. However, under such a scenario, this approach alone does not address the vulnerability of facilities like the beach parking lot and restrooms at Big Corona. Many of the resources and amenities would either need to be removed from this area entirely or would require site-specific adaptation measures to be more resilient to the evolving shoreline erosion hazards.

Development and infrastructure along the coast of Newport Beach has little to no ability to retreat landward due to their low-lying condition on a sand spit and the existing built out development around the perimeter of the bay. Consequently, managed retreat may not be a realistic option for Newport Beach. It is possible that other approaches may need to be taken such as significant beach nourishment and addition of sediment to raise the existing ground and elevate development. Additionally, providing the ability for water to flow through the first floors of structures during significant events, if needed, may need to be considered while upper floors serve as the operational areas of structures.

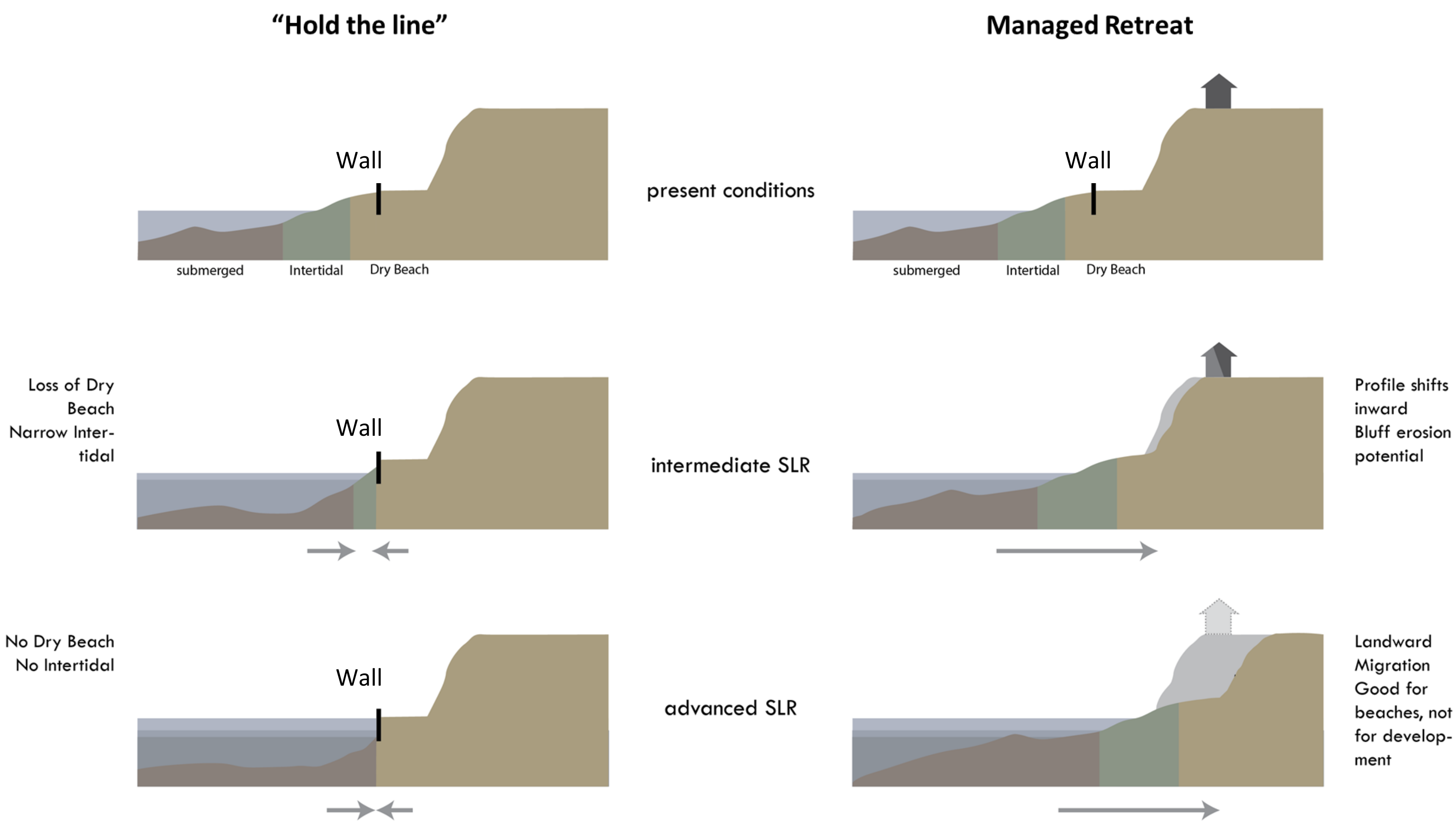


Figure 7-1: Illustration of Hold-the-Line Versus Managed Retreat Approaches

7.3 Beach Nourishment

Beach nourishment is a logical approach to offset the impacts from a retreating shoreline. A regular beach nourishment program would help mitigate the adverse effects of SLR on coastal resources located along the open coast of Newport Beach. A detailed accounting of recommended beach nourishment management actions for Newport Beach is provided in the *State of the Newport Coast Final Report* (M&N 2006a). As the management actions are being implemented, the City will be able to discern from surveys, aerial photographs, and other observations whether beach nourishment is needed as triggered by significant events or chronic erosion (M&N 2006a). Implementing a beach width monitoring plan could be an effective step towards establishing triggers for nourishment at the most vulnerable beaches within City tidelands.

Sand supplies for nourishment can vary, but the most obvious large-scale local sand supplies that are available to the City are from the Santa Ana River (upland) and from the open ocean (offshore). The Santa Ana River is the natural source of sediment in the region and local beaches are compatible with this sand source. Flood control channel maintenance operations within the Santa Ana River are required of Orange County on a regular basis, typically every 10 to 15 years, and can provide Newport Beach with sand (M&N 2006a). The most recent maintenance operation occurred in the vicinity of the 40th Street and 56th Street groins in 2016/2017. Approximately 600,000 cy of sand was dredged/excavated from the river and hydraulically pumped by pipeline into the West Newport nearshore between -10 feet and -30 feet MLLW (M&N 2017).

Other sources of sand may become available that the City may discover through notification or research, such as offshore sand from the ocean near the Surfside/Sunset Beach Nourishment Program sources, sand dredged from Newport Bay, and sand from upland sources. City staff have indicated that small-scale sand sources from excavation for projects at individual houses (underground parking garages) become available periodically and are accepted for placement near the 20th Street location of the Lifeguard Headquarters Building (Bauer, Personal Communication 2006a). That practice should continue assuming the sand is compatible with characteristics of the receiving beach (M&N 2006b). This represents “opportunistic sand” that can be permitted as a program for beach nourishment, as, has been done in the San Diego region (M&N 2006b).

7.3.1 West Newport Beach

Per the M&N 2006a study, West Newport Beach is dependent on nourishment to sustain its present condition (being sufficiently wide to protect backshore development from a severe storm wave event). Therefore, it is expected that some type of beach nourishment will be required on a regular, but relatively infrequent, basis. The priority location for initial nourishment is between 32nd Street and 44th Street, and if the quantity of sand to be provided is larger than the capacity of this reach, the secondary locations for fill are southeast to Newport Pier and northwest to 52nd Street (M&N 2006a).

Sand sources comprising relatively small quantities, i.e. 5,000 cubic yards or less, could be placed in front of the Marine Safety (Lifeguard) Headquarters Building for direct protection as the beach retreats and threatens the structure at this location. The sand should be placed as beach fill on the foreshore slope between the waterline and the beach berm. Sand should be spread along a slope at a ratio of approximately 10:1 (horizontal to vertical units in dimension) (M&N 2006a). Permits could be obtained ahead of time as part of an Opportunistic Beach Fill Program (M&N 2006b) that the City could use to streamline approvals of beach nourishment.

7.3.2 Balboa Peninsula Via West Newport Beach

Sand is difficult to deliver to Balboa Peninsula as trucks have to use City streets. Consequently, it is not advisable to directly nourish the beach berm at this site from a land-based operation. Rather, it is recommended to nourish the Peninsula with land-based sand by “over-nourishing” West Newport and placing the sand relatively close to Newport Pier. This “feeder beach” approach allows Balboa Peninsula to be fed by sand from West Newport, so placing a larger proportion of sand near the pier will result in indirect sand nourishment to the Peninsula. Sand should be placed along the western end of West Newport Beach on the foreshore slope between the waterline and the beach berm and then spread along a slope similar to that discussed above (M&N 2006a).

7.3.3 Big Corona Beach

Nourishment should occur at the east end of Big Corona Beach to fill a local area of erosion at the foot of the public access ramp from Inspiration Point. Sand should be placed within the “bowl” at the toe of the bluff area between the ramp end and the bluff toe on top of existing rip-rap. Sand could be placed in a beach berm or level layer over the existing beach to partially bury the lower portion of the ramp and the toe of the bluff. The beach at this site could be raised as much as 5 to 10 feet. Sand placed at this site would likely move naturally to the west over time and “feed” the rest of Big Corona Beach for an overall benefit, while providing important short-term protection for the access ramp. Beach nourishment should be done sensitively at this site to prevent impacts to rocky intertidal habitat to the east toward Little Corona Beach. Sand grain sizes should be similar to the existing beach with low percentages of silts and clays to prevent transport of finer-grained materials from the site toward the east to potentially deposit at rocky intertidal habitat areas (M&N 2006a).

Beach nourishment is considered a “soft protection” strategy and is temporary by design. In other words, the added beach width will begin dispersing soon after placement, and the length of time the dry beach remains at a site will vary. This rate will vary based on sediment supply, wave climate, and other factors driving longshore sediment transport. During stormy years and in between nourishment cycles the beach fill by itself may not be sufficient to protect sensitive assets along the back beach. To prevent damages during these conditions, assets sensitive to undermining from erosion, such as the Lifeguard Headquarters and Newport Elementary playground, would probably require some form of hard protection if these facilities are to remain in place.

8. Conclusions

This vulnerability assessment identifies potentially significant impacts to coastal resources in tidelands for SLR scenarios higher than 0.8 feet (25 cm). A resource's vulnerability to SLR is a product of its exposure to coastal hazards (shoreline erosion and flooding), its sensitivity to said hazards (potential damage or loss of function), and its adaptive capacity (ability to restore function or avoid damage). The long-term consequences of SLR pose a significant challenge locally and regionally. The impacts in particular to low-lying, narrow sandy beaches are significant for a SLR of 0.8 feet and higher. The long-term vulnerability of coastal resources will depend on what adaptation measures are implemented along the coast of Newport Beach.

As shown herein, tideland assets along the Newport Coast are vulnerable to shoreline retreat, which is predicted to accelerate with SLR. Long-term shoreline retreat coupled with storm-induced beach erosion has the potential to cause permanent damage to buildings and infrastructure in these hazard zones. Beach loss threatens structures and also has the potential to impact the diverse range of coastal assets dependent on the sandy beaches of Newport Beach. The public access, recreational opportunities, habitat, visual, and cultural assets that contribute to the City's vibrant beach town culture are all valuable to the locals that live in Newport Beach and its visitors.

The vulnerability of the coastal resources and specific tideland assets identified herein can be reduced through careful planning and adaptation measures implemented on regional, local, or site-specific scales. Adaptation efforts that are aimed at improving coastal resiliency will involve coordination with all key stakeholder groups and agencies as part of the City's efforts to understand the costs, benefits, and potential trade-offs of SLR adaptation measures. Understanding these local and regional costs, benefits, and trade-offs would help inform the adaptation planning process.

This report was based on the best available SLR science published by the OPC and consistent with CCC guidelines. SLR hazards were projected by CoSMoS Version 3.0, a multi-agency effort led by the USGS. The coastal processes affecting the City's shoreline are dynamic, as are the interactions between humans and the environment. The predictions described in this report are limited by the uncertainty inherent in projecting future climate conditions out to the year 2100 and beyond. Likewise, wave patterns, sediment supply, and shoreline development regulations are subject to change over time given the complexity and multitude of variables involved and the dynamic interactions therein.

There is considerable uncertainty around the timing of SLR, how future coastal processes may be affected, and what adaptation approaches will be applied in the future. The most effective way for the City to address the vulnerabilities described in this report is to monitor conditions, and then implement policies and programs that are flexible i.e. can be adapted in response to SLR, future beach conditions, and future development. Implementing a beach nourishment plan in association with the USACE Surfside/Sunset Beach Nourishment Project could be an effective step toward improving the resilience of valuable coastal assets in the City. In addition to a regular supply of sediment, this program should include detailed monitoring of shoreline conditions and impacts to coastal assets over time, which will provide an extremely valuable database that could be used to inform future adaptation efforts in the City.

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