City of Dana Point
Sea Level Rise Vulnerability Assessment

Prepared For:

City of Dana Point, Planning Division
33282 Golden Lantern
Dana Point, CA 92629

Prepared By:

moffatt & nichol
4225 East Conant Street
Long Beach, CA 90808

October 2019

Funded by CCC Grant LCP 16-10
CALIFORNIA COASTAL COMMISSION

Table of Contents

TABLE OF TABLES

TABLE OF FIGURES

Acronyms and Abbreviations

CCC	California Coastal Commission
CCSTWS-OC	Coast of California Storm and Tidal Wave Study for the Orange County Region
CCSTWS-SD	Coast of California Storm and Tidal Wave Study for the San Diego Region
City	City of Dana Point
CNDDB	California Natural Diversity Database
COAST	Coastal One-line Assimilated Simulation Tool
CoSMoS	Coastal Storm Modeling System
cm	centimeter
cy	cubic yard
cy/yr	cubic yard per year
FIRM	Flood Insurance Rate Map
ft	feet
ft/yr	feet per year
H++	Extreme SLR scenario due to rapid Antarctic ice sheet mass loss (Sweet et al, 2017)
H_s	Significant Wave Height
in	inch
IP	Implementation Plan
LCP	Local Coastal Program
lf	linear foot
LOSSAN	Los Angeles to San Diego Rail Corridor
LUP	Land Use Plan
m/yr	Meter per year
M&N	Moffatt & Nichol
mcy	million cubic yards
MHHW	mean higher high water
MLLW	mean lower low water
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
OCTA	Orange County Transportation Authority

OPC	Ocean Protection Council
PCH	Pacific Coast Highway
RBSP	Regional Beach Sand Projects
SANDAG	San Diego Association of Governments
SLR	sea level rise
SMCA	State Marine Conservation Area
SOCWA	South Orange County Wastewater Authority
SVI	social vulnerability index
TOT	Transient Occupancy Tax
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
yr	year

Document Verification

Client	City of Dana Point
Project Name	City of Dana Point LCP
Document Title	City of Dana Point Sea Level Rise Vulnerability Assessment
Document Sub-title	–
Status	Final Report
Date	October 29, 2019
Project Number	9867
File Reference	Q:\LB\9867\8 Deliverables\VA\Final VA

Revision	Description	Issued by	Date	Checked
00	Draft Report	AH/JS	6/13/2018	VC/MJM
01	Final Report	AH/JT	01/8/2019	VC
02	Revised Final	AH	10/29/2019	JT

Disclaimer

It is understood that estimating and projecting future weather, tidal, ocean, and onshore conditions as well as their impacts upon existing or contemplated developments or resources is difficult, complex, and based on variable assumptions, and further, is impacted by factors potentially beyond Moffatt & Nichol's ability to predict or control. Accordingly, any estimates, forecasts, reviews, or assessments provided as part of the Services are presented solely on the basis of the assumptions accompanying the estimates, forecasts, reviews, and assessments, and are subject to the information or data utilized at the time of this Project. As such, Moffatt & Nichol (M&N) makes no warranty that the mitigation measures will be adequate to protect against actual climate events. In addition, to the extent M&N utilizes materials provided by the Client or third parties, or material that is generally available, M&N is entitled to rely upon any such information concerning the Project, except to the extent it is explicitly provided that M&N will independently verify the accuracy or completeness of such materials or information.

Produced by:

Moffatt & Nichol
4225 East Conant Street
Long Beach, CA 90808
(562) 590-6500
www.moffattnichol.com

Executive Summary

Planning for and adapting to a changing coastline is a critical challenge facing many communities in Southern California. This Sea Level Rise (SLR) Vulnerability Assessment, a requirement as part of the Dana Point Local Coastal Program amendment process, aims to determine the potential vulnerability of infrastructure, land uses, and coastal resources in the Dana Point coastal zone. This is accomplished by first compiling an inventory of coastal resources then identifying how these resources will be affected by various increments of SLR, forming the basis for future policy development and adaptation strategies to mitigate potential impacts.

In order to capture the variety of coastal settings, littoral processes, and coastal resources found within Dana Point, the study evaluated SLR vulnerability across three coastal reaches: the bluff-backed beaches of North Dana Point, Dana Point Harbor, and the low-lying sandy beaches of South Dana Point. Resources within the coastal zone were identified through sources such as government databases, prior reports, and aerial imagery and include emergency services, utility infrastructure, transportation infrastructure, recreational assets, residential areas, and ecological assets.

SLR projections referenced within this study are based on the La Jolla projections included in the 2018 California Ocean Protection Council (OPC) SLR guidance, identified by the California Coastal Commission as the best-available science on the subject. The OPC guidance provides recommendations for selecting a sea level rise projection based on risk tolerance, grouping projections into the following categories.

- **Low risk aversion** – appropriate for applications where the consequences of SLR are limited in scale with minimal disruption or impact to coastal resources. These projections may be reasonable for use in planning and design of a recreational beach amenity (i.e. restroom, shower, concessions).
- **Medium-high risk aversion** – appropriate for applications with a longer design/service life in which damage from coastal hazards would carry a higher consequence and/or a lower ability to adapt, such as residential and commercial structures.
- **Extreme risk aversion** - appropriate for applications which pose a high risk to public health and safety, natural resources, and critical infrastructure under an extreme SLR scenario. The JB Latham wastewater treatment plant would be an example of a facility that should consider extreme risk aversion SLR scenarios.

SLR projections for each risk aversion category are conservative in nature and skewed toward the upper range of SLR projections. For example, the recommended SLR projection for a low risk aversion case is the upper end of the "likely range" of sea level rise projections, which has a 17% probability of occurrence at any given time horizon. Medium-high risk aversion projects are encouraged to use more conservative SLR projections, which have only a 0.5% probability of occurrence at a given time horizon. The extreme risk aversion projections are based on a recent study that evaluated the plausible upper bound of sea level rise, which has been called the H++ scenario (extreme SLR scenario due to rapid Antarctic ice sheet mass loss).

SLR scenarios evaluated within this study along with approximate timing based on OPC projections and risk aversion categories are presented in Table ES-1. Due to the 0.8-ft increment of available hazard data, minor approximations with regard to the exact timing and probability of selected SLR scenarios have been made as needed to align with risk aversion designations in OPC SLR guidance. The scenarios selected account for medium-high risk aversion projections through 2100. While possible under extreme conditions, there is a 99% chance SLR will not exceed 6 feet this century based on current projections.

Table ES-1: Sea Level Rise Scenarios and Potential Timing

SLR scenario analyzed feet (cm)	Probability and Timing for each Risk Aversion Profile		
	Low Risk Aversion (17% probability)	Medium-High Risk Aversion (0.5% probability)	Extreme Risk Aversion (H++ scenario)
1.6 (50)	2070	2050±	2040±
3.3 (100)	2110	2070	2060±
4.9 (150)	2140	2090±	2070±
6.6 (200)	> 2150	2100	2080±

Climate science is a constantly changing field, often with high degrees of uncertainty. In the case of California's SLR, the OPC has high confidence in estimates for SLR to around year 2050, after which emissions scenarios cause predictions to diverge. For the 2050 time horizon, the "likely range" of SLR is between 0.7 to 1.2 feet, which means there is a 66% probability that SLR will fall within this range. Under a worst-case, extreme SLR scenario (H++) 2.8 ft of SLR could occur by 2050. At 2100 the likely range of SLR is 1.8 – 3.6 feet, with a worst-case (H++) projection of 10.2 feet. The wide range of projections at the end of the century illustrate the need for adaptation planning when evaluating projects with life expectancies of 75-100 years.

Coastal resource exposure and vulnerability were assessed based on historic littoral processes, sediment supply, shoreline change, and oceanographic conditions within each study reach as well as future SLR hazard projections. The impacts to coastal resources from a range of coastal hazards under each SLR scenario were evaluated using the results of Coastal Storm Modeling System (CoSMoS) Version 3.0, Phase 2, a multi-agency effort led by the United States Geological Survey that incorporates physical process models to enable prediction of coastal currents, wave heights, wave runup, and total water levels. CoSMoS modeling results include predictions of shoreline erosion, coastal flooding, and cliff erosion under each SLR scenario.

Using CoSMoS modeling results, several thresholds were identified where potential coastal resource vulnerabilities may occur along North, Central, and South Dana Point (Table ES-2). Natural resources and recreational amenities will be among the first resources impacted by SLR due to the effects of coastal squeeze. Throughout Dana Point these resources are constrained from landward migration by development such as residential housing, the Los Angeles to San Diego Rail Corridor (LOSSAN), and Pacific Coast Highway (PCH). "Coastal squeeze" can be defined as the process by which sea level-dependent physical, cultural, or biological areas are pushed landwards with SLR but are prevented from natural landward migration due to a protected or non-erodible structure such as a seacliff or revetment. The dry beach and intertidal areas of Dana Strand, South Doheny State Beach, and Capistrano Beaches (and resources dependent on these areas) are vulnerable to permanent loss due to coastal squeeze based on CoSMoS shoreline projections for a 1.6-ft rise in sea level.

Table ES-2: Summary of SLR Thresholds for Coastal Resource Impacts

SLR	North Dana Point	Central (Harbor)	South Dana Point
1.6 ft	Significant beach loss in Dana Strand area Seasonal beach loss exacerbated at Salt Creek Beach	Limited shallow flooding in low-lying parking lots Reduced beach area in Harbor Increased wave transmission through breakwaters	Chronic beach erosion Seasonal flood and wave impacts to beachfront development Reduced beach area (Doheny, Capistrano & Poche)
3.3 ft	Minimal sandy beach present at Dana Strand Potential wave damage to coastal access trail along Salt Creek Beach Storm-related flooding of Monarch Bay Club Increased cliff erosion potential	Flooding throughout low-lying areas of Dana Point Harbor Minimal beach area in Harbor Further wave transmission through breakwaters	Chronic beach erosion Southern Doheny State Beach parking, residential beachfront development, and Capistrano Beach Park exposed to daily wave action Minimal beach area (Doheny, Capistrano & Poche)
4.9 ft **4.9 ft**	Revetments in Dana Strand exposed to daily wave action Further loss of beach area at Salt Creek Beach Increased cliff erosion potential	Extensive flood impacts in Dana Point Harbor Lack of beach area in harbor Potential breakwater overtopping during storms	Near nonexistent beach area south of San Juan Creek, development exposed to significant wave action Loss of majority of beach area at North Doheny State Beach
6.6 ft	Dana Strand heavily exposed to wave action Further loss of beach area at Salt Creek Beach Increased cliff erosion potential	Near-complete inundation of harbor interior parking lots Significant reduction in breakwater functionality	Minimal beach area throughout entire coastal reach Potential flood impacts at North Doheny State Beach parking during storm events

Continued shoreline erosion, accelerated by SLR, coupled with storm-induced beach erosion has the potential to cause permanent damage to development along Capistrano Beach, most of which is owned by the State, County, or private sectors. With a 1.6-ft rise in sea level, over half of the parcels along Beach Road could be subject to seasonal erosion impacts, which could be problematic for structures on shallow foundations without shoreline protection. The newer structures supported on pile foundations would be less sensitive to seasonal erosion but could be subject to wave uplift forces under this scenario during an extreme coastal storm event. A 3.3-ft rise in sea level represents a significant threshold at which the everyday shoreline is at or landward of the existing development at 135 parcels indicating the following: 1) there is little or no dry beach remaining in front of these parcels and 2) the existing structures would be subject to regular and more intense wave action given the higher water levels of this scenario. Shoreline projections for higher SLR scenarios indicate the daily shoreline position would be landward of existing development along all of Capistrano Beach. Long-term shoreline erosion not only threatens structures, it also has the potential to eliminate the dry sandy beach areas valued by the community.

More extreme sea level rise scenarios (4.9 and 6.6 feet) would result in significant loss of coastal resources of North Dana Point with an increased risk of damage to existing development along this reach. Dana Point Harbor would also experience frequent tidal flooding assuming no adaptation measures are put in place to upgrade harbor facilities such as the breakwaters, bulkheads, boating, and utility infrastructure. South of the harbor, the daily (non-storm) shoreline position is projected to be landward of almost all oceanfront development under these scenarios impacting Doheny State Beach, Capistrano County Beach, and the residential community along Beach Road.

The present-day coastal hazards and a persistent trend of shoreline erosion require some form of adaptation to protect and preserve coastal resources in Dana Point. As described in this study, each increment of sea level rise will accelerate these hazards impacting many resources valued by the community. Existing and future vulnerabilities can be mitigated through adaptation measures implemented on regional, local, or site-specific scales. Most of the City's coastline is managed by other entities such as the County of Orange and State of California, although this development is subject to the City's Local Coastal Program (LCP). Some of the adaptation measures recommended are as follows:

- Amend the City's LCP to include policies that educate the community and other stakeholders about the potential hazards associated with sea level rise, limit the exposure of existing and new development to coastal hazards, and provide a framework for adaptation measures that can mitigate impacts to coastal resources.
- Implement a monitoring program to gather additional data to better understand the local effects of SLR and coastal processes that can inform future adaptation efforts.
- Develop partnerships with other coastal land managers and identify local and regional adaptation pathways that will benefit a variety of coastal resources while balancing the costs, benefits, and trade-offs of each adaptation measure. Some of these adaptation measures include the following:
    - A regular beach nourishment program to help mitigate the adverse effects of coastal squeeze on natural and man-made resources in Dana Point. Beach nourishment, considered a "soft protection" strategy, is temporary by design and requires a regular program of re-nourishment to maintain an adequate supply of sediment to a littoral zone. Such a program requires significant financial resources that are often difficult for a single city or entity to support. An effective and sustainable beach nourishment program would likely require a collaborative effort from stakeholders such as Orange County Transportation Authority (OCTA), Caltrans, the City of San Clemente, and California State Parks whose assets would also benefit from a consistent nourishment program.
    - A living shoreline approach that mimics rocky intertidal habitat, potentially in combination with restored or enhanced reef structures. This could provide multiple ecological benefits for intertidal areas while reducing wave energy and erosion along the shoreline. The design of these features could also be fine-tuned to provide additional benefits such as sediment retention or potentially improved surfing conditions, and applications could vary to mimic the different nearshore rocky intertidal habitat types along Dana Point.

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. For this reason, SLR adaptation planning efforts should not rely on a single projection or scenario. Future SLR hazards for planning purposes should instead correspond to acceptable levels of risk based on the predicted lifespan, exposure, and vulnerability of specific coastal uses and resources. The most effective way for the City to address the vulnerabilities described in this report while accounting for the inherent uncertainties in SLR hazard planning is to implement policies and programs that are flexible and can be adapted in response to SLR, future beach conditions, and future development. Regular updates to the vulnerability assessment, at 10 year intervals, would provide an opportunity to update the findings in this study with the best available science on sea level rise projections and coastal hazards. The updated assessment should also evaluate the effectiveness of the policies, programs and projects implemented by the City and other entities to mitigate the adverse effects of sea level rise.

1. Introduction

This assessment aims to determine the potential vulnerability of infrastructure, land uses, and coastal resources in the Dana Point coastal zone. This assessment will inform an amendment to the Dana Point LCP in accordance with the California Coastal Commission (CCC) Sea Level Rise Policy Guidance (2015). Considering and planning for the effects of climate change on the coast is important. The ocean economy generated more than $4 billion toward Orange County's gross domestic product (GDP) and accounted for over 55,000 jobs, including $2 billon in wages and salaries in 2015, about half of which was in the tourism and recreation sector (NOEP 2017). The cliff-backed beaches of North Dana Point, the Harbor, and beaches of South Dana Point all provide important resources that contribute to the local coastal and ocean economy. This study will evaluate the potential effects of sea level rise (SLR) on Dana Point's communities and coastal resources in order to begin planning for and adapting to a changing coastline.

Figure 1-1: Photo Looking South from Dana Point Headland (Photograph by D. Ramey Logan)

1.1 Study Approach

The purpose of this SLR Vulnerability Assessment is to understand how rising seas could impact coastal resources in the City of Dana Point (City). The term "coastal resource" is used to describe natural or manmade features that provide a benefit to the City. The term "asset" is used to describe a specific resource or facility that was evaluated. The first step is to establish an inventory of coastal resources. The next step is to identify how coastal hazards will evolve with various increments of SLR. By comparing the hazard zones with coastal resources in the City, one can understand what magnitudes of SLR present thresholds at which impacts that are significant. A resource's vulnerability to SLR is a product of its exposure to hazards, its sensitivity to said hazards, and its adaptive capacity.

- **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 wave and water level fluctuations would be considered more exposed than a resource that only experience some minor flooding during an extreme event.

- **Sensitivity** is the degree to which a resource is impaired by exposure to a coastal hazard. For example, a structure with a shallow foundation (i.e., slab on grade) would be more sensitive to undermining from erosion than a pile-supported structure.
- **Adaptive capacity** is the ability of a resource to adapt to evolving coastal hazards. Beaches can be thought to have a natural ability to adapt because sand will migrate upward and landward in response to rising sea levels if sufficient sand exists in the system and landward space is available for this migration. Infrastructure typically has a low adaptive capacity because increased coastal hazards that exceed the design capacity often require significant improvements to maintain the same level of protection.

The vulnerability assessment informs the LCP amendment by determining potential consequences and key SLR thresholds for the City. This information will be used to develop policies and adaptation strategies for the amended Land Use Plan (LUP) and Implementation Plan (IP) to help mitigate potential consequences.

2. Coastal Setting

The City, shown in Figure 2-1, is located in Southern Orange County and bounded by the cities of San Clemente to the southeast and Laguna Beach to the northwest. The City comprises the Dana Point Headland (its namesake), which is a notable landform and natural boundary between the narrow pocket beaches to the north, and wider sandy beaches to the south.

A regional elevation map of the City (Figure 2-2) illustrates the typical condition of a narrow beach zone backed by coastal cliffs that vary in height and distance from the current shoreline. Salt Creek is the main tributary of the Dana Point Coastal Streams Watershed and drains a 7-square-mile watershed (County of Orange 2013) that discharges to the Ocean north of the Dana Point Headland. San Juan Creek, which drains a 173-square-mile watershed (County of Orange 2013), discharges to the Ocean at Doheny State Beach and is the primary source of sediment for beaches south of Dana Point Harbor (USACE 1991).

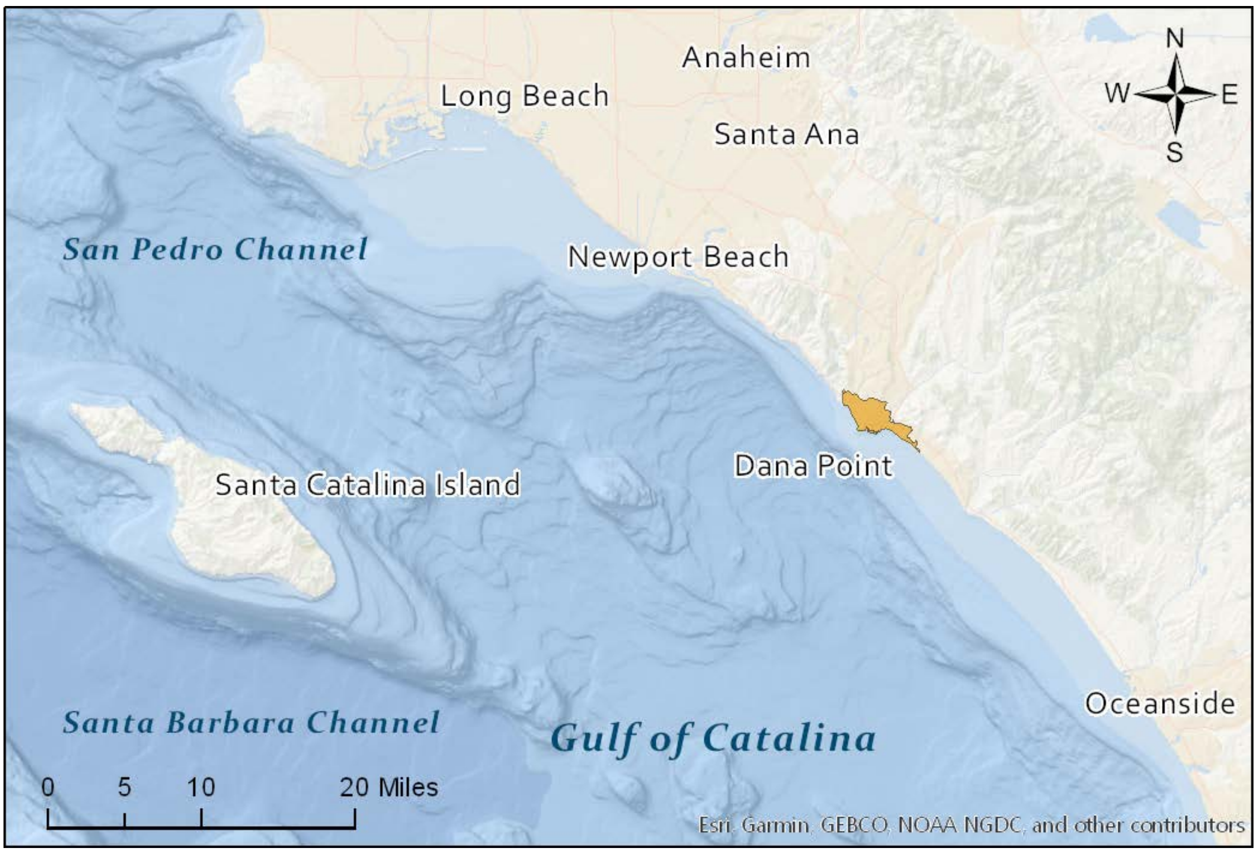


Figure 2-1: Vicinity Map of the City of Dana Point

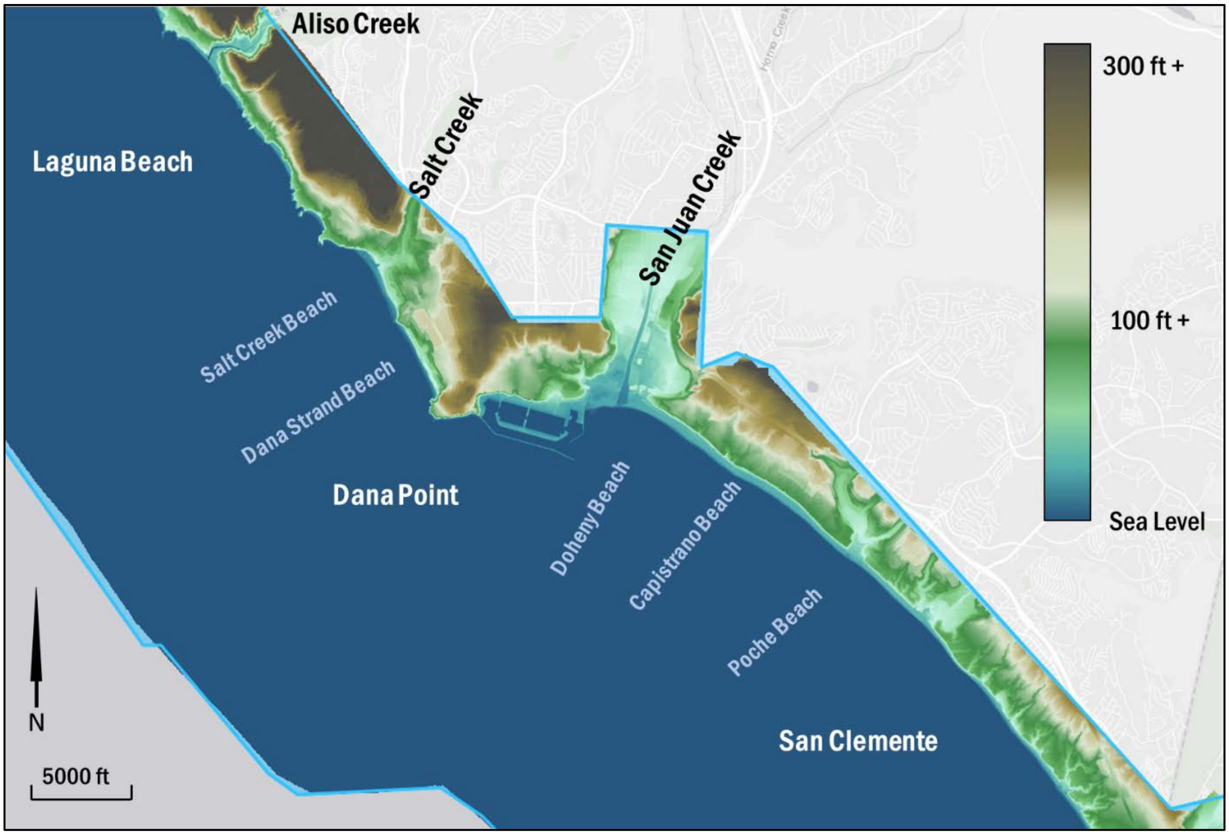


Figure 2-2: Regional Elevation Map (NOAA 2018a)

2.1 Study Reaches

Dana Point can be broken down into three different coastal reaches, mapped in Figure 2-3. The coastal setting, littoral processes, and coastal resources are unique within each of the three reaches. A description of the reach boundaries and unique characteristics is provided below with more detail on the coastal processes provided in Section 3.

1) North Dana Point – This reach extends from the northern City boundary at Monarch Bay to the Dana Point Harbor. This reach is characterized by narrow pocket beaches backed by coastal cliffs in between rocky headlands. Privately-owned development lines most of the clifftop, and the Monarch Bay Club is located on the back-beach area north of Salt Creek.

2) Dana Point Harbor/Central – This reach encompasses the harbor complex located between the Dana Point Headland and Doheny State Beach. The harbor is protected by a system of rubble mound breakwaters and revetments. Development in and around the harbor is managed by the County of Orange and includes resources that support passive and active recreation, visitor-serving development, tourism, and the ocean economy.

3) South Beaches – This reach extends from the east jetty of Dana Point Harbor to the southern City boundary at Poche Beach. This reach is characterized by sandy beaches backed by relatively low-

lying development, the LOSSAN, and PCH. The development along the beachfront consists of Doheny State Beach, Capistrano Beach Park, and the residential community along Beach Road.

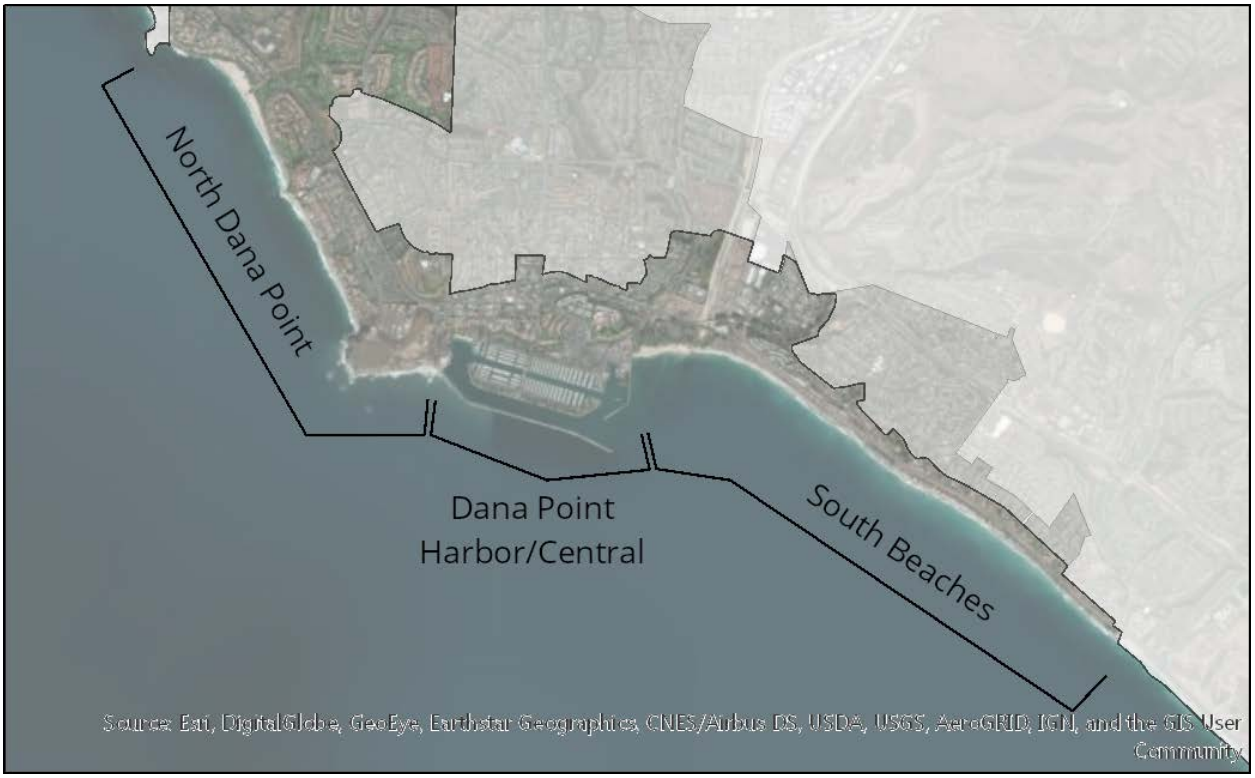


Figure 2-3: Study Reaches within the City of Dana Point

3. Coastal Resources

An inventory of coastal resources was created to identify resources, assets, communities, land uses, and infrastructure potentially at risk within the coastal zone. These resources were identified through a variety of methods, including publicly available government databases, reports, and aerial imagery. The inventory of resources is summarized in Table 3-1 and focuses on all resources within the maximum extent of modeled hazard layers discussed in Section 6. These resources were mapped using GIS and can be found on the hazard overlay maps in Appendix A.

Table 3-1: Summary of Coastal Resources Inventory

Resource	Description	Data Source
Police Services	OC Sheriff and Harbor Patrol	City of Dana Point
Schools	Public: Richard Hills Dana Elementary, Richard Hills Dana Exceptional Needs Facility Private: San Clemente Christian School	City of Dana Point
OCFA	Orange County Fire Authority Stations (OCFS No. 29 & No. 30)	City of Dana Point
Dana Point Arterials	Major Roads and traffic signals	County of Orange (OC Landbase); City of Dana Point; Caltrans
Public Access Points	Coastal Access Points	California Coastal Commission, City of Dana Point
State Marine Protected Area	Dana Point State Marine Conservation Area	California Department of Fish and Wildlife, Marine Region GIS Lab
Railroad	OCTA, LOSSAN	County of Orange (OC Landbase)
Utilities	Stormwater, potable and non-potable water, wastewater, water quality BMPs; power and telecommunication infrastructure	City of Dana Point
Parks (Dana Point)	Dana Point Parks	City of Dana Point
Parks (Orange County)	Salt Creek, Capistrano Beach, regional bike path and pedestrian trail	County of Orange (OC Landbase)
Dana Point Harbor	Harbor infrastructure, upland development, boating infrastructure	County of Orange (OC Landbase)
Doheny State Beach	State Park, camping, day-use, regional bike and pedestrian trail	California State Parks

Resource	Description	Data Source
Historic Properties	Properties with potential historic status	City of Dana Point
Parcels	Property boundaries	County of Orange (OC Landbase)
Ecological	Endangered Species, nearshore habitat, State Marine conservation Area (SMCA)	City of Dana Point, California Natural Diversity Database

4. Coastal Processes

Coastal processes refer to the waves, water levels, and transport of sediment that shape the coastline of Dana Point. 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 shorelines of Dana Point. The influence of SLR on coastal processes will be discussed in Section 6.

4.1 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). The City of Dana Point spans two littoral cells on either side of the Dana Point Harbor. The Laguna Beach littoral cell extends 13 miles from the Newport Bay entrance to the Dana Point Harbor and includes 23 mini sub-cells consisting of pocket beaches backed by sea cliffs and separated by headlands with rocky reef extensions (Everest 2013). The primary sources of sediment to the pocket beach north of Dana Point Headland are fluvial discharges from Aliso Creek and Salt Creek (Everts Coastal 1997).

South of Dana Point Harbor is the Oceanside littoral cell, which extends 51 miles from Dana Point to La Jolla. The primary sources of littoral sediment for beaches south of the Harbor are San Juan Creek and erosion of coastal bluff and dunes. However, development along the coastline has significantly reduced the contribution of sediment from coastal bluffs and dunes. Since the net direction of sediment transport is toward the south, other sources, such as San Mateo Creek and cliffs along San Clemente, are not major sources for beaches of South Dana Point. Sinks include Aeolian (wind-blown) losses to dunes and cross-shore transport to offshore. Some sinks, such as dunes, can later become sand sources as dunes erode during extreme wave events or as sea levels rise.

Fluvial discharge from San Juan Creek is the largest natural source of sediment for the southern coastline of Dana Point. The sediment contribution to the local beaches from San Juan Creek has been estimated between 34,000 and 56,000 cubic yards per year (cy/yr), on average (Coastal Environments 2014). The United States Army Corps of Engineers ([USACE] 2012) estimated an average annual sediment delivery of 26,700 cubic yards per year (cy/yr) and noted that most of this is likely lost offshore or trapped updrift of San Clemente. Figure 4-1 shows the delta formed at the San Juan Creek mouth in April 2005, four months after a major flood event on January 10-11, 2005.

Figure 4-1: San Juan Creek Delta, April 2005 (Google Earth)

The fluvial discharge rates are averaged over a long period of time and do not reflect the episodic nature of these events. There have not been any notable discharges from San Juan Creek since 2005. In addition to a recent lack of substantial precipitation events, other factors have contributed to a reduced long-term sediment yield from the watershed. Urbanization of the watershed, construction of dams, reservoirs and debris basins, and continued sand and gravel mining all reduce the delivery of sand to the coast (Everest 2013). The Coast of California Storm and Tidal Wave Study for the San Diego Region (CCSTWS-SD) estimated a 20-30% reduction of the natural (pre-dam) sediment yield from within the San Juan Creek watershed (USACE 1991). That estimate was based on reports prepared in the late 1980s. In the two decades since those studies, watershed development has continued, and the reduction in sediment delivered to the coast has probably increased.

A study by Coastal Environments (2014) provided an assessment of littoral sediment transport patterns and a sediment budget for the coast between Dana Point and San Mateo Point (Dana Point Sub-cell). Data was aggregated from sediment studies spanning the 1980s to the 2000s, and it was estimated that the sediment budget for the Dana Point Sub-cell is in a 56,000 cy/yr deficit (erosion) in dry years and in a 3,000 cy/yr surplus (accretion) in wet years. This discrepancy helps explain why the prolonged drought over recent years has resulted in erosion issues south of San Juan Creek.

Beach nourishment has not provided a significant source of sediment to the littoral cell since the 1960s, when over 1.6 million cubic yards (mcy) of sediment was placed at the San Juan Creek mouth from upland and sea cliff sources, construction activities along San Juan Creek, and Dana Point Harbor construction (M&N 2017). Other sediment management programs for Dana Point include 118,000 cy/yr placed over the 1960-1978 timeframe (USACE 1991).

San Clemente has also experienced erosion issues and has implemented an Opportunistic Beach Fill Program with Project #1 adding 5,000 cubic yards (cy) of sand in 2005 and Project #2 adding 12,000 cy of sand in December 2016. The CCC has approved up to 250,000 cy of nourishment for their program. Potential future sediment management programs include the USACE Beach Fill Plan, which would place approximately 251,000 cy in the vicinity of the San Clemente Pier (USACE 2012). Unfortunately, sediment placed along the San Clemente coastline is unlikely to offer much benefit to the beaches of Dana Point due to the net direction of sediment transport. However, perhaps there is an opportunity to collaborate with San Clemente and other stakeholders on a more regional beach nourishment program that could extend benefits across a wider region.

4.2 Shoreline Change

The beaches of Dana Point are sensitive to changes in sediment supply driven by natural processes but are also influenced by anthropogenic effects (i.e., construction of Dana Point Harbor, installation of coastal structures, land development, impoundment, and flood control works on San Juan Creek, upstream sand and gravel mining, and periodic beach nourishment). A sediment deficit, meaning more sediment leaves the sub-cell than is supplied, results in a trend of shoreline erosion. Long-term shoreline changes are often related to sediment supply (described in Section 4.1), 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.

4.2.1 Long-term Shoreline Change

Moffatt & Nichol (1993) provided an assessment of historic shoreline change behavior within the City. A detailed study of shoreline change in the Doheny Beach area was performed by Coastal Environments (2014). Studies by the USACE (1991 and 2012) performed an assessment of shoreline change south of Dana Point Harbor (Oceanside Littoral Cell). The quantitative results from these studies vary because each study averages shoreline change over different time periods. However, a few general conclusions are consistent between the studies:

1) Construction of the Dana Point Harbor influenced shoreline change trends to the south resulting in accretion of downcoast beaches until the late 1980s. Since that time, beaches south of San Juan Creek have experienced a long-term trend of erosion.

2) The long-term (decadal) shoreline change trend can shift from erosional to accretional (and vice versa) dependent upon fluvial discharges from San Juan Creek over a given time period.

Prior to harbor construction, the long-term shoreline change trend (1934-1970) was slightly erosional. After construction of the harbor, the long-term shoreline change (1970-1988) between Doheny State Beach and Poche Beach shifted to an accretional trend. After construction of the harbor, the upcoast end of the littoral cell was shifted from the Dana Point Headland to the east breakwater of the harbor. The breakwater became the new control on the shape of the crenulate bay southeast of the harbor (M&N 1993). Coastal Environments (2014) estimated the shoreline between the east breakwater and the groin at San Juan Creek (Thor's Hammer) advanced by roughly 200 feet (ft) after construction of the harbor. Shoreline advances further downcoast were attributed to wave blocking and diffraction at the end of the harbor breakwater. The wave approach angle and height of waves along the Capistrano Beach area were affected, which reduced longshore sediment transport and the shoreline advanced (M&N 1993). The highest rates of accretion over this period occurred along the northern end of the Capistrano Bay Community (M&N 1993).

Figure 4-2: Aerial Image *of Thor's Hammer Groin (Copyright © 2008. Kenneth and Gabriel Adelman, California Coastal Records Project)*

The Coastal Environments' (2014) study provides the most recent estimates of long-term shoreline change within the City of Dana Point. Their data indicate that beach widths west of Thor's Hammer Groin have experienced dynamic fluctuations but have remained relatively wide (>300 ft) and stable between 1983 and 2011. However, East Doheny Beach has experienced a long-term trend of erosion over this same time period (Coastal Environments 2014).

At the southern end of Doheny State Beach, USACE (2012) documented a shoreline accretion rate of 8 ft per year (ft/yr) from 1960 to 1980. This pattern shifted dramatically over the following decade with an erosion rate of -12 ft/yr measured from 1980 to 1989 at profile DB 1805. Shoreline change data for East Doheny State Beach reported by Coastal Environments (2014) indicates this rate of erosion has continued through 2010.

Recent evidence indicates the erosion trend downcoast of San Juan Creek has continued to present day, perpetuated by a long-term drought, with beaches in Dana Point and San Clemente suffering from continued beach loss and storm damage during the 2015-2016 El Niño. Emergency shoreline protection structures were put in place at South Doheny State Beach and Capistrano Beach Park to prevent further undermining of the beach parking lots.

The most recent study of littoral process and shoreline change upcoast of the Dana Point Headland was performed by Everts Coastal (1997) as part of the Coast of California Storm and Tidal Waves Study for the Orange County Region (CCSTWS-OC) prepared by the USACE (2002). The Salt Creek & Dana Strand beaches were reported to have a relatively stable to slightly accretional long-term shoreline change trend. However, the Everts Coastal (1997) report points out factors such as watershed development, seawall construction, and SLR that could reverse this trend. For example, based on the infilling rate of reservoirs and debris basins in the Aliso Creek watershed, Everts Coastal lowered the annual fluvial sediment yield by 33% below previous estimates. This represents a significant reduction in sediment supplied to Salt Creek and Dana Strand beaches.

4.2.2 Seasonal Shoreline Change

The shoreline is also sensitive to water level changes and wave energy, which result 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. 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 these seasonal changes is illustrated in Figure 4-3. The seasonal shoreline change was quantified by the USACE (1991) with data collected prior to 1989, and a maximum seasonal shoreline change of about 50-70 ft was measured from beach profiles along Doheny State Beach.

Upcoast of Dana Point Headland, there are similar cross-shore seasonal changes driven by the wave climate with annual fluctuations of 200 ft near Salt Creek (M&N 1985). Winter erosion down to bedrock along the Dana Strand beach is relatively common (M&N 1985). In addition to the cross-shore movement of sand, there is also a seasonal alongshore shift in shoreline orientation evident in recent aerial imagery from google earth. During summer months sand is pushed north by south swells and results in a wider beach at the north end of both Salt Creek and Dana Strand beaches. The reverse happens in wintertime with a wider beach at the south end, though to a lesser degree, since more sand is pulled offshore by more energetic waves.

Seasonal beach loss during winter months depletes the storm buffer provided by a wide sandy beach. Most of the coastal damage experienced recently has been a result of storm-induced erosion during winter months. Storm related erosion can result in significant beach loss over the course of a few days. The most extreme events occur when large wave events coincide with high water levels such as the El Niño storm events during the 1982-1983 season, 1988, and most recently in 2015-2016.

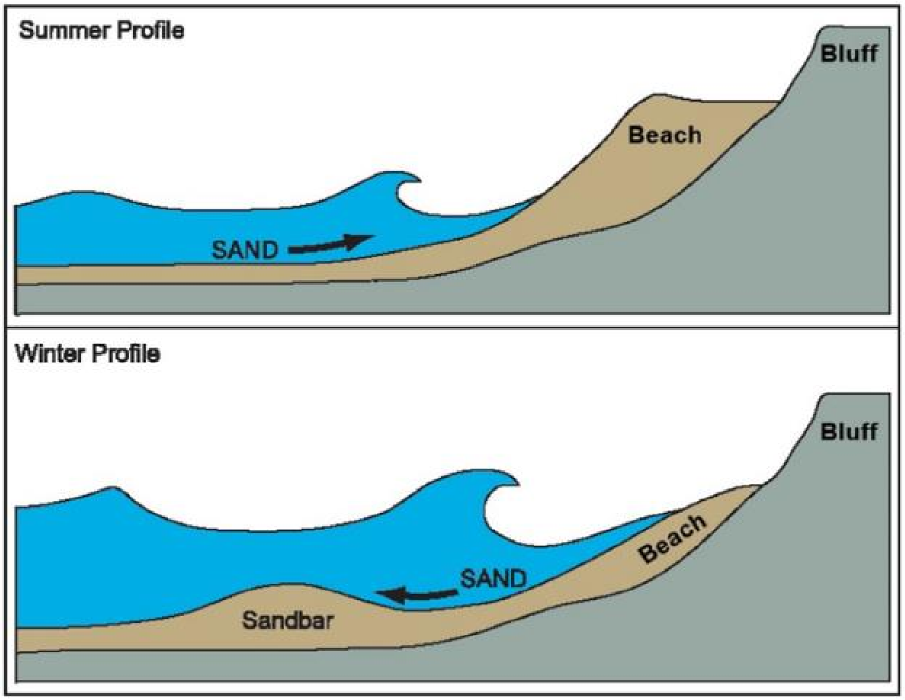


Figure 4-3: Schematic of Seasonal Shoreline Change (Patsch and Griggs 2007)

4.3 Oceanographic Conditions

Oceanographic conditions play a significant role in determining coastal hazards such as flooding and erosion. These conditions drive coastal processes that influence the behavior of sediment transport and, consequently, the shoreline position at Doheny State Beach. The following sections provide a general understanding of the expected wave and water level conditions to predict shoreline changes and impacts.

4.3.1 Water Levels

The tides in Southern California are semidiurnal, meaning there are two low and two high waters each lunar day (~25-hour period). The La Jolla tide gage (Station 9410230), operated by the National Oceanic and Atmospheric Administration (NOAA), provides a long-term sea level record near the study area. The gage is located on the Scripps Pier and has been collecting data since 1924. These data are applicable to the Dana Point coastline and can be used to characterize the variability in existing water levels illustrated in Figure 4-4.

Astronomical tides make up the most significant amount of the total water level. Typical daily tides range from mean lower low water (MLLW) to mean higher high water (MHHW), a tidal range of about 5.3 ft. During spring tides, which occur twice per lunar month, the tide range increases to almost 7 ft 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 ft. The largest spring tides of the year, which occur in the winter and summer, are sometimes referred to as "king" tides and result in high tides of 7 ft or more above MLLW and tidal ranges more than 8 ft.

In addition to astronomical tides, factors such as sea level anomalies (El Niño events) and storm surge also contribute to the water levels along Dana Point. These events can increase the predicted tides over the course of several days to several months. An example of this occurred on November 25 and 26, 2015 when a king tide of about 6.7 ft above MLLW was predicted, but a water level of 7.8 ft was measured at NOAA station 9410230 in La Jolla. The tide series from this event is shown in Figure 4-5. The predicted astronomical tide was elevated by more than 1 ft due to a sea level anomaly related to the strong El Niño and high ocean temperatures during the 2015-2016 winter season (Doherty 2015). The water levels of late November 2015 exceeded the 100-year water level of 7.6 ft (NOAA 2018b) on two consecutive days at this tide station.

Ocean water levels are dynamic and typically vary within predictable ranges. However, it's not uncommon to experience sea level anomalies that significantly increase the predicted water level above the astronomical tide. When considering the effects of SLR on coastal hazards, it's important to keep in mind that SLR increases this entire range of existing water levels.

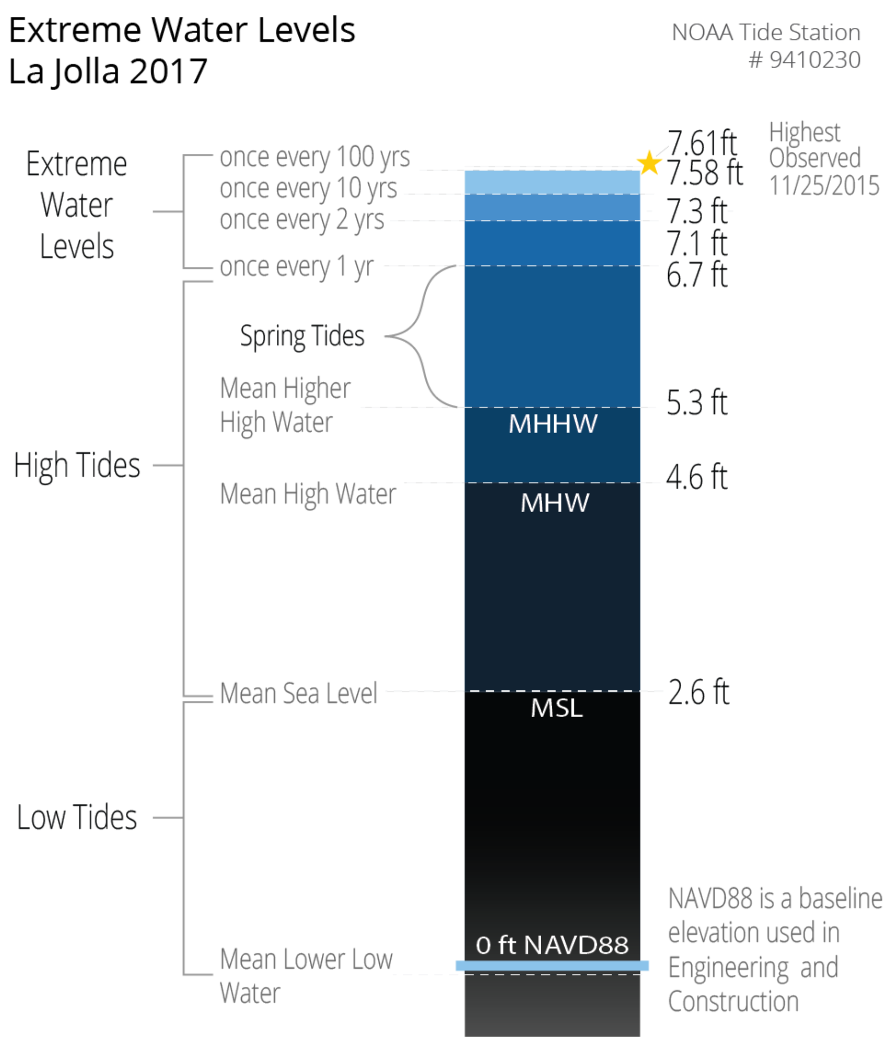


Figure 4-4: Daily and Extreme Water Levels Based on the La Jolla Tide Station (NOAA 2018b)

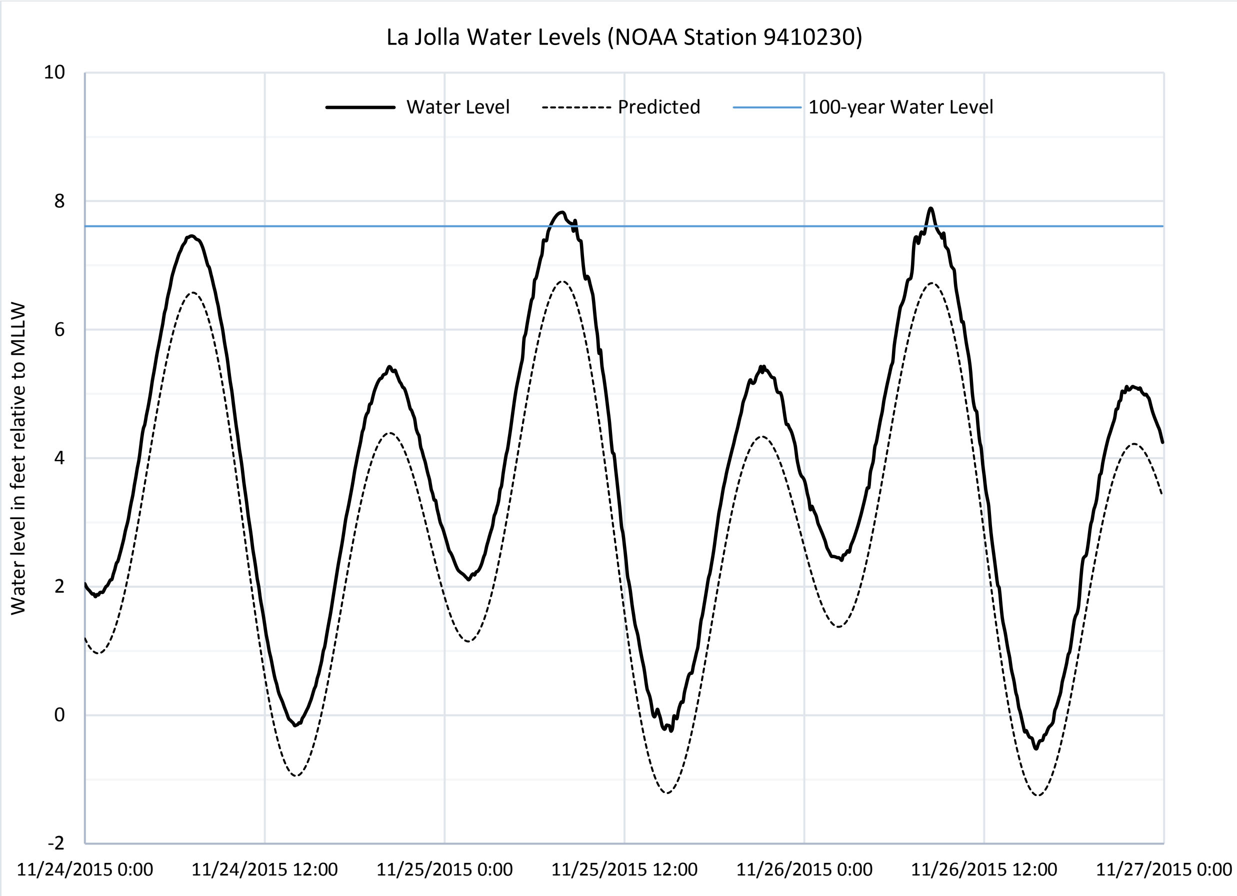


Figure 4-5: November 2015 La Jolla Tide Series, Station 9410230 (NOAA 2018b)

4.3.2 Waves

Waves act to transport sand in both the cross-shore (perpendicular to shore, onshore-offshore transport) and alongshore directions (parallel to shore, downdrift transport) and can also cause short-duration flooding events by creating dynamic increases in water levels. Thus, the wave climate (or long-term exposure of a coastline to incoming waves) and extreme wave events are important in understanding future vulnerabilities along the Dana Point coastline.

The general wave exposure of Dana Point is characterized by south swells in summer, which are typically smaller wave heights with long wave periods (~18-22 seconds) and west-northwest swells in winter months that have much larger wave heights and wave periods in the 16-20 second range. While extreme wave events can damage coastal resources, the year-round wave exposure is also an asset to the local surfing community. Exposure to a wide range of swells make for consistent waves at a variety of breaks from Salt Creek to Poche Beach, including the popular Doheny Beach (Figure 4-6).

Figure 4-6: Surfing at Doheny Beach (July 2017)

The nearshore wave exposure along the coastline varies with shoreline orientation. Salt Creek and Dana Strand, which face southwest, are more exposed to west swells than Doheny Beach, which faces south and is sheltered by the harbor breakwater. Likewise, Capistrano Beach and the Beach Road community are outside the shelter of the breakwater and experience a higher exposure to west swells. Coastal Environments (2014) found that a west swell approaching Doheny Beach from 270 degrees with a 16-second wave period would have a nearshore wave height that is ~50% lower than the offshore deepwater wave height. During a south swell approaching from 195 degrees, the same beach would have a nearshore wave height larger than the offshore deepwater wave height.

The USACE (1991) characterized extreme wave events in the Oceanside Littoral Cell as part of the CCSTWS-SD by analyzing historic data from the largest tropical and extratropical storms on record. Based on this analysis, the 10-year deepwater significant wave height (H_s) was estimated to be ~20 ft and the 100-year H_s ~28 ft.

For much of Southern California, especially coastlines exposed to south swell like Dana Point, the largest wave event on record was the September 1939 tropical storm. A maximum wind of 50 knots was recorded at the Los Angeles-Long Beach Outer Harbor with wave heights of 30 to 40 ft estimated by people ashore (M&N 1985). Ships in the Catalina Channel reported 45-ft high waves that resulted in significant damage to the Los Angeles-Long Beach Harbor breakwater. A wave event of this magnitude today would result in considerable damage to development and resources within the coastal zone of Dana Point.

More recently, the Coastal Data Information Program (CDIP) measured nearshore (shallow-water) wave data using a gage installed roughly 1,000 ft offshore of the San Clemente Municipal Pier in about 30 ft of water. The gage (ID 052) collected measurements from 1983 to 1998 before it was de-commissioned, with a large gap from July 1988 to July 1991 (USACE 2012). The range of the most commonly occurring significant wave height was 2.7-3.3 ft with a maximum wave height of 12 ft measured January 18, 1988 (USACE 2012). Table 4-1 provides a summary of the maximum significant wave height recorded each year. The significant wave height is defined as the average of the highest one-third of waves in a wave spectrum. The theoretical maximum wave height in a given spectrum can be two times the significant wave height.

For example, during the January 30, 1998 event, the largest significant wave height measured offshore of the pier was about 10 ft. During this same storm the maximum wave heights may have reached 20 ft.

Table 4-1: Annual Maximum Significant Wave Height near San Clemente Municipal Pier, 1983-1998 (USACE 2012)

Date	Significant Wave Height, H_s (ft)
12/10/1983	10.2
4/1/1984	6.1
11/29/1985	7.2
2/16/1986	11.7
3/16/1987	7.4
1/18/1988	11.9
11/15/1991	6.8
1/30/1992	7.6
2/18/1993	8.7
2/7/1994	6.6
1/5/1995	10.6
10/26/1996	7.4
12/6/1997	7.6
1/30/1998	9.8

CoSMoS Version 3.0 model provides nearshore wave heights for a range of storm events including the annual, 20-year, and 100-year recurrence intervals. The nearshore wave heights for an annual and 100-year wave event, provided in Figure 4-7, were generated by using the Our Coast Our Future (OCOF) web-based application (Ballard et al 2016) that can be accessed to view all of the CoSMoS hazard data. The nearshore wave heights for an annual event range from 8-10 ft with largest waves focused at the Dana Point Headland and Salt Creek. These values are consistent with the annual maximum wave heights measured off of San Clemente (Table 4-1). Nearshore wave heights for a 100-year event range from 12-15 ft upcoast of the Dana Point Headland with lower wave heights (8-10 ft) downcoast of the Harbor. These wave heights were used to drive the CoSMoS shoreline erosion and coastal flooding models discussed in Section 6.

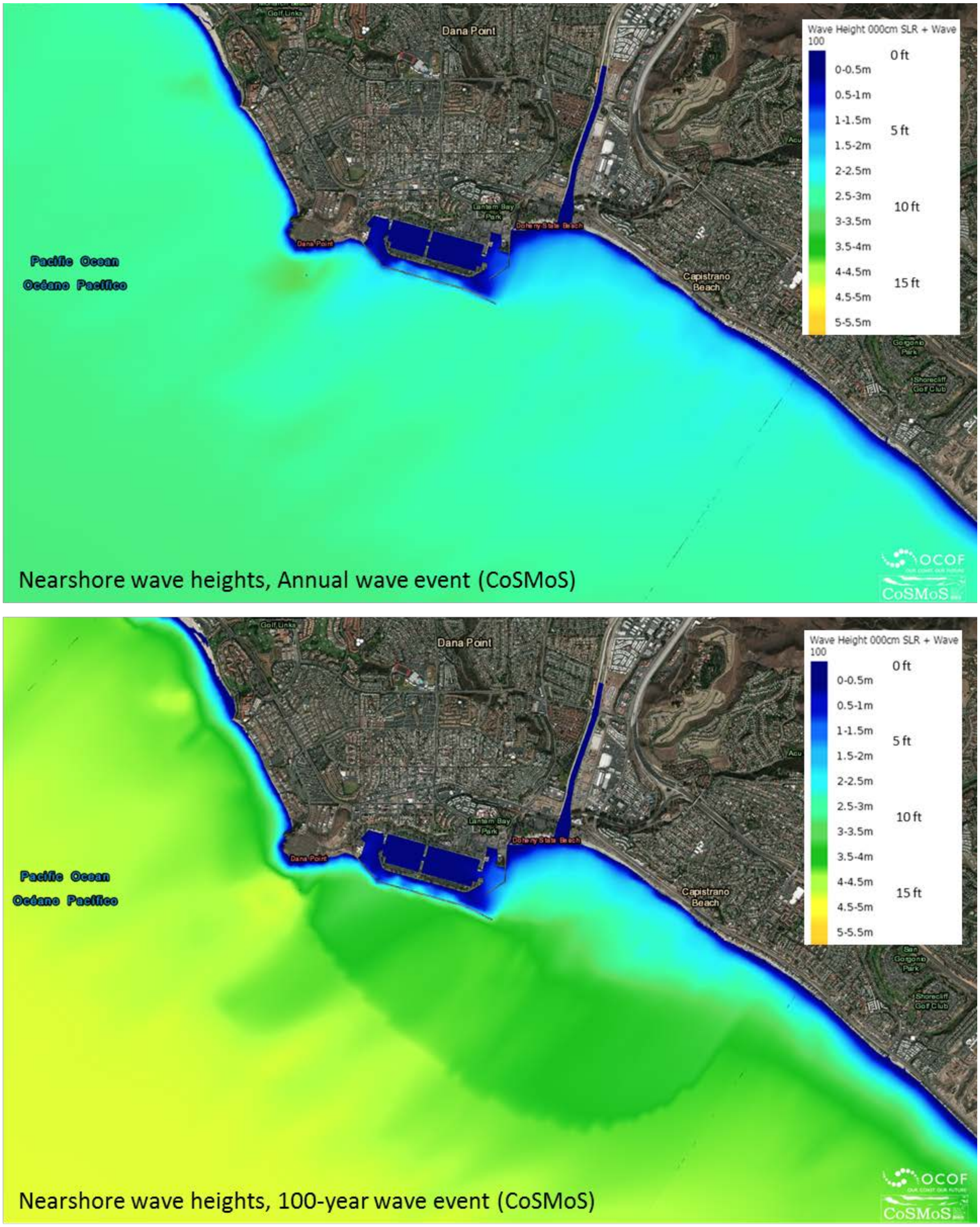


Figure 4-7: CoSMoS Nearshore Wave heights (Ballard et al 2016)

5. Sea Level Rise

5.1 What is Sea Level Rise?

SLR science involves both global and local physical processes, as illustrated in Figure 5-1. Models are created based on science's best understanding of these processes on global and local scales; therefore, they are dynamic and periodically updated to reflect these changes. On a global level, the most recent predictions come from the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) released in 2013. The AR5 projections for SLR were 50% higher than the Intergovernmental Panel on Climate Change's Fourth Assessment Report (AR4) (released 2007) due to the addition of ice sheet dynamics on SLR. At the state level, the CCC recommends using the best available science, which is expected to be updated every 5 years.

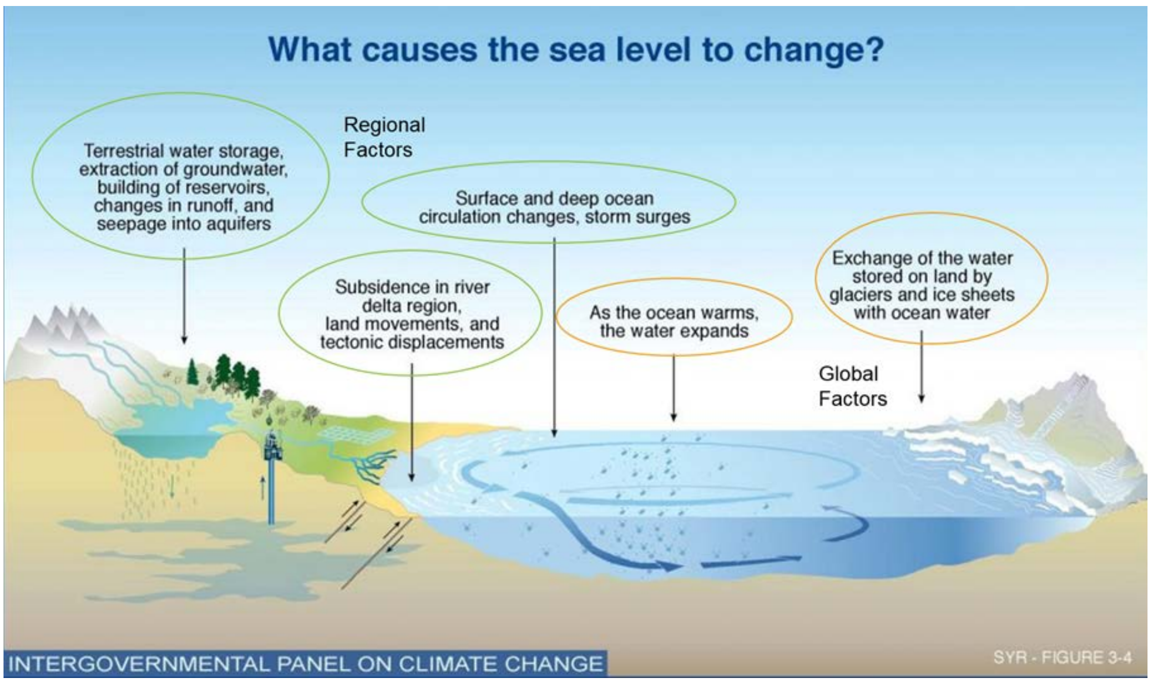


Figure 5-1: Regional and Global Factors that can Contribute to Changes in Sea Level (IPCC 2013)

5.2 Projections and Probability

State of California OPC Science Advisory Taskforce updated the best available science through the *Rising Seas in California: An Update on Sea Level Rise Science* report, released in April 2017. This report was then used to update the OPC's California State Guidance in 2018. The 2018 OPC SLR Guidance is now referenced as the best available science throughout the updated CCC SLR Policy Guidance document (2018).

The OPC (2018) Guidance projects SLR for multiple emissions scenarios and uses a probabilistic approach based on Kopp et al. 2014 to generate a range of projections at a given time horizon for 12 tide gauges along the California coast. The projections for the La Jolla tide gauge are referenced in this section. CCC SLR Policy Guidance recommends using projections associated with a high-emissions future given that worldwide emissions are currently following the high-emissions trajectory. The 2018 California State Guidance Document lays out a risk decision framework that explains when to use low- or high-risk aversion in the planning process. With this framework, the probabilistic projections inform a decision-making process rather than trying to estimate the exact rate or occurrence of SLR based on an individual scenario or projection.

For the 2050 time horizon, the “likely range” of SLR is between 0.7 to 1.2 feet. Kopp et al. 2014 estimated there is a 66% probability that SLR will fall within this “likely range.” The likely range of SLR at the 2100 time horizon is 1.8–3.6 feet for a high-emissions scenario. The upper end of the “likely range” is recommended for low risk aversion situations where impacts from SLR greater than this amount would be insignificant or easily mitigated. The state recommends this high-risk tolerance (low aversion) to be used when considering resources where the consequences of SLR are limited in scale and scope with minimum disruption and where there is low impact on communities, infrastructure, or natural systems. This “low-risk aversion” curve is shown in orange in Figure 5-2. At any given time horizon there is a 17% chance that SLR will exceed this curve.

For medium-high risk aversion situations, more conservative (lower probability) projections for SLR are recommended by the OPC Guidance. These projections have a 1-in-200 chance (0.5% probability) of occurring at a given time horizon and would be appropriate for use on projects where damage from coastal hazards would carry a higher consequence and/or a lower ability to adapt, such as residential and commercial structures. A sea level rise of 2 feet is projected at the 2050 time horizon, 3.6 feet at 2070, and 7.1 feet at 2100. The “medium-high risk aversion” curve is shown in red in Figure 5-2 and is most applicable for the residential and commercial development along the City’s shoreline.

The OPC guidance also includes a specific singular scenario (H++) based on projections by Sweet et al 2017, which incorporates findings of DeConto and Pollard (2016), that predict Antarctic ice sheet instability could make extreme sea-level outcomes more likely than indicated by Kopp et al. 2014 (OPC 2017). Because the H++ scenario is not a result of probabilistic modeling, the likelihood of this scenario cannot be determined. Due to the extreme and uncertain nature of the H++ scenario, it is most appropriate to consider when planning for development that poses a high risk to public health and safety, natural resources, and critical infrastructure (OPC 2018). The H++ extreme risk aversion curve is shown in purple in Figure 5-2.

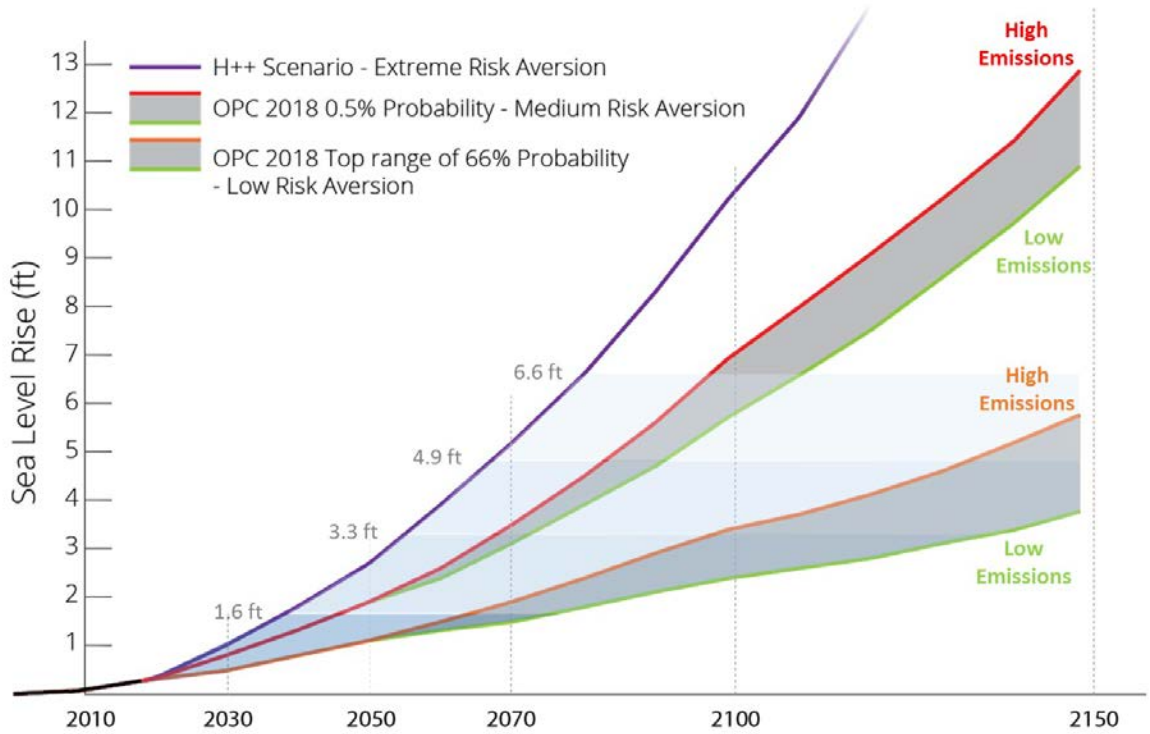


Figure 5-2: Approximate Sea Level Rise Projections for Three Risk Aversion Levels (OPC 2018)

5.3 Selected Sea Level Rise Scenarios

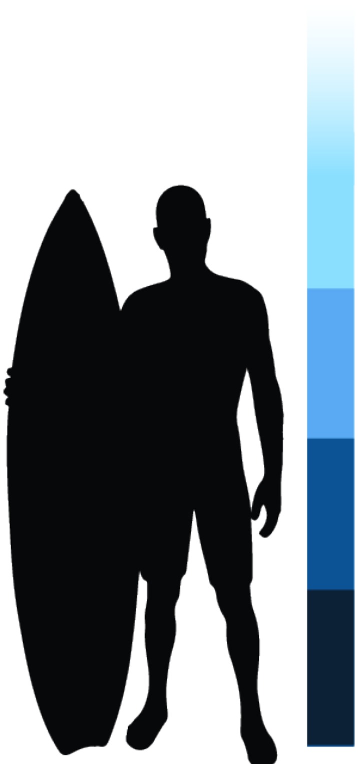
Climate science is a constantly changing field, often with high degrees of uncertainty. In the case of California's SLR, the OPC has high confidence in estimates for SLR to around year 2050, after which emissions scenarios cause predictions to diverge. Due to the high degree of uncertainty associated with predicting when and at what rate SLR will occur, this study looks at a range of SLR increments (scenarios) starting with present day conditions and including extreme SLR. Four scenarios have been selected for this study that consider increments of SLR between 1.6 and 6.6 ft, as shown in Figure 5-3, and based on available hazard data for the region discussed in Section 6. The probabilities that sea level rise will meet or exceed a particular height over a given time horizon are based on Kopp et al. 2014 and described below:

1. Sea level rise of 1.6 ft (50 cm) is representative of the low risk aversion projection for 2060, which means there is an 83% probability sea level rise will not exceed this amount over the next 40 years. There is less than a 5% probability that this amount of SLR will occur before 2050. Under a worst-case extreme SLR scenario (H++) this amount of SLR could occur by 2040.

2. Sea level rise of 3.3 ft (100 cm) is representative of the medium-high risk aversion projection for 2070 which means there is a 99.5% probability sea level rise will not exceed this amount over the next 50 years. However, under a worst-case extreme SLR scenario (H++), this amount of SLR could occur by 2060.

3. Sea level rise of 4.9 ft (150 cm) represents the medium-high risk aversion projection for the 2080-2090 time horizon. There is a ~95% probability that 4.9 ft of SLR does not occur until after 2100. However, under a worst-case extreme SLR scenario (H++) this amount of SLR could occur by 2070.

4. Sea level rise of 6.6 ft (200 cm) is representative of the medium-high risk aversion projection for 2100, which means there is a ~99.5% probability sea level rise of this magnitude will not occur this century. This scenario provides a conservative projection for SLR to be applied on projects with a longer design life (75-100 years) and subject to medium-high consequences if SLR is underestimated.



Sea level Rise above '91-'09 baseline	When might it occur?*
6.6 feet (200 cm)	2080 to 2150+
4.9 feet (150 cm)	2070 to 2130
3.3 feet (100 cm)	2060 to 2100
1.6 feet (50 cm)	2040 to 2070

* ranges are estimated from OPC (2018) at La Jolla for low to extreme risk aversion projections

Figure 5-3: Selected Sea Level Rise Scenarios and Range of Timing

6. Sea Level Rise Hazard Mapping

The effects of SLR on coastal processes such as shoreline erosion, storm related flooding, and cliff erosion were evaluated using results of the CoSMoS Version 3.0, Phase 2. Other SLR hazard viewers such as the NOAA Sea Level Rise Viewer are also available, but these tools lack the regional focus and depth of information provided in CoSMoS modeling efforts. CoSMoS is a multi-agency effort led by the United States Geological Survey (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 results provide predictions of shoreline erosion (storm and non-storm), coastal flooding during extreme events, and cliff 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.

6.1 CoSMoS Sea Level Rise Scenarios

A total of 10 SLR scenarios are available, which include 0.8 ft (0.25 m) increments from 0 to 6.6 ft (0 to 2 m) and an extreme SLR scenario of 16.4 ft (5 m). Table 6-1 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 on the OCOF web tool, which provides a useful interface for mapping the different scenarios (http://data.pointblue.org/apps/ocof/cms/).

Table 6-1: 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 and cliff erosion
Current – 2100	Hold-the-Line, No Beach Nourishment	0 - 6.6, 16.4 ft (0 - 2, 5 m)	Flood hazards, shoreline and cliff erosion
Current – 2100	No Hold-the-Line, Beach Nourishment	0 - 6.6, 16.4 ft (0 - 2, 5 m)	Shoreline and cliff erosion
Current – 2100	No Hold-the-Line, No Beach Nourishment	0 - 6.6, 16.4 ft (0 - 2, 5 m)	Shoreline and cliff erosion

6.2 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 ft along the shoreline. The projected water levels used in the flood mapping consider future shoreline change, tides, sea level anomalies like El Niňo, storm surge, and SLR. Future wave conditions used in the model are based on forecasted conditions out to year 2100.

There are also a few limitations to consider when viewing the CoSMoS hazard data. Flooding results are available only for the Hold-the-Line, No Beach Nourishment management scenario, which assumes future shoreline retreat will be halted at the existing development line and protected by coastal structures. The Hold-the-Line assumption restricts shoreline erosion beyond the line of development in the model, which in some locations is very close to the existing shoreline.

Flooding was allowed to occur beyond the line of development, but results only show relatively minor flooding, even for the higher SLR scenarios combined with an extreme coastal storm. For example, South Doheny State Beach and Capistrano Beach Park experienced significant flooding in 2015 from a relatively minor wave event that coincided with a high water level. However, the CoSMoS results show these locations do not experience flooding under a 100-year event combined with 5 ft of SLR. It is not clear what assumptions were made for the type and height of coastal structure used to Hold-the-Line, or the potential for scour in front of such a structure. These parameters are key in evaluating the wave runup height and potential for flooding landward of the structure. In our opinion, the assumptions made in the CoSMoS model to determine wave runup, overtopping, and flooding along the existing development line lead to an under-estimate of the coastal flooding potential for each SLR scenario. It may be prudent to verify these CoSMoS findings in a subsequent effort.

For cases where the flooding hazards are not sufficient to identify impact thresholds, the shoreline erosion projections available from the CoSMoS Coastal One-line Assimilated Simulation Tool (CoSMoS-COAST) model offer more options for evaluating future coastal hazards because of the different management scenarios available. These projections are discussed in the following section.

6.3 Shoreline Erosion Projections

Simplified shoreline process calculations such as the Bruun rule illustrate that with 1.6-3.3 ft of SLR, Dana Point beaches could lose approximately 50-100 ft in beach width. CoSMoS results are more refined and include long-term erosion resulting from SLR and projected wave conditions. Beach erosion was modeled with 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 were predicted for the four management scenarios in Table 6-1.

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. However, there has not been a consistent nourishment program in Dana Point, and historic nourishments are not well defined in terms of the placement volumes, locations, and dates. Therefore, the CoSMoS-COAST model does not accurately reflect how a regular beach nourishment program could reduce the long-term shoreline erosion rates in the future. Since a regular beach nourishment program was not incorporated into the CoSMoS-COAST model, the difference in future shoreline projections between with and without beach nourishment is negligible. Additional modeling, beyond the scope of this study, would be required to illustrate how a consistent nourishment program could help mitigate shoreline erosion due to SLR.

The CoSMoS-COAST shoreline projections are based on an initial shoreline mapped from a 2009-2011 LIDAR data set. Therefore, the initial shoreline doesn't reflect the recent erosion driven by a sediment supply deficit and El Niño storm events. In many locations the current shoreline is significantly landward of the CoSMoS "initial shoreline," especially downcoast of San Juan Creek. This would indicate that perhaps the projected erosion due to each SLR scenario may reach further inland than depicted.

6.4 Cliff Erosion Projections

The coastline north of Dana Point Headland consists of a series of bays and headlands shaped by non-uniform retreat of the bounding sea cliffs and shore platforms, mostly in the past 18,000 years of SLR (Everts Coastal 1995). Seacliff erosion is an episodic process that typically occurs during extreme wave events that strip sand from the beach exposing the cliff base to direct wave attack. Over years or decades, there may be little or no evidence of cliff erosion, followed by a short duration but severe event that causes a significant amount of erosion. Three primary factors that influence sea cliff erosion by marine processes are wave conditions at the cliff, sea cliff resistance to erosion, and duration of wave attack (Everts Coastal 1995).

CoSMoS Version 3.0, Phase 2 provided cliff erosion projections based on a range of SLR scenarios. Similar to the shoreline erosion modeling, the historic rates of cliff retreat were used to inform future rates of retreat, including the effects of SLR. The historic rate of cliff retreat was based off of the difference in cliff edge from the 1930s (determined by a "T-sheet") to 2010 (determined from LIDAR Survey). This method has a significant amount of uncertainty (+/- 10.8 m) because of the limited accuracy of the 1930s "T-sheets." This translates to a +/- 0.5 ft/yr (0.15 m/yr) uncertainty in the historic rates of retreat provided in Table 6-2 at locations in Dana Point. In some locations the historic rate of retreat is within the uncertainty limits of the analysis. Along Salt Creek and Dana Strand beaches, extensive development has significantly altered the bluff face to improve stability. The regional scale and scope of the CoSMoS study does not factor in the site-specific details that affect cliff retreat at a given location.

Table 6-2: Summary of CoSMoS Cliff Retreat Rates along North Dana Point

Location	Historic Cliff Retreat Rate (ft/yr)	Projected Cliff Retreat Rate with 3.3 ft of SLR (ft/yr)	CoSMoS Transect Numbers
Monarch Bay	~1	~1.6	1390-1396
Salt Creek*	~1.25	~1.9	1383-1385
Ritz Carlton	~0.2	~0.3	1378-1380
Dana Strand – North*	~0.1	~0.2	1374-1377
Dana Strand – South*	~1.3	~1.8	1368-1372
Dana Point Headland	~0.8	~1.25	1359-1364

These locations have had substantial human modification (development & grading) of the bluff face prior to 2010.

Everts Coastal (1995) studied sea cliff retreat in South Orange County in support of the CCSTWS-SD to inform a sediment budget analysis for the region. Similar to CoSMoS, Everts Coastal was limited by scale and scope and so did not attempt to quantify retreat rates at a sufficient level of detail for use in determining building setback lines or estimating time-dependent potential for damage to structures in the path of a retreating cliff. The study found rock resistance to wave-caused erosion to be the most significant control on sea cliff retreat. Headlands such as Dana Point and Monarch Point comprised of the San Onofre Breccia rock formation are highly resistant to erosion and had the lowest retreat rates, evidenced by the prominent headlands formed by each. Rocks forming the back-beach line in the bays tend to be weak and much less resistant to wave-caused scour. The Monterey formation of Dana Strand to Salt Creek has a low to moderate resistance to erosion and a higher rate of cliff retreat. The mean long-term cliff retreat rate from Dana Point to Monarch Point was estimated to be 0.2 ft/yr using a geomorphic model (Everts Coastal 1995). This average long-term rate was based on past cliff retreat to SLR ratios with an uncertainty of +/- 50%.

Young (2018) found that historic rates of cliff retreat (1930-1998) did not correlate well with recent rates of cliff retreat (1998-2010), suggesting there may be problems with using historic retreat rates to project future cliff positions. Possible reasons for the lower recent rates were anthropogenic changes, varying time periods and forcing mechanisms, the stochastic nature of cliff retreat, and variable quality data sources (Young 2018). Young also provides a clifftop hazard index that compares the rate of cliff face retreat to the rate of clifftop retreat. If cliff face retreat exceeds the clifftop retreat at a given location, the cliff becomes steeper and more unstable. This could be a useful metric for evaluating hazards facing clifftop development in Dana Point because it accounts for both marine and subaerial processes of cliff erosion.

For purposes of this vulnerability assessment, a cliff erosion hazard zone has been mapped but not the projected cliff position data for each increment of SLR provided by CoSMoS. Specific cliff retreat projections were not mapped because of the limited site-specific information applied to the model, potential problems with projecting future retreat based on historic clifftop retreat rate, the inconsistencies between previous studies, and the stochastic nature of cliff retreat. However, cliff retreat is a known hazard in Dana Point, and it is widely accepted that as sea level rises, the rate of cliff retreat will also increase. The cliff hazard zone mapped generally captures the first row of development that would be vulnerable to an increased rate of cliff erosion. If compared to the CoSMoS projections, the cliff erosion hazard zones generally capture the projected cliff retreat for a 3.3-ft (1 m) SLR scenario.

Specific policies associated with development adjacent to coastal bluffs are provided under the Public Safety, Land Use, and Conservation/Open Spaces Elements of the General Plan. The City may consider a LCPA for new and/or modified policies and development standards to address findings in this report, if they are not already adequately addressed in the City's LCP. The City will also consider adaptation strategies identified in Section 8 of this report to further advance the City's understanding of the effects of SLR and coastal erosion with advancing science and costal bluff monitoring.

7. Vulnerability Assessment

The purpose of this assessment is to identify potential significant physical impacts and their various externalities to better understand future local hazard conditions under a range of SLR scenarios. A resource's vulnerability to SLR is a product of its exposure to 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 results of the vulnerability assessment are generally organized from north to south by geographic area. Resource categories and topics common to the entire study area, such as beach access and recreation, ecological resources, social vulnerability, and environmental justice, are evaluated separately at the end of this section.

7.1 North Dana Point

Coastal resources along North Dana Point include the beaches from Monarch Bay to Dana Strand, coastal access trails and amenities, cliff-top development, and multiple stormwater outfalls, including the Salt Creek outfall. The primary hazards of concern along this reach are shoreline and cliff retreat driven by SLR as well as a reduced sediment supply. The first SLR impacts along the narrow cliff-backed beaches of North Dana Point can be characterized as coastal squeeze. Coastal squeeze can be defined as the process by which sea level-dependent physical, cultural, or biological areas are pushed landwards with SLR but are prevented from natural landward migration due to a protected or non-erodible structure such as a sea cliff or revetment. Along Salt Creek and Dana Strand beaches the dry beach and intertidal zone (and resources dependent on these areas) are at risk of permanent loss due to coastal squeeze.

The CoSMoS shoreline projections indicate the beaches from Monarch Bay to Dana Strand will experience significant beach loss under a 1.6-ft SLR scenario with almost complete beach loss with 3.3 ft of SLR. The loss of beach will have public access and recreational impacts along this stretch of coast. The revetment that lines the back-beach may also experience more severe wave attack with each additional increment of SLR. A higher SLR scenario of 6.6 ft would result in complete beach loss along Dana Strand, and the revetment protecting this development would be subject to almost constant wave action.

The Monarch Bay/Salt Creek reach typically has a wider sandy beach than Dana Strand but is subject to large seasonal fluctuations that can periodically leave portions of the beach with little or no dry sand. A 1.6-ft rise in sea level would exacerbate these seasonal fluctuations, resulting in regular loss of a sandy beach during winter months. A 3.3-ft rise in sea level would result in a higher frequency of runup, overtopping, and damage to the coastal access trail currently protected by a rubble mound revetment. Higher rates of SLR (4.9-6.6 ft) would likely require a reconfiguration of access trails and beach amenities due to the significant loss of beach and potential for storm-related wave runup and overtopping to impact facilities along the back beach.

The Monarch Bay Club, located on the back-beach area north of Salt Creek (Figure 7-1), is elevated and protected by a stepped concrete wall. Given the setback from the existing shoreline and elevated facility, the club has a low exposure to hazards under a 1.6-ft SLR scenario. Once SLR exceeds 3.3 ft, there is potential for flooding during an extreme storm event due to wave runup and overtopping of the concrete wall. Higher SLR scenarios of 4.9 and 6.6 ft would likely increase the frequency and magnitude of wave overtopping during extreme events or periods where little to no beach fronts the facility.

Figure 7-1: Aerial Image of Monarch Bay Club taken Sept. 2008
(Copyright © 2002-2015 Kenneth & Gabrielle Adelman, California Coastal Records Project)

There is a significant amount of residential clifftop development along North Dana Point, in addition to the Ritz Carlton Resort. Many of the existing residential structures are located in close proximity to the existing cliff edge. These resources could be exposed to cliff-erosion hazards that are expected to increase with each increment of SLR as the cliff-base is subject to more frequent wave attack. The cliff hazard zone mapped in Appendix A generally captures the first row of development (~20 homes) that would be vulnerable to an increased rate of cliff erosion. If compared to the CoSMoS projections, the cliff-erosion hazard zones generally capture the projected cliff retreat for a 3.3 ft (1 m) SLR scenario. However, given the limitations in trying to project future cliff-edge positions and the stochastic nature of cliff erosion (described in Section 6.4), it is difficult to estimate SLR thresholds at which cliff erosion would impact existing development, and these thresholds could vary from parcel to parcel. The subject of cliff erosion and influence of SLR along the southern California coast is a topic of active academic research. As this research advances and monitoring data is collected, the City will be able to better evaluate long-term hazards to clifftop development in North Dana Point.

Figure 7-2: Aerial Image of Blufftop Development at Northern Boundary of the City taken Sept. 2008
(Copyright © 2002-2015 Kenneth & Gabrielle Adelman, California Coastal Records Project)

7.2 Dana Point Harbor

Dana Point Harbor, built in the late 1960s and dedicated in 1971, spans 260 acres in Dana Cove and is protected by two breakwaters (east and west breakwaters). The west breakwater is approximately 5,500 linear feet (lf) and the east breakwater is 2,250 lf. The harbor is owned and managed by the County of Orange and is built partially on tidelands granted to the County by the State of California. The harbor consists of a variety of land uses including the Ocean Institute, Dana Point Pier, Baby Beach, parks and open space, a marina (made up of two basins), a boat launch ramp, dry docks and storage facilities, and commercial development (Figure 7-3). The Dana Point Harbor is currently in the planning phase of a proposed $300 million redevelopment project.

As part of California Assembly Bill 691 (AB-691), Orange County is required to perform a SLR vulnerability assessment for its granted public trust tidelands at Dana Point Harbor. This study is in process and will support the LCP amendment with a more detailed analysis of the vulnerabilities within the harbor.

Figure 7-3: Dana Point Harbor Broken into Areas by Use and Function (aerial from Google Earth)

Structures and development in Dana Point Harbor (including parking lots in the marina and wharf) sit on engineered fill at approximately 9 to 15 ft North America Vertical Datum of 1988 (NAVD88

) and stabilized by a concrete bulkhead (Figure 7-4). The harbor's main hydraulic connection to the ocean is the entrance channel in the east; however, the breakwaters were designed to be semi-permeable to allow for better water circulation within the harbor.

The harbor area is a valued resource for both the City and the region. It contains a calm water beach (Baby Beach), historic ships such as the Pilgrim and Spirit of Dana Point, art galleries, the Ocean Institute, the County-owned Dana Point Youth & Group Facility, whale watching and sports fishing hubs, commercial areas, hotels, and yacht clubs. Orange County-granted trust lands at the harbor produced $27 million in gross revenue in 2017.

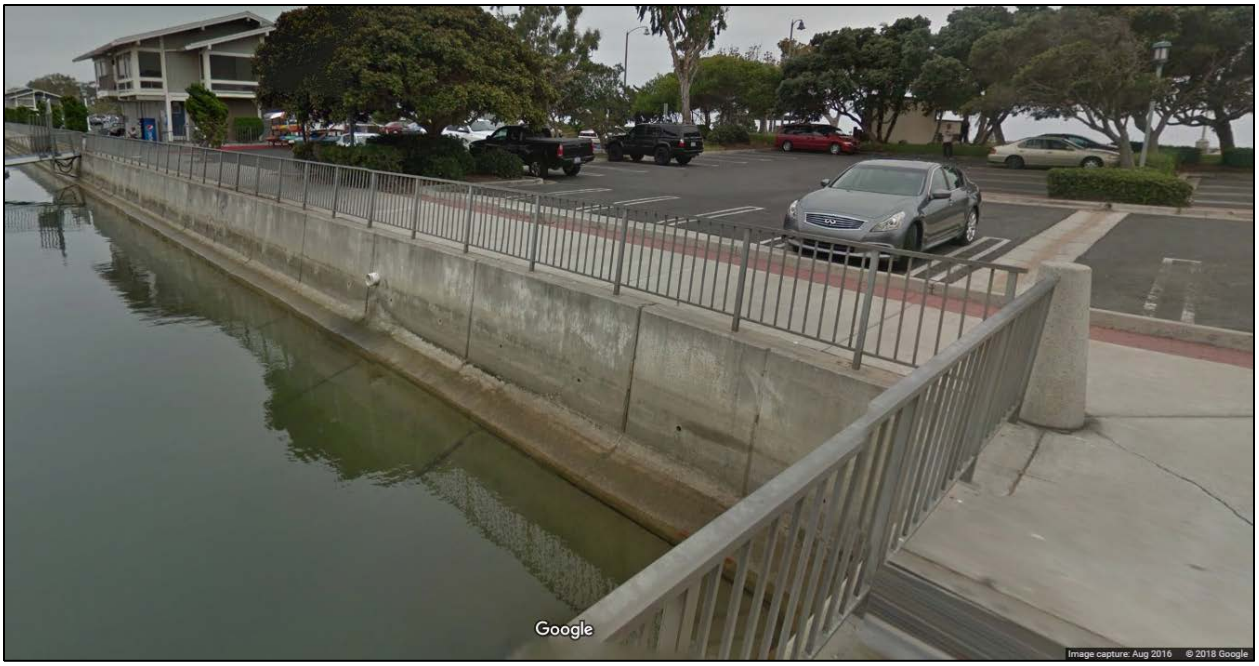


Figure 7-4: Photo of Typical Edge Condition for Dana Point Marina: Concrete Bulkhead with Rail Fencing (Google Streetview 2016)

SLR up to 1.6 ft could impact several resources within the harbor, even during non-storm conditions. Baby Beach could lose approximately 50 ft of available flat, sandy beach area during high tides, potentially impacting the recreational opportunities at this beach. The importance of sandy beaches and beach recreation will be discussed further in Section 7.8. Loss of beach width at this low wave energy site could be mitigated with additional sand placement, though this type of adaptation may extend the beach profile into the harbor.

During an extreme storm event (100-year) combined with 1.6 ft of SLR, the low-lying parking lots, walkways, and trails along the bulkhead could experience temporary flooding. CoSMoS projects water levels during this type of event could reach elevations of 10 ft NAVD88. Flooding would be shallow (<1 ft depth) and temporary, occurring during the peak of the tide cycle during the storm event. Water levels of this magnitude could also put stress on some marina infrastructure, such as the boat launch ramps, gangways, and docks.

Figure 7-5: Dana Point Harbor – Coastal Flooding with 3.3 ft of SLR

SLR of 3.3 ft appears to be a critical threshold for the harbor area in terms of exposure to flooding and inundation. Areas around the entire harbor (Figure 7-5) could be inundated regularly during high tides with 3.3 ft of SLR, including the walkways and adjacent lots of the two marina basins, the wharf and boat ramp area, and the park space adjacent to Baby Beach. Water depths would vary based on the severity of the high tides and could be inundated for minutes to hours at a time. The harbor perimeter walkways and wharf parking lots could see flooding for large time periods due to their low-lying elevations. This type of inundation can also damage utility infrastructure that supports the harbor and surrounding development. Storm drains with shallow slopes subject to tidal influence could experience biofouling, a reduction in capacity, or both.

Marina infrastructure such as docks, gangways, utilities, and piles would likely need upgrades in order to accommodate the higher water levels within the harbor. A 3.3-ft rise in sea level could also impact the wave climate within the harbor. This magnitude of SLR combined with extreme storm waves would increase the wave energy transmitted through and over the west breakwater and could result in damage to the breakwater itself. Even if the breakwater remained intact, the increased wave energy could result in damage to interior revetments, navigation challenges during storm events, and possibly damage to moored vessels and docks.

Higher SLR scenarios (4.9 to 6.6 ft) evaluated are well above this threshold and so would result in greater depth and duration of flooding throughout the developed areas of the harbor (parking lots, roads, businesses, etc.). The extent of flooding increases for each increment of SLR, covering most of the dry storage, boatyard, and launch ramp parking area. While most harbor development is exposed to flooding at the 6.6-ft SLR scenario, the flooding extents do not reach the primary access route (Dana Point Harbor

Drive). While significant adaptation efforts would be required to maintain harbor facilities and uses, there is higher adaptive capacity in the regional transportation network providing vehicular access to the harbor.

7.3 San Juan Creek & Adjacent Facilities

The beach profile response to SLR will also impact the San Juan Creek estuary during both storm and non-storm conditions. As rising seas push sand higher and landward, the water surface elevation required to breach the berm during a storm event will also increase. With higher magnitudes of SLR (3.3 ft and higher) the increased beach berm elevation and estuarine water levels could be problematic for adjacent facilities and could result in limited drainage capacity or nuisance flooding during certain conditions. During extreme storm events, higher ocean water levels may also elevate the riverine water surface profile for a certain distance upstream. The extent of this impact has not been evaluated for each SLR increment but would likely be most problematic for SLR in excess of 3.3 ft when freeboard provided by existing levees may not be sufficient for containing the facilities design flow rate.

7.3.1 JB Latham Treatment Plant, South Orange County Wastewater Authority (SOCWA)

South Orange County Wastewater Authority's (SOCWA's) primary wastewater treatment plant is located within the Dana Point Coastal Zone along San Juan Creek. The facility treats approximately 6.7 million gallons per day with a total capacity close to double that at 13 million gallons per day. The facility was built in 1964 and is close to completing enhancements. These upgrades include equipment retrofitting and structural and seismic upgrades. The facility sits at relatively lower elevations ranging from 11 ft to 16 ft NAVD88. The facility also includes several large sedimentation and treatment basins that extend to depths near 0 ft NAVD88.

While direct flooding is not projected for this area in any of the selected CoSMoS flood and SLR scenarios, it is identified as a flood-prone, low-lying area. This designation means the site is lower than the projected flood elevations and would experience flooding if hydraulically connected. The facility is currently protected from flooding by the San Juan Creek levees and high elevations of PCH seaward of the facility but is within the FEMA Preliminary 1% Probability Riverine Flood Zone (Figure 7-6). This flood zone was determined based on historical floods and did not include a detailed study of the impacts of SLR on flood profiles of San Juan Creek.

This facility is critical to SOCWA's operation and is considered a critical asset for the region. The consequences of flooding could result in degraded water quality and concerns for public health in addition to the cost of damages for SOCWA. The OPC guidance recommends use of the extreme risk aversion scenario for planning or design of critical facilities, which would have considerable public health, safety, or environmental impacts if damaged. SLR projections for extreme risk aversion applications are based on the worst case (H++) scenario in which ~5 feet of SLR occurs by 2070 and ~10 feet by 2100.

While extreme SLR and coastal hazards present a long-term concern for the facility, the more urgent risk is due to fluvial hazards (San Juan Creek). Measures to reduce the risk of flooding could include levee upgrades or site-specific resiliency improvements to prevent irreversible damage or significant downtime during and after a flood event.

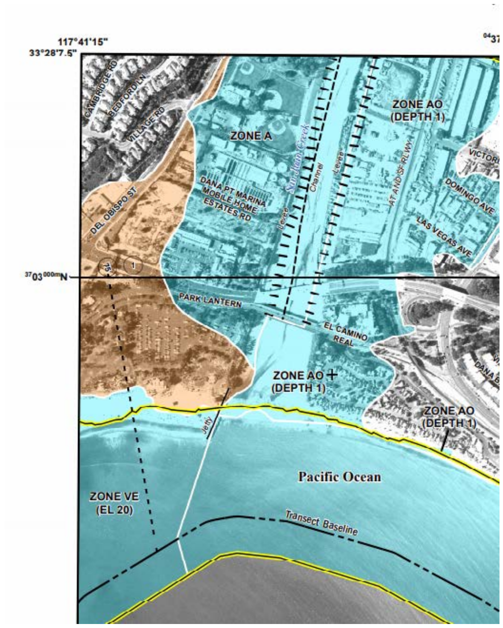


Figure 7-6 FEMA Floodplain – Lower San Juan Creek

7.4 Doheny State Beach

Doheny State Beach, first opened in 1931, was California's first state beach and is operated and maintained by California State Parks. The beach spans the San Juan Creek river mouth and includes campgrounds, day-use areas, parking, restrooms, and other park facilities. The shoreline comprises a narrow, sandy beach with cobble and a hard-bottom reef offshore of the north-day-use area (Figure 7-7). Beyond the state beach facilities, a railway, road (PCH), and buildings front coastal bluffs. A pedestrian bridge provides access over PCH and the railway near the southernmost beach restroom.

Doheny State Beach is a popular location for public beach access and recreation, particularly in the summer months, with the highest number of visitors on weekends and holidays. During these high attendance periods, all available parking spaces at Doheny State Beach are utilized. This beach is frequented by locals and visitors from surrounding southern Orange County communities. Some visitors travel from surrounding counties, and the site is a camping destination for campers statewide and beyond.

Facilities and beach amenities available at Doheny State Beach include the parking lot, restrooms, picnic areas, and campgrounds. The facilities are served by underground utilities that run under parking areas, roadways, and other rights-of-way within the park and include water, sewer, electrical, gas, and telephone. While recreational beach use and picnicking peaks in the summer, the beach and facilities attract a steady stream of visitors year-round, and the campground is almost always at full occupancy.

Figure 7-7: Doheny State Beach Site Map (M&N 2018)

Doheny State Beach experienced significant beach erosion during the 2015-2016 El Niño event, leaving the parking areas and beach restroom vulnerable to undermining and damage. In response, California State Parks placed approximately 1,072 lf of emergency rock revetment in front of parking areas and a restroom along the south day-use lot. The storm-induced erosion during the 2015-2016 El Niño event was also a result of the long-term trend of shoreline erosion south of San Juan Creek, attributed to a decreased natural supply of sediment (Section 4.1).

SLR is projected to increase the exposure of the already narrow beaches as higher water levels cause the beach profile to shift upwards and landwards. The impacts of coastal squeeze will be evident along Doheny State Beach as the park is constrained from major landward relocation by the railroad and PCH. Erosion is projected to worsen with 1.6 ft of SLR, further exposing the beach and facilities to damage from large wave events. Additionally, projections suggest that beaches could be seasonal in portions of the south day-use lot. With SLR of 3.3 ft, erosion is projected to extend into the parking lots and up to the railroad in the southern portions of the south day-use lot. These impacts shift further landward with higher SLR scenarios (4.9 and 6.6 ft) resulting in loss of the sandy beach and parking areas along the south day-use lot assuming there is no shoreline protection in place.

The non-storm shoreline projection for the 3.3 ft SLR scenario indicates significant beach loss in front of the campground, which means seasonal erosion would likely result in damage or loss of parts of the campground areas along with temporary flooding during storm events. The campground is currently protected by a sand berm, which will become difficult to maintain in its current position under this scenario. Higher SLR scenarios (4.9 and 6.6 ft) indicate the typical shoreline position would encroach into the existing campground resulting in regular flooding and erosion that would damage the first row of ocean front sites and potentially the access road as well.

The north day-use lot is better protected against both seasonal and long-term shoreline erosion because of a more sheltered wave climate and the Thor's Hammer Groin, which helps retain a wider beach upcoast of San Juan Creek. Despite these factors, SLR will also impact the recreational beach area of the north day-use area as well. According to CoSMoS projections, the dry beach area will be reduced by about 50% under a 3.3-ft SLR scenario and completely lost under a 6.6-ft SLR scenario. Flooding of the entire north day-use parking area would be expected under a 6.6-ft SLR scenario in combination with an extreme storm event. California State Parks is currently drafting potential short-term and long-term strategies to adapt to present and projected hazards.

7.5 Capistrano Beach Park

Capistrano Beach Park opened in the 1980s and is operated by Orange County Parks. The site includes a day-use parking lot, recreational facilities, and restrooms. The parking lot and restrooms are protected by a rock revetment at the northwestern portion of the site, a timber seawall in the middle portion, and emergency sandbags in the southern portion. The site includes a runoff outfall and is backed by the LOSSAN railroad.

Similar to Doheny State Beach, Capistrano Beach Park experienced significant erosion during the 2015-2016 El Niño event. The erosion-related damage was focused on the north and south ends of the park where wave action had caused scour and failure of the parking lot and sidewalks. The storm-induced erosion and deposition of sediment across the parking lots was a result of high water levels during the El Niño season but, like south Doheny Beach, can be attributed to the long-term trend of erosion due to a decreased natural supply of sediment. A sandbag revetment was constructed along the southern portion of the park to prevent further undermining of the parking lot.

On November 30, 2018, large waves and shoreline erosion resulted in failure of the timber seawall in front of the basketball court and restroom building. The seawall failure is an example of how chronic erosion not only threatens natural and recreational resources but also places additional strain on shoreline protection infrastructure. Over the past several years the timber pile seawall has been subject to more frequent and intense wave action since there is little or no beach remaining to dissipate wave energy. The wave event that resulted in seawall failure was not an extreme event. With a significant wave height in the 6-7-ft range and a 14-second wave period, the conditions were representative of a typical winter season wave event. The wave conditions occurred over a neap tide cycle where the maximum tide reached about 5 ft above MLLW. Had the waves been larger or occurred over a high tide cycle, the damage could have been much worse.

Shoreline erosion and wave uprush during the spring and summer of 2019 resulted in damage to a storm drain outfall and threatened the stormwater treatment system adjacent to the bike path. These conditions triggered an emergency repair project to place a temporary shoreline protective device in the form of geotextile sandbags along 150 lf of beach to protect stormwater infrastructure and the partially undermined bike path and pedestrian trail which is heavily used by the public. The multiple shoreline erosion emergencies in this location have triggered a coastal development permit (CDP) application that will evaluate site-specific adaptation measures to mitigate the impacts from continued shoreline erosion and wave impacts.

SLR is projected to increase the amount of erosion at the site, which has limited opportunities for landward relocation due to Beach Road, the railroad, and PCH. According to the CoSMoS shoreline projections, 1.6 ft of SLR would result in a seasonal to non-existent beach fronting the protective facilities along the beach park. This could greatly increase the exposure of the parking lot and facilities to direct wave action, causing more frequent flooding and damage to park facilities and the need for increased maintenance. Narrow beach widths could likewise reduce the use of the beach to limited portions of the year and decrease the amount of towel space. Projections for 3.3 ft of SLR indicate a permanent loss of dry sandy beach along the park. Under this scenario the existing shoreline protection structures would be subject to regular wave action and more frequent overtopping and flooding of park facilities. Higher SLR scenarios (4.9 and 6.6 ft) predict the typical shoreline position to be significantly landward of existing park amenities. Orange County Parks is working on a plan to adapt the facility to both present and long-term hazards.

7.6 Capistrano Beach Development

Capistrano Beach (also known as Capo Beach) makes up the southern portion of Dana Point and includes the Capistrano Bay Community Services District, a thin stretch of beachfront development along Beach Road. The Capistrano Bay Community Services District includes four historic properties and has a variety of development types with varying dates of completion. The area includes single-story development on concrete pads as well as more recent multistory development on piles. Beach Road varies from approximately 12 ft NAVD88 in the southern edge to approximately 20 ft NAVD88 in the north.

Due to the narrowness of the beach in front of the development, the homes are exposed to large wave events. Many of the homes have installed protective structures. These structures vary from parcel to parcel and include rock revetments, wooden seawalls, loose rock, sandbags, or a combination of these and other materials.

SLR poses threats to the Capistrano Bay Community Services District in two major ways. The first is through changes to the shoreline. SLR is projected to exacerbate erosion and push the beach profile higher and further inland. This process could leave the already narrow beach vulnerable to more frequent erosion episodes that threaten development. Beaches also provide a buffer to dissipate energy from damaging waves. Narrower beaches will reduce this natural buffer and increase the exposure of homes to large wave events. The second way SLR increases the exposure of these homes to coastal hazards is by increasing the potential for flood damage due to wave runup and overtopping. Higher water levels combined with a narrower beach will result in higher wave runup and overtopping that increases the potential for coastal flooding of these properties.

In order to assess the vulnerability of the beachfront development, a simple parcel analysis was conducted using CoSMoS-COAST's projected shoreline and associated potential erosion for each increment of SLR used for this study. Parcel data was collected from the Orange County Landbase Database in October 2017 and clipped to the "non-erodible shoreline" identified by CoSMoS. The clipped parcels represent the developed portion of each parcel. The exposure of each clipped parcel was then assessed based on its relative position to projected shoreline and potential erosion zones. If a portion of a clipped parcel was within or seaward of the projected shoreline uncertainty, it was identified as exposed to daily wave action. If a clipped parcel was within or seaward of the potential erosion zone, it was identified as exposed to seasonal storm impacts. And lastly, if a clipped parcel was landward of the potential erosion zone, it was identified as exposed to extreme events. It should be noted these exposures are cumulative (i.e., a parcel identified as exposed to daily wave action is also exposed to extreme events). The different exposure levels are graphically illustrated in Figure 7-8.

The results of this analysis are mapped in Figure 7-9 for each SLR scenario. From this simplistic analysis, the northern and southern edges of the Capistrano Bay Community Services District appear to be the most exposed to shoreline hazards, though all the parcels are exposed to either seasonal impacts or daily wave action with +3.3 ft of SLR. The southern portion of the Capistrano Bay Community Services District could be considered more vulnerable to these hazards due to its already narrower beach and lower elevations than development in the northern area. CoSMoS 100-year flood projections show the southern edge of Beach Road flooded with +1.6 ft SLR.

The type of exposure and number of parcels affected are quantified in Figure 7-10 for each SLR scenario. Based on the preliminary Flood Insurance Rate Map (FIRM) panels released by FEMA, all 201 parcels along the Capistrano Bay Community Services District will be exposed to flooding from an extreme coastal event at the current sea level. This exposure is expected to increase in frequency based on the shoreline erosion projections from CoSMoS. With a 1.6-ft rise in sea level, over half of the parcels could be subject to seasonal erosion impacts, which could be problematic for structures on shallow foundations without shoreline protection. Some of the newer structures, supported by pile foundations, would be less sensitive to seasonal erosion. A 3.3-ft rise in sea level represents a significant threshold at which the everyday shoreline is at or landward of the existing development at 135 parcels indicating that 1) there is little or no dry beach remaining in front of these parcels and 2) the existing structures would be subject to regular and more intense wave action given the higher water levels of this scenario. Shoreline projections for higher SLR scenarios (4.9 and 6.6 ft) indicate the daily shoreline position would be landward of existing development along all of the Capistrano Bay Community Services District assuming no shoreline protections or beach nourishment programs are in place.

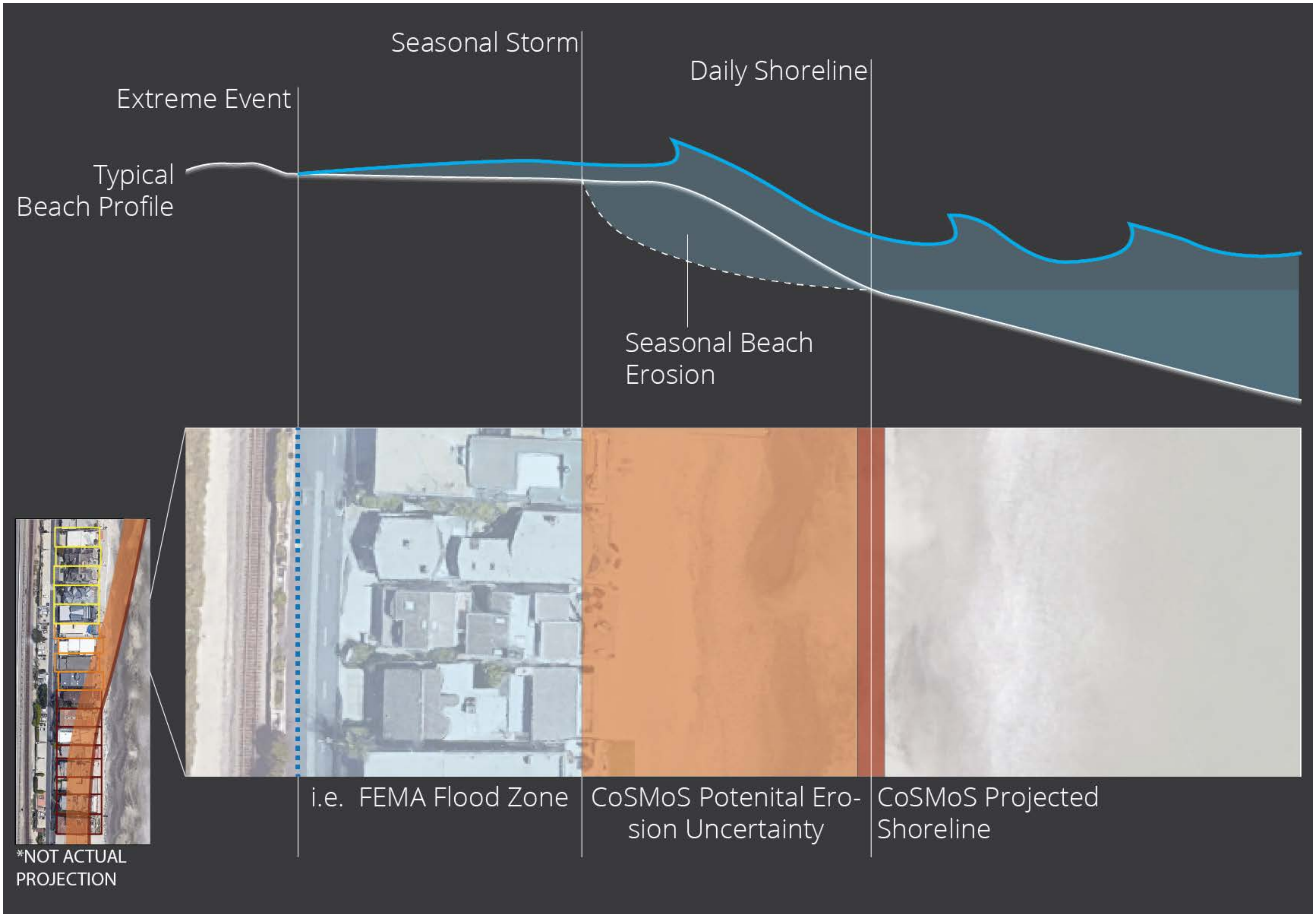


Figure 7-8: Exposure Levels for Capistrano Beach Development

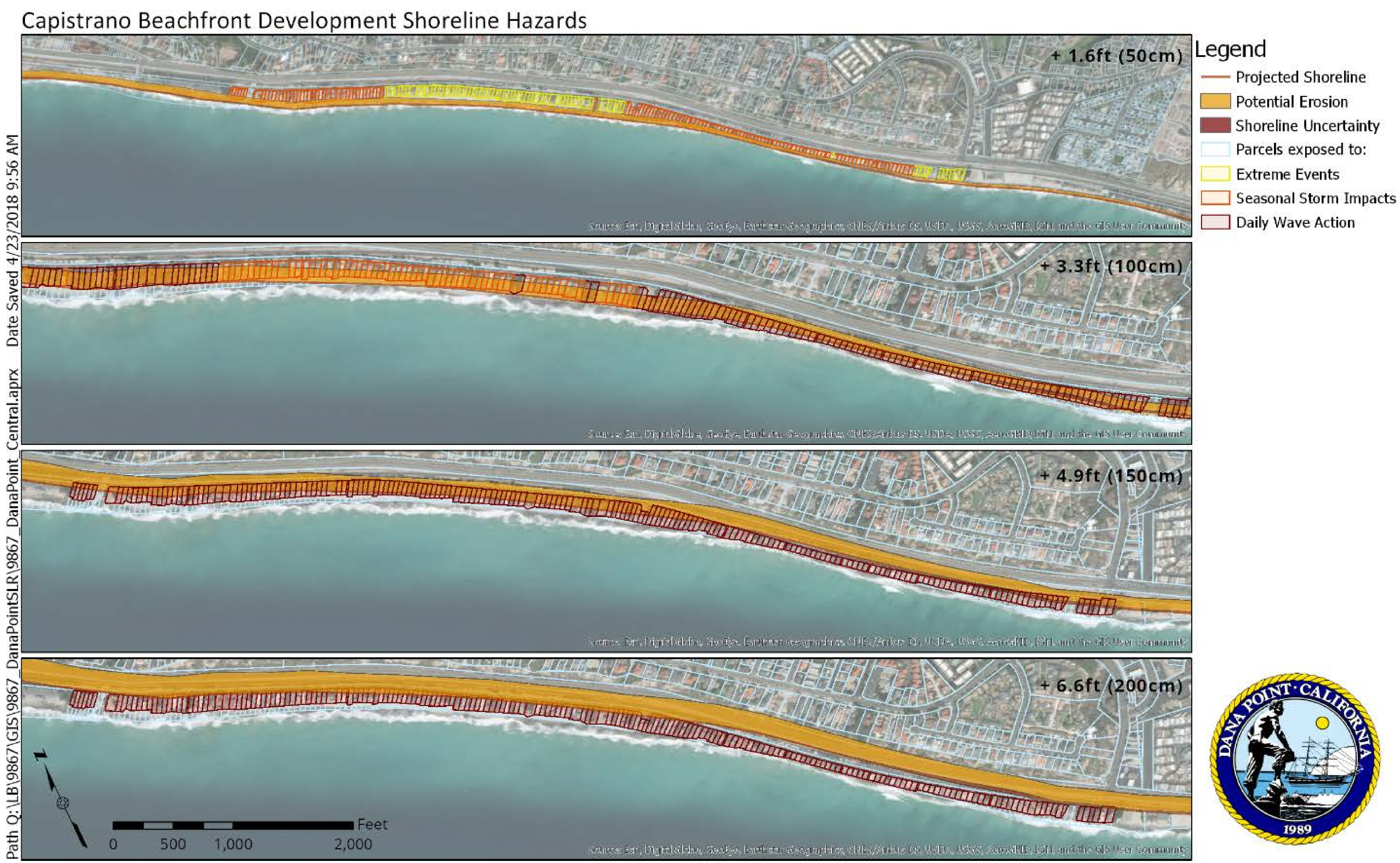


Figure 7-9: Mapped Shoreline Erosion Hazards along Capistrano Beach Development

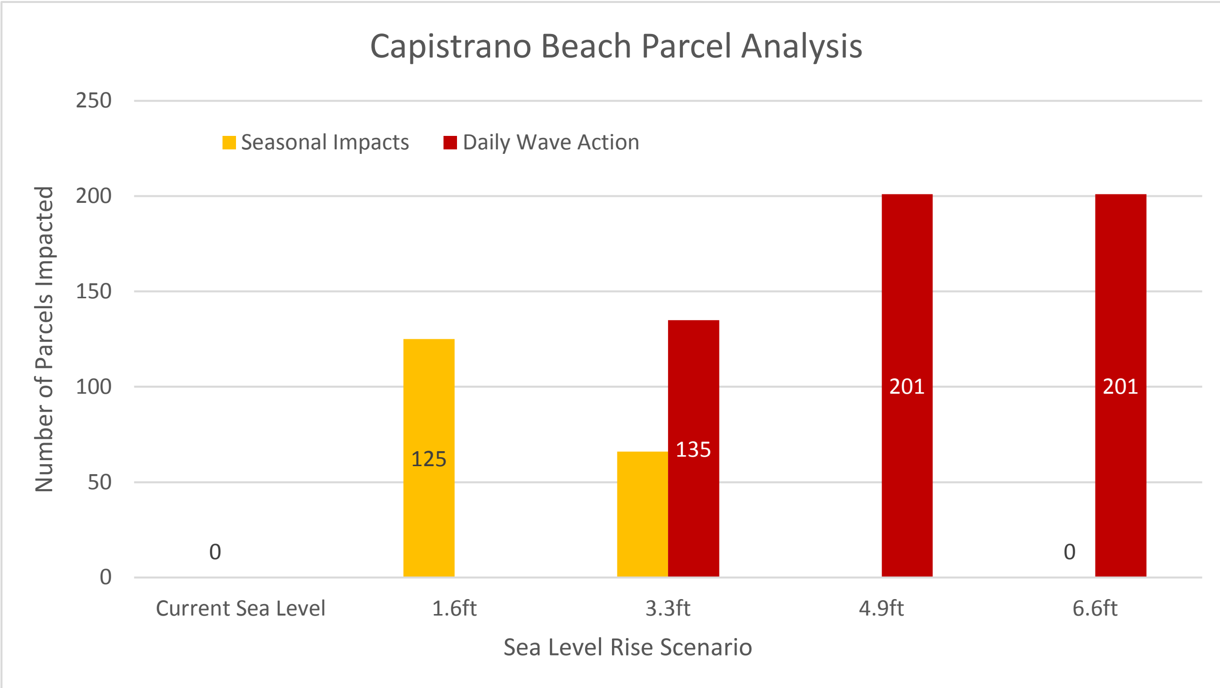


Figure 7-10: Parcels Exposed to Shoreline Erosion Hazards

There are several limitations associated with using CoSMoS shoreline projections for this analysis. CoSMoS's analysis uses a 2010 initial shoreline that does not account for recent erosion occurring during the 2015-2016 El Niño season. This could mean that the shoreline could retreat sooner than projected by CoSMoS depending upon other littoral processes that drive shoreline change such as sediment supply, wave climate, and El Niño events. Additionally, these projections do not account for future beach nourishment or other adaptation efforts that may increase beach widths. With consideration for these limitations, shoreline change is eventually inevitable for this area, and adaptation efforts for beachfront development should address increased erosive pressure and higher exposure to wave attack.

Another limitation of the CoSMoS results is the method applied for mapping flood hazards due to wave runup and overtopping. Flooding was allowed to occur beyond the line of development, but results only show relatively minor flooding, even for the higher SLR scenarios combined with an extreme coastal storm. For example, South Doheny State Beach and Capistrano Beach Park experienced significant flooding in 2015 from a relatively minor wave event that coincided with a high water level. However, the CoSMoS results show these locations do not experience flooding under a 100-year event combined with 5 ft of SLR. It is not clear what assumptions were made for the type and height of coastal structure used to Hold-the-Line, or the potential for scour in front of such a structure. In our opinion, the assumptions made in the CoSMoS model to determine wave runup, overtopping, and flooding along the existing development line lead to an under-estimate of the coastal flooding potential for each SLR scenario.

7.7 Poche Beach

Poche Beach is a relatively narrow beach at the southern boundary of Dana Point. The beach is maintained by Orange County Public Works to manage water levels in the Prima Deshecha Canada (M01) Flood

Control Channel outfall. The large culvert drains a 4,450 acre watershed in San Clemente, Dana Point, and San Juan Capistrano. The only point of access to Poche Beach is a recently renovated pedestrian underpass that runs alongside the open drainage culvert under the railroad (Figure 7-11). Ocean waves build up a sand and cobble beach berm that elevates ponded water levels in the Prima Deshecha Channel, which can flood the pedestrian underpass and limit access to Poche Beach.

In 2010, Orange County completed a $3 million runoff-treatment facility to improve historically poor water quality conditions at the beach. This facility is between the highway and the railroad just north of the channel. In 2012, Orange County acquired state and federal approval to breach the pond when water levels flood the pedestrian underpass and pipe clean water from the treatment facility to the surf zone, bypassing the scour pond where a study suggested it was becoming re-polluted.

SLR poses several issues for Poche Beach. Rising water levels will cause the beach to migrate landwards and upwards, increasing the ponded water levels in the channel, causing more frequent flooding of the pedestrian access underpass. With 1.6 to 3.3 ft of SLR, the existing pedestrian access could be permanently inundated to the point where it's no longer a viable access path to the beach. Additionally, increased buildup of sand landward could create flood control capacity issues for the drainage channel, potentially requiring increased maintenance and upgrades. Flood control capacity challenges would only increase for higher SLR scenarios (4.9 and 6.6 ft) possibly requiring modifications to railroad and PCH infrastructure. Presumably a new pedestrian access path would have to be created since the existing path does not have capacity to handle this amount of SLR.

Figure 7-11: Poche Beach Access - Pedestrian underpass alongside Prima Deshecha Channel (Google Street View)

7.8 Beach Access and Recreation

Dana Point's beaches are well-known, well-visited, and integral to both local and regional identity. Dana Point's beaches provide protection to coastal structures from waves and areas for recreation, in addition to habitat integral to regional ecosystems. A simple Bruun rule calculation for a typical beach profile illustrates that with 1.6 ft of SLR, Dana Point beaches could lose approximately 50 ft in beach width. With 3.3 ft of SLR, beaches could recede more than 100 ft from present conditions. This simple calculation does not account for long-term or acute erosion patterns but rather describes how a typical beach profile responds to SLR.

As part of the Orange County Coastal Regional Sediment Management Plan (OCCRSMP) published in 2013, an economic analysis of the county's beaches was conducted by Dr. Phil King. The five beaches identified by the study in Dana Point had an annual attendance of approximately 7.7 million, contributed in total approximately $222 million in annual spending, and generated $12.7 million in city, county, and state taxes (Everest 2013). These figures are summarized in Table 7-1 and illustrate the scale of value that these beaches have for the city and the region. Long-term erosion and storm related damages due to SLR can decrease the recreation, habitat, and spending value of these beaches (King et al. 2011). Because many of the beaches in Dana Point are already very narrow, a 50 to 100 ft loss of beach width would have a significant impact on the recreational opportunities available and the economic benefits these opportunities create. Shoreline projections for higher SLR scenarios (4.9 and 6.6 ft) indicate almost complete beach loss at locations listed below which would translate to significant economic loss for the region.

Table 7-1: Economic and Tax Impacts of Dana Point Beaches (OCCRSMP 2013) - Amounts in 2010 $USD

Beach	Annual Attendance	Total Annual Spending	Total City Taxes	County Tax	State Tax
Monarch Beach	220,000	$6,143,567	$54,987	$31,798	$264,982
Salt Creek Beach	3,967,715	$118,511,291	$1,345,161	$605,074	$5,042,284
Dana Point – Baby Beach	1,214,374	$34,223,823	$327,808	$176,799	$1,473,325
Doheny State Beach	1,827,231	$47,044,457	$296,803	$247,786	$2,064,883
Capistrano County Beach	516,788	$15,805,704	$116,844	$80,325	$669,376

Surfing has been a staple recreation activity for the City since the 1930s. The city's most popular breaks are at Doheny State Beach with other popular breaks at Salt Creek Beach. The quality of breaks at both Salt Creek and Doheny Beach can be attributed to shallow nearshore reefs and cobble fields. It is difficult to assess the specifics of how SLR could impact surf at the various breaks, but a few general conclusions can be drawn based on the understanding of littoral processes. A landward and upward shift of the beach profile in combination with higher water levels will alter the surf conditions at most beach breaks. Additionally, long-term beach erosion, if met by armoring such as revetments or sea walls, can affect access and cause undesirable wave reflection that could impact surf breaks. Cobble reef breaks like Doheny Beach and the Point at Salt Creek would likely experience waves focusing on different areas of the cobble reefs (likely closer to shore) with the outer reef becoming more sensitive to the tide. Future adaptation strategies should consider these potential impacts to preserve these popular and economically valuable assets.

City, County, and State revenues have the potential to be impacted from SLR that could result in narrowed beaches (owned by OC Parks and State) and increased coastal erosion. It is difficult to calculate the exact financial impact associated with SLR as the beaches are one of many factors that draw visitors to Dana Point and contribute to the revenue generated. Other elements that make Dana Point enticing to residents and tourists that are not impacted by SLR but do add to the City's attraction include: the proximity to the ocean, weather, coastal views, and many others factors that would have little to no impact from SLR. The Economic Development Department of the City provided the data below from 2018 that includes specific revenues generated:

- Annual City visitors: Approximately 3 Million Visitors including to the State Beach with approximately $330 spent per visitor
- Transient occupancy tax (TOT) revenue: Approximately $12 Million annually
- Property taxes: Approximately $8 Million annually
- Property values: Mean property value $810,000
- Sales tax revenue: Approximately $5.6 Million annually
- General revenue generated by tourism: Approximately $34.2 Million in state and local tax

7.9 Ecological Resources

Ecological resources within the Dana Point coastal zone include Dana Point Headland Conservation Area, Dana Point SMCA, as as well sandy beach habitat and nearshore marine habitat. According to the California Natural Diversity Database (CNDDB), several federal and state listed species can be found in Dana Point's Coastal Zone. These species are listed in the table below.

Table 7-2: Federal and State-listed Species found in Dana Point (CNDDB 2018)

Common Name	Federal Status	State Status	CA DF&W Status
American Peregrine Falcon	Delisted	Delisted	Fully Protected
California Brown Pelican	Delisted	Delisted	Fully Protected
Light-Footed Ridgway's Rail	Endangered	Endangered	Fully Protected
Southwestern Willow Flycatcher	Endangered	Endangered	-
Least Bell's Vireo	Endangered	Endangered	-
Tidewater Goby	Endangered	None	Species of Special Concern
Steelhead Trout	Endangered	None	-
Quino Checkerspot Butterfly	Endangered	None	-
Pacific Pocket Mouse	Endangered	None	Species of Special Concern
California Red-Legged Frog	Threatened	None	Species of Special Concern
Western Snowy Plover	Threatened	None	Species of Special Concern
Coastal California Gnatcatcher	Threatened	None	Species of Special Concern
Willow Flycatcher	None	Endangered	-
Little Willow Flycatcher	None	Endangered	-

7.9.1 Dana Point Headland Conservation Area

The Headland Conservation Area spans four conservation parks: Harbor Point Conservation Park, Dana Point Preserve, Hilltop Conservation Park, and South Strands Conservation Park. The Dana Point Headlands Conservation Area contains over 150 species of plants and animals that are native to coastal Southern California. Several rare and indigenous plant communities are found on the site, including southern coastal bluff scrub, native grasslands, maritime succulent scrub, mixed chaparral, and coastal sage scrub. The unique setting and mix of habitats on the Headlands also provide a home for rare and threatened plants and animals. The Headlands are home to the federally listed Pacific Pocket Mouse and Coastal California Gnatcatcher (Danapoint.org 2018).

A public trail system, approximately 3 miles in length, links all the conservation parks and public open space areas of the Headlands. The system includes pedestrian trails, coastal and beach access, scenic overlooks, and the Nature Interpretive Center (Danapoint.org 2018).

7.9.2 Dana Point State Marine Conservation Area

The Dana Point SMCA maintains legacy protection of intertidal invertebrate species such as kellet whelks, top shells, limpets, sea cucumbers, and abalone while allowing lobster, urchin, and finfish. The SMCA spans from Aliso Point to the bend in the southern Dana Point Harbor breakwater. This SMCA protects both subtidal and intertidal habitat, including the Dana Point tidepools and hard-bottom reefs at Dana Strand Beach and Salt Creek Beach.

Figure 7-12: Rocky Intertidal Habitat at Salt Creek beach (City of Dana Point)

Because nearshore habitat is dependent on tide levels, rises in sea level will mean some species will need to migrate further up in elevation to maintain the appropriate exposure to the tides. The rocky shelfs and reefs are relatively fixed in elevation and backed by cliffs or development. This limits the potential for new intertidal habitat and causes coastal squeeze where intertidal habitat bands are squeezed smaller by SLR. Larger amounts of SLR have a greater probability of resulting in a net loss of intertidal habitat due to the existing elevation profiles at Dana Point and Dana Strand Beach. A loss of this critical habitat could have negative impacts to regional ecosystems and fisheries.

7.9.3 Sandy Beach Habitat

Sandy Beach habitat includes sandy beaches and their adjacent surf zones. Sandy beach ecosystems are strongly linked with nearshore ecosystems and can directly impact the conditions that support different types of species. Sandy beach habitat can be used for feeding and nesting by multiple species, some of which are considered critical resources by the State of California.

The California grunion (Leuresthes tenuis) is a member of the New World silversides family, Atheriniopsidae, along with jacksmelt and topsmelt. Their usual range extends from Point Conception, California, to Point Abreojos, Baja California (CA Department of Fish & Wildlife 2018). They inhabit the nearshore waters from the surf to a depth of 60 ft. Tagging studies indicate that they do not migrate. Grunion leave the water at night to spawn on beaches during the spring and summer months. Loss of beach width due to SLR and long-term erosion will directly impact the available habitat of the California grunion.

Many bird species, such as the California Least Tern and Western Snowy Plover, also use sandy beach habitat to nest and feed. The Western Snowy Plover is a federally listed species and is sensitive to loss of suitable nesting and feeding habitat. The loss of beach width due to SLR will decrease the potential for suitable habitat for this listed species.

7.9.4 Nearshore and Estuarine Marine Habitat

Nearshore marine habitat consists of low to moderate relief reefs (1 to 4 ft) with patches of sand. This habitat includes seagrasses and marine algae, including surfgrass, brown algae, and red algae.

San Juan Creek is a low relief creek with generally low flows of freshwater with potentially large intermittent seasonal flows. The creek has historically been temporarily blocked by buildups of sand berms at the mouth of the creek, causing lagoons that can last anywhere from days or years (Figure 7-13). Federally listed species such as the Tidewater Goby, Steelhead Trout, and California Red-Legged Frog have been found in the creek and can be affected by the formation or breaking of these lagoons.

SLR will impact the tidal influence on the creek, potentially affecting daily changes in water quality. The salinity profile of the creek will likely increase upstream as the low-relief creek becomes more tidally influenced. The migration of the beach profile upwards and landwards could also impact the frequency at which the berms buildup and transform the creek into a lagoon.

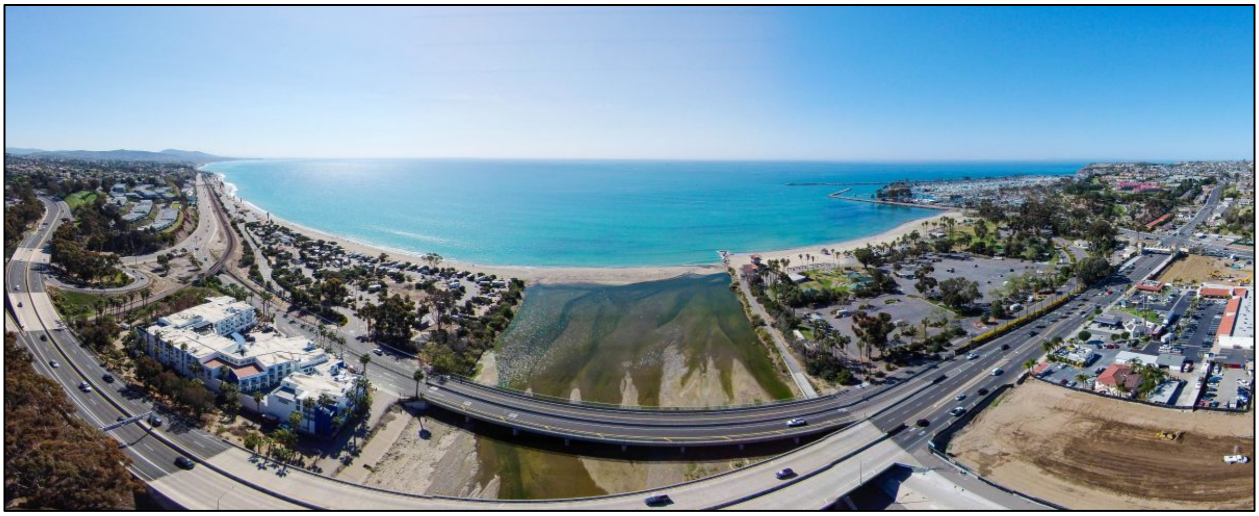


Figure 7-13: San Juan Creek River Outlet looking towards Pacific Ocean (Project Clean Water)

7.10 Social Vulnerability

Social vulnerability is a broad term referring to how the impacts of physical hazards such as flooding can be amplified by social characteristics. These characteristics can include income, poverty, education, females as head of household, race, linguistic isolation, age, housing type and age, and physical and mental illnesses and disabilities. These characteristics are associated with higher sensitivity and/or lower adaptive capacity to flooding and sea level rise, and thus, can be used to inform adaptation planning (USC Sea Grant 2013).

7.10.1 Vulnerable Populations

SLR related hazards can have disproportionate effects on vulnerable populations. Some factors used to characterize vulnerable populations include age, disability, family status, homelessness, and linguistic isolation as well as populations who are institutionalized or burdened by poverty (Cutter et al. 2003). For example, a linguistically isolated population could be disproportionally impacted if the notice to evacuate to safe areas outside a coastal hazard zone could not be communicated. Other vulnerable populations could have more difficulty adapting to evolving hazards or recovering from a damaging storm event.

These factors are used to determine a Social Vulnerability Index (SVI) and are mapped in Figure 7-14 for the City of Dana Point. A brief analysis of the SVI for census tracts within Dana Point suggests that the higher SVI scores in the region could be driven by higher populations living in mobile homes and assisted living facilities within the census tract along the northside of San Juan Creek that spans both Dana Point and San Juan Capistrano. This census tract also includes the Dana Point Community Center and Del Obispo Community Park, which includes the Dana Point Senior Center. Strategies that increase the effectiveness of alerts and consider barriers to mobility such as developing community preparedness programs are examples of ways to help reduce the vulnerability of these populations.

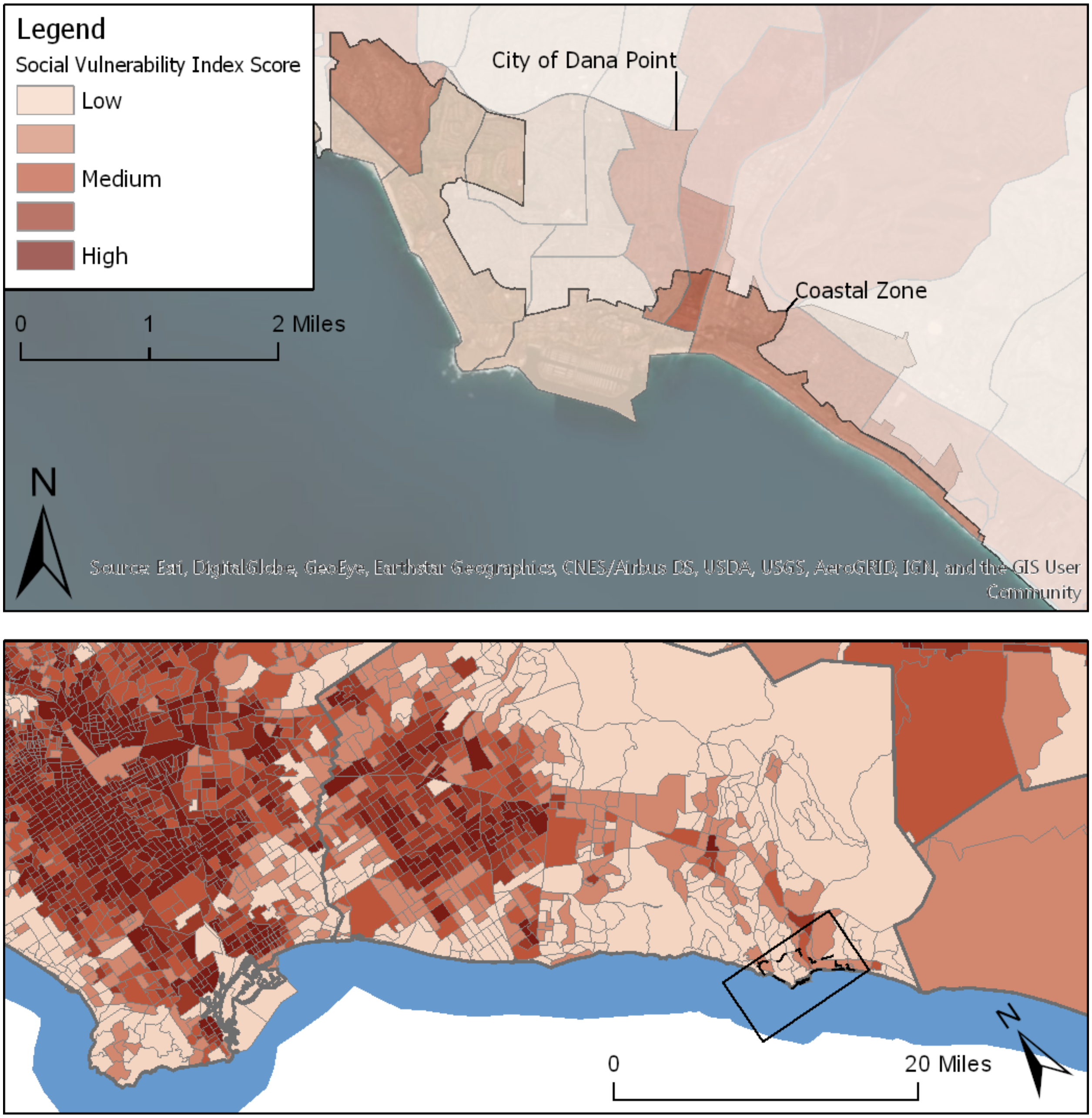


Figure 7-14: Social Vulnerability Index Mapped for Study Area and Region
(SVI data from Center for Disease Control)

7.11 Environmental Justice

With the passage of California Assembly Bill 2616, environmental justice was recognized as a component of consideration when issuing coastal development permits. Environmental justice refers to the equitable distribution of environmental benefits throughout the state and is described in the bill as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Burke 2016).

Environmental justice, as applied to SLR, can guide decisions with tradeoffs that affect coastal access and recreation, economic opportunity, or unequal exposure to environmental hazards.

Resources, like beaches, will be among the first impacted by SLR. A retreating shoreline will gradually reduce the opportunity for low-cost recreational opportunities available at beaches throughout Dana Point. In many cases, the retreating shoreline will eventually reach public or private development, resulting in difficult trade-offs to consider when evaluating adaptation strategies. For example, is it worth protecting the parking lots and campgrounds with revetments if there is no sandy beach remaining? Is it justified to “hold-the-line” in order to protect homes at the cost of beach access? These are a few examples of the environmental justice issues that arise when considering adaptation strategies to mitigate SLR impacts.

8. Adaptation Measures

The following strategies represent potential SLR adaptation measures to reduce impacts identified in the SLR Vulnerability Assessment. The list of adaptation measures builds on work done by other municipalities that are updating their LCPs and references applicable strategies listed in the CCC SLR guidance document. Listed strategies and descriptions are not intended to be exhaustive or fully developed, but instead used to identify general adaptation strategies and priorities for further analysis. Please refer to the most recent LUP for specific policy language associated with each strategy. The areas in Dana Point where strategies would be relevant are denoted as follows:

A – All areas, N – North Dana Point, H – Dana Point Harbor, S – South Beaches

8.1 Understanding Sea Level Rise Hazards

Knowledge of the timing, magnitude, and location of future SLR hazards is critical to SLR planning efforts. Adaptation measures within this section focus on ways to best obtain, utilize, and disseminate current and future SLR information to inform decision-making in coastal areas.

Adaptation Measure	Description	Area
Use of best-available science	Identification and use of best-available sea-level and coastal hazard science is required for site-specific vulnerability assessments, coastal development permit applications, and preparation of technical reports.	A
Identified planning horizons	Development or redevelopment requires the use of appropriate planning horizons and incorporation of SLR-related risks and uncertainties associated with such planning horizons.	A
Sea-level rise hazard maps	Published maps that identify areas exposed to hazards under different SLR scenarios and designate areas that require further monitoring or analysis. The maps would be used in combination with other adaptation measures including site specific geological studies, siting to avoid hazards/shoreline armoring, coastal bluff development setbacks, and real estate disclosures to provide additional analysis and disclosure of potential hazards for properties.	A

Adaptation Measure	Description	Area
Real estate disclosure of hazards	Real estate transactions involving new development or substantial redevelopment in identified hazard areas must include a coastal hazards disclosure that fully informs both parties of projected risks over the anticipated lifetime of the property.	A
Assumption of risk, waiver of liability and indemnity	Within identified areas subject to current or future hazards, including those related to SLR, owners of newly developed or redeveloped property are required to formally assume the risks associated with the property.	A
Community outreach	Outreach efforts designed to inform community residents and stakeholders, including disadvantaged communities and vulnerable populations, of potential future coastal hazards and solicit input during the decision-making process on proposed adaptation strategies and development standards.	A
Hazard monitoring	Ongoing hazard monitoring efforts conducted in select areas to better understand potential SLR impacts and inform future planning and mitigation decisions. Refer to Section 8.5.2 for more information on a proposed bluff monitoring program.	A

8.2 Managing Development in Hazard Areas

Siting and construction standards in new coastal development or redevelopment projects represent key opportunities to reduce SLR hazard impacts to new and existing development. Adaptation measures within this section focus on encouraging responsible development to reduce exposure to coastal hazards over the duration of development.

Adaptation Measure	Description	Area
Siting to avoid hazards	New development must be sited in a way that avoids coastal hazards, protects coastal resources, and minimizes risk to life and property to the maximum extent possible for the anticipated life of the development, accounting for future hazards due to SLR.	A

Adaptation Measure	Description	Area
Siting to avoid additional shoreline armoring	New development must be sited in a manner that does not require construction of new shoreline protective devices that substantially alter natural landforms to provide geologic stability.	A
Bluff development setbacks	New development along bluff tops must meet a required setback from the bluff top inland of which stability can be reasonably assured for the duration of development without need for shoreline protective devices.	N
Redevelopment thresholds	Redevelopment within hazard areas will become subject to the standards of new development if a structure is altered in a manner that equals or exceeds 50% of the value of the structure before the start of construction or results in the demolition of 50% of the structure.	A
Legal nonconforming structures	Improvements to existing legally non-conforming structures in hazard areas must not increase the hazardous condition of the structure by developing seaward or extending the anticipated duration of development in a non-conforming location.	A

8.3 Coastal Hazard Reduction

Enhancements and additions to existing coastal hazard reduction measures are often necessary to account for potential increases in hazard levels due to SLR. Adaptation measures within this section focus on direct protection from current and future SLR hazards through both structural and nature-based means.

Adaptation Measure	Description	Area
Living shorelines through habitat restoration	Habitat at risk from future SLR will be restored to allow for upward migration, enhancing protection provided to landward resources. Refer to Sections 8.5.1 and 0 for more discussion of these strategies.	N

Adaptation Measure	Description	Area
Infrastructure upgrades	Flood risks within high-hazard areas will be addressed through a combination of elevation, relocation, redesign, and retrofitting as necessary to preserve recreational and commercial use. Refer to Section 8.5.4 for a discussion of infrastructure upgrades to improve resilience in Dana Point Harbor.	H
Repair and maintenance of existing shoreline armoring	Legally permitted shoreline protective devices may be repaired and maintained provided that such activities do not enlarge or extend armoring past the extent necessary to protect associated structures from identified coastal hazards, demonstrated through an engineering or geological study.	A
Evaluation of existing shoreline armoring	Applications for new development or redevelopment protected by existing shoreline-protective devices shall be required to evaluate the necessity of such shoreline armoring, including whether the existing device can be removed or modified to better protect coastal resources.	A
Shoreline armoring	Shoreline armoring may be used to protect existing structures or resources under circumstances authorized by Section 30235 of the Coastal Act, provided adverse impacts are minimized per Section 30253.	A
Design for flood hazards	New development in flood hazard areas must be designed in a way that minimizes flood risk over the anticipated life of the development.	A

8.4 Community-Scale Hazard Mitigation

Coastal processes that affect SLR hazards often extend beyond the parcel scale. Participating in regional hazard mitigation planning can substantially increase the efficiency and cost-effectiveness of SLR resilience measures. Adaptation measures within this section focus on potential regionally coordinated programs that could benefit coastal resources in Dana Point and beyond.

Adaptation Measure	Description	Area
Beach nourishment	Participate in development and implementation of a coordinated beach nourishment program throughout the region to offset coastal squeeze of sandy beach habitat and maintain sufficient beach width and elevation necessary for recreational use. Refer to Section 8.5.5 for more discussion on a regional beach nourishment program.	A
Sediment management	Participate in development and implementation of a coordinated sediment management program for the San Juan Creek watershed in conjunction with beach nourishment efforts to restore or enhance historical sources of sand in the watershed and provide additional sediment to the Oceanside Littoral Cell.	S
Mitigation financing	Explore a variety of mitigation funding mechanisms such as Geologic Hazard Abatement Districts, County Service Areas, and Federal and State grant programs to fund capital and maintenance costs associated with future mitigation projects.	A

8.5 Adaptation Measure Evaluation

8.5.1 North Dana Point - Rocky Intertidal Habitat Restoration

Goal

Maintain and enhance areas of rocky intertidal habitat along the bluff toe that are threatened by habitat loss due to SLR and coastal squeeze. Provide multiple ecological benefits of intertidal areas while reducing wave energy and erosion at the bluff toe.

Concept

Conduct restoration of rocky intertidal habitat at risk from future SLR through placement of native rock or bio-activated material in targeted areas to enhance the erosion protection provided by such habitat to surrounding bluffs. Such a measure would be conceptually similar to oyster reef living shorelines implemented in calm wave environments, though an application along North Dana Point would have to account for a more energetic wave environment.

Overview

Rocky intertidal habitats are found throughout California, including the bluff backed areas of North Dana Point (Figure 8-1). These transition zones provide important habitat areas for a diverse array of marine invertebrates and plant life. An essential element of what maintains the high levels of biodiversity found in rocky intertidal areas is the dynamic environment provided by tidal cycles, wave action, and sediment movement. SLR has the potential to disrupt this ecological balance, reducing benefits to surrounding ecosystems and diminishing shoreline protection functions. A living shoreline approach that incorporates rocky intertidal habitat restoration could be employed to offset these adverse impacts within North Dana Point.

Figure 8-1: Rocky Intertidal Habitat in Southern California

Living shorelines refer to shoreline stabilization techniques that primarily consist of native material, combining vegetation or other living elements along with a structural element to provide stability. The use of native vegetation allows living shorelines to reduce coastal erosion while also providing critical habitat values. Working within existing ecosystems also reduces maintenance needs by employing structures that are compatible with natural coastal processes. A typical living shoreline concept applied in a sheltered coastal environment is illustrated in Figure 8-2.

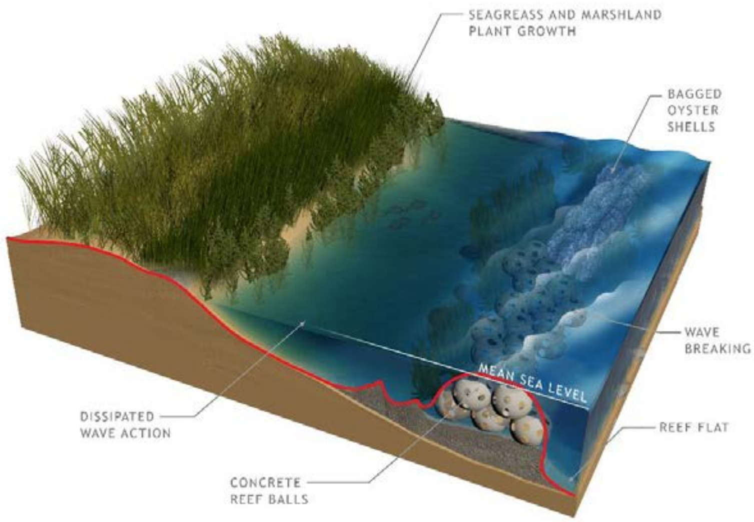


Figure 8-2: Typical living shoreline concept applied in a calm wave environment

Living shorelines have been employed in a number of forms including coastal mangroves, salt marshes, oyster reefs, reef balls, dunes, and seagrass or kelp beds, but limited examples exist that aim to replicate or enhance rocky intertidal habitat. Most living shoreline projects have been implemented along sheltered coastlines as opposed to the open coast of North Dana Point, which is subject to more dynamic water levels, wave energy, and sediment transport. The San Francisco Bay Living Shorelines Project, a pilot study of the effects of eelgrass and oyster reef restoration in the San Rafael region, found evidence of wave attenuation within restored habitats, though there is uncertainty whether these findings would hold under a more extreme wave environment.

A living shoreline project based on stable rocky intertidal habitat within North Dana Point, potentially in combination with restored or enhanced reef structures, would represent a novel approach to living shorelines that, while currently lacking established standards and guidelines, could prove to be an important element of long-term climate resilience. While standards and guidelines are currently limited for such an approach, recent studies have shown that biological communities associated with riprap along Southern California shorelines are largely similar to communities in natural rocky habitats (Pister 2009), suggesting that placement of rocky structures could successfully recruit existing intertidal communities over time. There are also products such as ECOncrete®'s tide pool (Figure 8-3) that are designed to mimic natural rock pools typical to rocky coasts and increase local biodiversity and biological productivity. The design of these features could also be fine-tuned to provide additional benefits such as sediment retention or potentially improved surfing conditions, and applications could vary to mimic the different nearshore rocky intertidal habitat types along North Dana Point.

Figure 8-3: ECOncrete Tide Pools (www.econcretetech.com)

Potential Applications

- Install material that mimics existing offshore rocky intertidal habitat in Monarch Bay at higher shoreline elevations.
- Re-configure the non-engineered revetment along Salt Creek to resemble tide pool features by incorporating flatter slopes and shelf structures.
- Establish nearshore reefs in Dana Strand to provide localized sand retention and potentially improve surfing conditions.

Challenges

- Regulations associated with the State Marine Protected Area in the region may restrict amount or type of material placement.
- Evaluation of associated benefits is more complex than traditional approaches and would most likely require pilot projects with detailed monitoring to quantify impacts and benefits.
- Specific design guidelines for such a project in a dynamic wave environment are lacking. A pilot project would provide an opportunity to evaluate different configurations and approaches.
- The level of protection provided by restored areas may vary due to the natural fluctuations associated with coastal habitats. As such, this strategy would have to strike a balance between allowing the shoreline to naturally adapt and conducting routine maintenance to achieve a reliable level of protection, which could undermine the project’s categorization as a “living shoreline.”

8.5.2 North Dana Point - Bluff Monitoring

Goal

Gather high resolution data over regular intervals to monitor site-specific bluff erosion processes and rates to reduce the uncertainty associated with regional bluff erosion projections. Utilize resulting data to inform coastal erosion hazard mitigation strategies and actions.

Concept

Develop a plan for monitoring bluff conditions along North Dana Point to assess the impacts of erosion due to SLR, the results of which will be tied to thresholds for further mitigation actions to stabilize bluffs and prevent damage to surrounding homes. The monitoring plan could be a City-scale effort or a larger-scale effort coordinated with other agencies and municipalities that can leverage ongoing research on bluff erosion processes.

Overview

Coastal bluff and cliff erosion is one of the most prominent hazards along the entirety of the California coastline. Unlike sandy beaches that can erode and accrete seasonally, cliff erosion has no natural process that can offset land area loss. SLR can exacerbate erosion hazards by exposing greater areas to wave energy and other coastal processes, accelerating the loss of cliff and bluff environments that represent important assets in terms of tourism, recreation, and residential development.

The link between SLR and increased bluff erosion is well established, but uncertainty remains regarding the precise timing and extent of erosion impacts. Coastal bluff monitoring programs provide actionable data in the face of these uncertain projections that can be used to determine whether mitigation thresholds have been met or surpassed. A number of methodologies can be employed to carry out such a monitoring program, including 3D topographic modeling through LIDAR (Light Detection and Ranging).

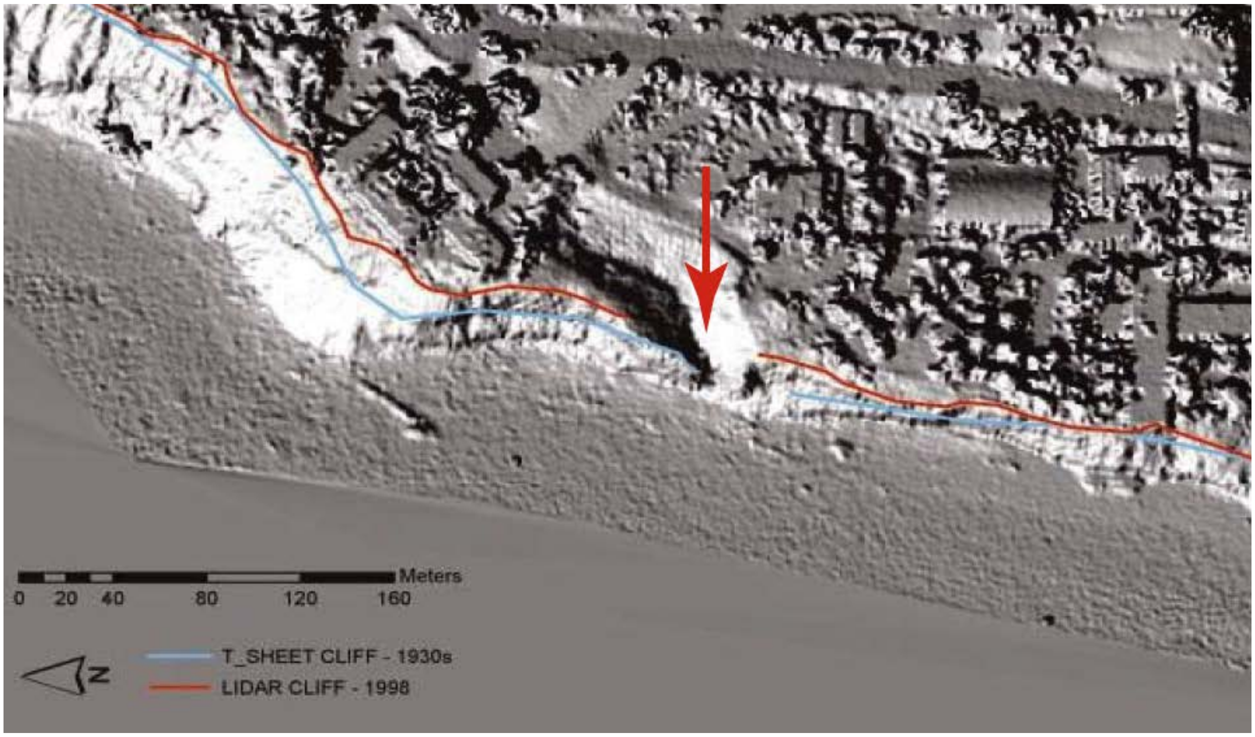


Figure 8-4: Example of Bluff Monitoring using LIDAR Techniques (Hapke & Reid, 2007)

Potential Applications

- Conduct surveys at 5-year intervals using LIDAR or a similar technology that allows for 3D modeling of the bluff face and documentation of bluff top and toe position, nearshore slope, bluff face slope, and other bluff features as needed.
- Perform supplementary surveys immediately following any significant bluff erosion events or landslides.
- Document survey findings in reports and update bluff hazard projections as necessary based on best available information and methods, including any updates in SLR science or projections.
- Findings from the monitoring data and analysis can be used to update hazard zones for which bluff hazard policies would apply.

Challenges

- Resource requirements to coordinate and implement a successful monitoring program.
- Agreement upon and establishment of mitigation thresholds and actions.
- Ongoing data management.

Policies

Specific policies associated with development adjacent to coastal bluffs are provided under the General Plan and address requirements for site-specific geotechnical studies and setbacks from the coastal bluff edge. The LCPA that will follow the Vulnerability Assessment will consider new and/or revised policies to address findings in this report. The City will also consider adaptation strategies identified in Section 8 of this report to further advance the City's understanding of the effects of SLR and coastal erosion with advancing science and coastal bluff monitoring. Some of the General Plan policies to ensure existing and future structures are safe from erosion on coastal bluff properties includes the following:

Public Safety Element

Policy 1.1: Require review of soil and geologic conditions by a State Licensed Engineering Geologist under contract to the City, to determine stability prior to the approval of development where appropriate (Coastal Act/30250, 30253).

Policy 1.2: Monitor and document known and potential geologic hazards in the City.

Policy 1.3: Adopt standards and requirements for grading and construction to mitigate the potential for bluff failure and seismic hazards.

Policy 1.4: Provide for structural setbacks from the bluff top edges based upon recommendations by a State-Licensed Engineering Geologist.

Policy 1.5: Adopt blufftop setback requirements based upon the severity of the conditions. The minimum 25-foot blufftop structural setbacks mandated by the Coastal Act may be inadequate.

Policy 1.6: Prevent future development or revitalization of bluff top properties that may pose a hazard to owners, occupants, property, and the general public.

Policy 1.9: New bluff top development should be designed and located to ensure geological stability and to eliminate erosion or destruction of the site or surrounding area.

Conservation/Open Space Element

Policy 2.10: Adopt setback standards which include, at a minimum, a 25-foot setback from the bluff edge or which take into consideration fifty years of bluff erosion (whichever is most restrictive for a particular blufftop site). When necessary, require additional setbacks of buildings and site improvements from bluff faces, which will maximize public and structural safety, consistent with detailed site-specific geotechnical report recommendations (Coastal Act/30253).

8.5.3 Dana Point Harbor - Targeted Infrastructure Upgrades

Goal

Leverage the unique opportunity of proposed harbor revitalization initiatives to build adaptive capacity into new and redeveloped harbor infrastructure.

Concept

Increase the resilience of the revitalized Dana Point Harbor by implementing adaptation strategies such as structure elevation, relocation, drainage improvements, flood-proofing or redesign to better accommodate future hazards due to SLR.

Overview

Project funding and coordination are often significant hurdles to coastal hazard mitigation efforts. The revitalization initiative within Dana Point Harbor presents an opportunity to incorporate SLR considerations into infrastructure redesign and upgrades by leveraging funding sources and building upon prior planning efforts.

There are several ways in which infrastructure can become more resilient to SLR hazards. The most direct adaptation strategy is to reduce the probability of infrastructure failure. Within the harbor, such a strategy would involve increasing the capacity of existing flood protection structures or providing multiple layers of defense against coastal flooding and inland flooding. The vulnerability assessment indicates SLR of 3 ft or more would result in coastal flooding of low-lying areas throughout the harbor (mostly parking lots). SLR will also reduce the capacity of gravity storm drain lines as high ocean water levels could limit conveyance capacity. An example of drainage improvements to accommodate increased coastal and inland flooding is illustrated in Figure 8-5. This adaptation measure includes multiple features such as impermeable surfaces, deployable flood walls and pump stations in order to accommodate the potential for increased flooding in the future.

Alternatively, or in combination, the perimeter bulkhead could be modified or replaced to increase the crest elevation and reduce the potential for coastal flooding of harbor development. Increased perimeter protection could also be accomplished with secondary features such as berms or walls setback from the primary bulkhead and integrated with the pedestrian paths around the harbor.

The infrastructure, which supports commercial and recreational boating activities, include protective structures (breakwaters), floating docks and piles, utilities, restrooms, parking and a launch ramp. Adaptation strategies for the breakwaters are discussed in Section 8.5.4. The floating docks, guide piles and utility infrastructure of the marinas are perhaps the most adaptive infrastructure in the Harbor since they are designed to function with the ~8-foot tide range. However, depending on the pile top elevations, there may not be sufficient freeboard to accommodate the higher SLR scenarios. The typical service life of floating docks is 20-30 years with some newer products designed to last up to 50 years. Any future marina upgrades should include an appropriate amount of freeboard in the dock mooring system to accommodate SLR over the anticipated service life. Other marina elements to consider in future project planning include landside utility infrastructure and access gangways, which may need to be modified to accommodate higher water levels and reduce the risk of flooding.

Adaptation efforts should also focus on minimizing the disruption, damage, and aftermath in the event of infrastructure failure. Anticipating and planning for failure is an important consideration given the inherent uncertainty involved in SLR hazard projections. Relocation of critical facilities away from high-hazard areas and the use of redundant flood hazard reduction measures, such as permeable buffer areas or flood-proofing, can both be employed to reduce impacts if hazards exceed the capacity of flood protection measures. Consideration should also be given to minimizing recovery time following a hazard event by designing structures and systems in a manner such that critical uses and functions are quickly restored. While each of these strategies can be effective when used in isolation, implementation of multiple strategies provides significant resilience to SLR hazards.

Potential Applications

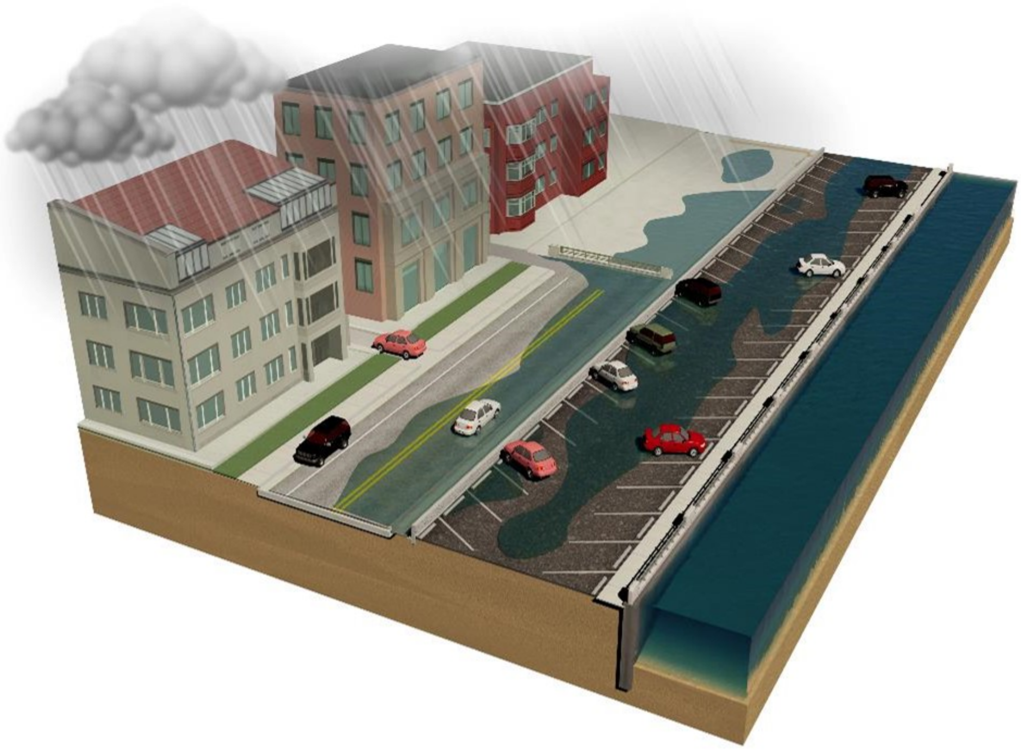
- Transform existing access trails, park areas, and parking lots into multi-benefit zones that include integrated flood protection measures such as elevated paths or runoff storage and detention features.
- Increase capacity of bulkheads, marina docks, and piles to handle higher water levels without damage or disruption.
- Incorporate SLR projections into the design of new buildings and other long-term infrastructure investments through measures such as elevated floors and critical utilities. Design should allow for a range of adaptation options to allow infrastructure to adjust appropriately as new SLR information is released.

Challenges

- Coordination among multiple stakeholders involved in harbor revitalization.
- Identification of critical or high-priority infrastructure for SLR hazard planning.
- Determination of acceptable risk levels for various infrastructure types.
- Balancing initial infrastructure investment against uncertainty surrounding future impacts.
- Consensus decision-making regarding trade-offs between increased flood protection and redesign or relocation of existing infrastructure.

BEFORE

Ponding of low-lying areas will occur more frequently as higher ocean water levels will reduce the conveyance capacity of gravity storm drain systems.



AFTER

Flood protection can be improved through a variety of measures including:

- Reducing runoff (convert parking lots to green space)
- Added conveyance (pump station)
- Added flood storage capacity (retention ponds)

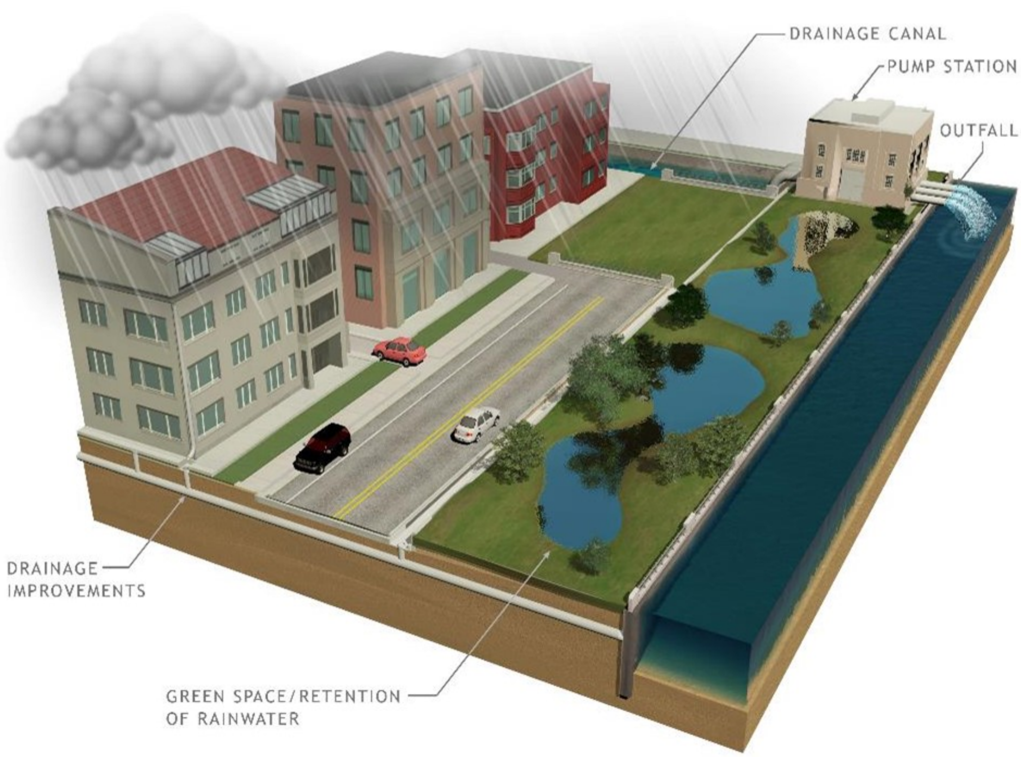


Figure 8-5: Example of Landside Drainage Improvements to Reduce Flooding (USACE 2015)

8.5.4 Dana Point Harbor - Maintain Outer Harbor Breakwaters

Goal

Prevent loss of wave protection from outer breakwaters due to SLR.

Concept

Coordinate with USACE to inspect, maintain, and enhance breakwaters surrounding the harbor as necessary to preserve protective functions, accounting for increased wave stress and potential overtopping due to SLR.

Overview

The eastern and western breakwaters of Dana Point Harbor provide critical wave protection to inner harbor infrastructure and navigability within the harbor. The breakwaters also facilitate the accumulation of sand at Doheny State Beach. These structures will be exposed to greater wave heights and water levels as sea levels rise. If wave heights exceed initial design values, or if breakwater infrastructure is not adequately maintained under increased wave exposure, the functionality of breakwater structures may decline significantly under projected SLR scenarios (Figure 8-6). Wave transmission occurs from penetration through a rubble-mound structure and overtopping of the breakwater, both of which will increase with SLR.

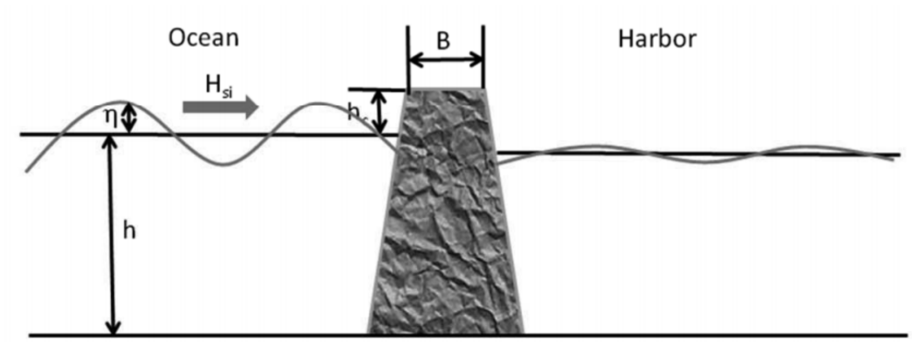


Figure 8-6: Conceptual Sketch of Wave Transmission through a Breakwater (Li et al. 2011)

As sea levels rise, Dana Point Harbor breakwaters in their current state will be subject to increased wave overtopping and wave transmission through permeable breakwater structures, each reducing the protective function of the structures. Theoretical increases in wave transmission through breakwaters under different SLR scenarios were evaluated during preliminary assessments of Dana Point Harbor infrastructure. Results indicate that the effectiveness of harbor breakwaters could be significantly reduced under severe SLR scenarios as initial wave heights rise and breakwater freeboard is decreased, resulting in a potential 3-ft increase in wave height within the harbor (Table 8-1). This increase in wave energy would not only impact navigation within the harbor but would also increase flood risk due to wave runup and overtopping of interior harbor development.

Table 8-1: Theoretical Increases in Breakwater Wave Transmission under Various SLR Scenarios

SLR Scenario	Initial wave height, in ft (m)	Breakwater freeboard, in ft (m)	Transmitted wave height, in ft (m)
No SLR	10.2 (3.1)	10.5 (3.2)	0.7 (0.2)
1.6 ft (50 cm)	10.5 (3.2)	9.2 (2.8)	1.3 (0.4)
3.3 ft (100 cm)	10.8 (3.3)	7.5 (2.3)	2.3 (0.7)
4.9 ft (150 cm)	11.2 (3.4)	5.9 (1.8)	3.0 (0.9)
6.6 ft (200 cm)	11.5 (3.5)	3.9 (1.2)	3.9 (1.2)

Overtopping and wave transmission can be reduced through several structural means including elevation of crest height, slope adjustments, and additional armoring to reduce permeability. If redesign or reinforcement is not feasible, additional maintenance can also be employed to ensure maximum functionality of structures in their current state. Maintenance could also be supplemented by secondary wave protection within the harbor, providing a level of redundancy in the event of breakwater failure. Breakwater adaptation measures can also incorporate "green" design elements aimed at enhancing the ecological value of the structure. Figure 8-7 is an illustration of a "Living Breakwater" concept currently in the design phase along the southwestern shoreline of Staten Island, New York. This concept was developed through the Resilient by Design competition to respond to damage from Superstorm Sandy and was awarded $60 million of Community Development Block Grant Disaster Recovery (CDBG-DR) funds. The living breakwater concept applies several ECOncrete® products designed to increase local biodiversity and biological productivity.

<u>Potential Applications</u>

- Structural improvements to outer breakwaters through crest elevation, additional armoring, or structure redesign.
- Incorporate "living breakwater" design elements enhance habitat value of structures.
- Increased maintenance frequency of existing harbor breakwaters.
- Use of secondary wave protection within the harbor.

<u>Challenges</u>

- Permitting challenges associated with new or improved shoreline protection structures.
- Breakwater improvements would require significant investment from the USACE or other funding sources.
- Coordination with USACE during project planning and implementation.

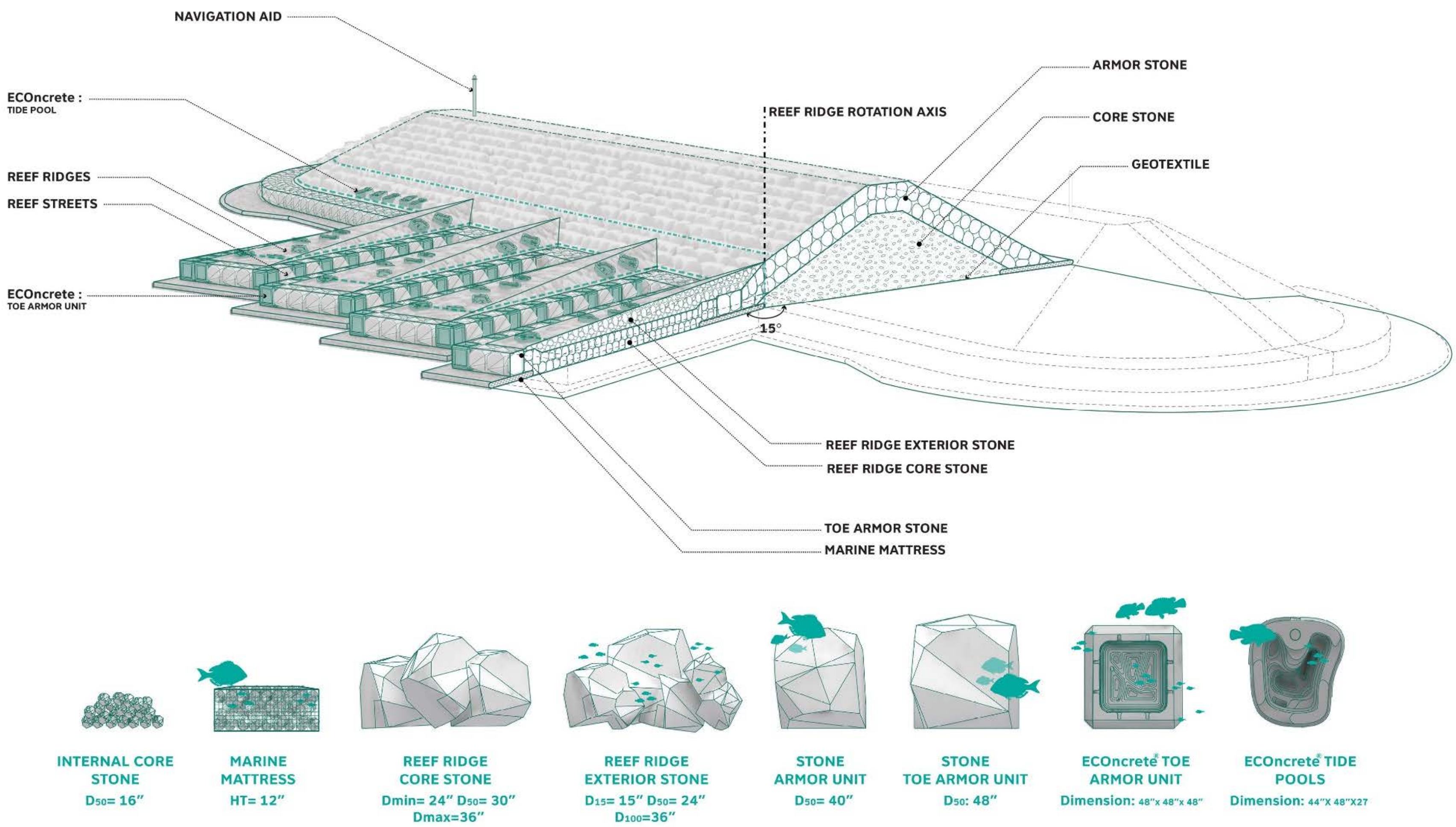


Figure 8-7: Living Breakwater Concept (Staten Island, New York)

8.5.5 North and South Dana Point - Regional Beach Nourishment

Goal

Implement a coordinated beach nourishment program to offset the reduction in natural sediment supply to local beaches and provide a shoreline more resilient to the effects of climate change, such as prolonged drought and SLR.

Concept

Combine resources of multiple governments, agencies, and stakeholders to implement an organized regional beach nourishment program. Regional nourishment efforts should focus on key beaches that can act as sand engines, where placed sand would transport down-coast providing lasting benefits beyond the initial placement zone.

Overview

Beach nourishment programs can provide an alternative shoreline protection method when other techniques such as managed retreat or shoreline armoring are not feasible. Sand placement from inland or offshore sources allows local beaches to maintain or increase their width as sea levels rise, providing a buffer to wave energy while preserving recreational and environmental value. Beach nourishment also complements other forms of adaptation to provide multiple layers of protection that can be customized for each individual stretch of coastline.

Several nourishment projects have been successfully implemented in Southern California and can be used to guide efforts within Dana Point, including recent nourishments at Cardiff Beach (Figure 8-8 and Figure 8-9) and Solana Beach as part of the San Elijo Lagoon Restoration Project. Approximately 300,000 cy of sediment dredged from the lagoon were placed on Cardiff Beach along a 2,150-ft length of shoreline. This volume of beach nourishment was sufficient to provide a post-nourishment beach width of about 300 ft. Another 146,000 cy was placed along a 1,500-ft length of shoreline at Solana Beach, resulting in a post-nourishment beach width of about 200 ft (Figure 8-10).

To be successful and cost-effective, beach nourishment programs should account for local and regional oceanographic processes and include monitoring efforts to evaluate performance of the program. Knowledge of sand transport and erosion rates along local coastlines is key to determining the amount and timing of sand placements and preserving the life span of nourishment efforts. The coastal setting of Dana Point, at the northern end of the Oceanside Littoral Cell, presents a unique opportunity for use as a feeder beach where a regional nourishment program would act as a sand engine, providing a regular supply of sediment to downcoast beaches. This program would mimic the natural supply of sediment to the region historically provided by San Juan Creek.

Beaches of north Dana Point could also benefit from nourishment to offset the coastal squeeze impacts driven by SLR and a reduced natural supply of sediment to the coast. The pocket beaches at Salt Creek and Dana Strand are semi-confined littoral cells with the sandy beach held in place by the Dana Point

Headlands and Monarch Point. Beach nourishment could be an effective and economical measure to mitigate SLR impacts since the loss of sediment downcoast is relatively low.

Figure 8-8: Cardiff Beach Nourishment Baseline Conditions

Figure 8-9: Cardiff Beach Nourishment Progress as of March 21, 2018

Figure 8-10: Solana Beach Nourishment Progress 2018

A regional beach nourishment effort, rather than a piecemeal city-by-city approach, would effectively take advantage of local variations in sediment transport and maximize the benefits of nourishment throughout the northern Oceanside Littoral Cell. A regional approach would also provide an opportunity to leverage state and federal funding sources across the region, reducing the cost burden on individual governments or agencies. The USACE Surfside-Sunset Beach nourishment program is an excellent example of a regional beach nourishment program that provides benefits to multiple stakeholders including the Cities of Seal Beach, Huntington Beach, Newport Beach, the County of Orange, Caltrans, and State Parks. A similar opportunity exists at Dana Point where a regional beach nourishment project would benefit the Cities of Dana Point, San Clemente, the County of Orange, the LOSSAN, and State Parks.

While natural processes can be leveraged to increase the effectiveness of nourishment programs, beach nourishment efforts involve an inherent level of variability due to changes in seasonal local erosion rates and episodic erosion events. For this reason, nourishment projects should not be considered one-time events, but should instead include adaptability measures and planned maintenance efforts. Nourishment planning on a regional or watershed level can facilitate adaptability by allowing for opportunistic nourishment events and coordinated nourishment activities along neighboring stretches of coastline, ultimately increasing the long-term efficiency of beach nourishment projects.

The San Clemente Shoreline Feasibility Study (USACE 2012) along with regional nourishments funded by San Diego Association of Governments (SANDAG) in 2001 and 2012 illustrate the different scales of nourishment that could be applied from Dana Point through San Clemente. The recommended plan for San Clemente involves placement of 251,000 cy in the vicinity of the San Clemente Pier to increase beach width by about 50 ft with follow up nourishments every 5 years on average for 50 years. The estimated cost of the initial nourishment is about $11.3 million with a total project cost of $161 million over 50 years (USACE 2012).

The SANDAG Regional Beach Sand Projects (RBSP) involved larger scale nourishments at several locations. RBSP I placed about 2 mcy at 12 beaches throughout San Diego and nourished about 6 miles of shoreline at a cost of $17.5 million in 2001 (Levy & Tucker 2012). RBSP II placed about 1.5 mcy at 8 different beaches at a cost of $28.5 million in 2012. The SANDAG projects highlight the economy of scale when considering beach nourishment as a shoreline management strategy. The total price per cubic yard for the RBSP II project (~$19/cy) is less than half of the estimated cost for the initial nourishment at San Clemente (~$45/cy). The high cost of mobilization and demobilization is one reason larger nourishments are more economical. Other key factors in estimating cost include the distance from the borrow site (source) to the placement site. The San Clemente Shoreline Feasibility Study (USACE 2012) identified an offshore source of sediment at Oceanside that was found to be suitable for beach nourishment with an estimated quantity of about 20 mcy.

Potential Applications

Initial nourishment efforts would likely need to target multiple locations in Dana Point and San Clemente, similar to the SANDAG RBSP I project, which nourished multiple beaches in San Diego. For purposes of estimating the volume and cost of an initial nourishment, we assumed placement volumes at the beaches listed in the table below.

Table 8-2: South Orange County Regional Nourishment - Initial Placement Volume Estimate

Beach	Length (ft)	Nourishment Template (cy/ft)	Initial Nourishment Volume (cy)
South Doheny to Capo Beach Park	6,000	75	450,000
Capistrano Bay Community	8,000	75	600,000
Salt Creek to Dana Strand	8,000	37.5	300,000
North Beach – San Clemente	2,000	75	150,000
Pier Bowl – San Clemente	3,400	75	250,000
		Total Volume:	**1,750,000**

- The volume/foot of shoreline for beaches of South Dana Point was based on the proposed nourishment template at San Clemente designed to add ~50 feet of beach width per foot of shoreline. This nourishment volume was reduced by ~50% at North Dana Point to reduce potential for impacts to environmental resources and surfing breaks.
- Based on the scale of this nourishment and assuming that material is available offshore of San Clemente, we can assume the cost/volume would be at the lower end of the coast range and similar to the RBSP projects. Based on these simple assumptions, the rough order of magnitude cost of the initial nourishment could be in the range of $30 to 50 million.
- After the initial nourishment efforts, a regular nourishment program along South Doheny State Beach and Capistrano Beach could act as a feeder beach for downcoast areas. Occasional re-nourishment would also be need for North Dana Point. The amount and frequency of nourishment could be adapted based on factors such as the supply of sediment from San Juan Creek, coastal storm activity (recent or forecast), and the rate of SLR. The estimated re-nourishment interval would likely fall within a 5-10-year range but may not require the same amount of volume depending on how much of the initial nourishment volume remains in the littoral system.
- Implement funding mechanisms such as those applied by SANDAG for RBSP I and II, a private model based on a similar effort in Broad Beach, FEMA grants, or a combination of sources. There

may be an opportunity for Dana Point to partner with SANDAG on future large-scale nourishment efforts.

- The regional program should include measures in place for opportunistic beach nourishment as sources become available. Potential sand sources include harbor dredging, dredging of flood control channels and debris basins, offshore sources, and watershed maintenance activities. The OCCRSMP identifies interior and nearshore areas of Dana Point Harbor, San Juan Creek, and the Palisades Reservoir as potential local sediment sources, with numerous potential sources further inland.

Challenges

- Securing regular funding and coordination of activities among multiple stakeholders. There is certainly a significant cost for a beach nourishment program of this scale. However, it's important to also weigh the potential costs of accelerated beach loss due to SLR (without nourishment). The OCCRSMP (Everest 2013) estimated there are over 10 million visitors to these beaches annually that account for almost $290 million in annual spending, almost $18 million in City, County and State taxes and about $1.8 million in TOT for local communities. These numbers clearly illustrate the economic benefits of sandy beaches in south Orange County and could provide a source of revenue for funding a regional beach nourishment program.
- Environmental permitting processes associated with CEQA and NEPA., particularly for beaches of North Dana Point where the State Marine Protected Area designation could prohibit placement of sediment in this location.
- Physical and chemical sediment compatibility determinations.
- Ongoing beach width and elevation monitoring requirements.
- Timing of nourishment activities to avoid disruption to recreational use of beaches.
- Potential loss of nourishment material following coastal storm events.

8.5.6 South Dana Point - Hybrid Dune Living Shorelines

Goal

Protect coastal development and enhance coastal habitat without the use of additional shoreline armoring that disrupts coastal processes.

Concept

Establish a dune system on the seaward side of coastal resources threatened by SLR to protect vulnerable community assets while creating beach habitat to offset the effects of coastal squeeze. This concept is a blend of strategies aimed at preserving the variety of resources that depend on natural beach processes.

Overview

Hybrid shoreline management approaches act as a middle ground between traditional coastal armoring and a living shoreline that relies solely on natural protective functions. As their name implies, hybrid shoreline management measures use a combination of structural and “soft” techniques such as beach nourishment to allow for additional flexibility in project design. If implemented successfully, such an approach can provide the additional co-benefits of habitat restoration along with the increased protection of structural measures.

Hybrid dune systems specifically involve a rock revetment or cobble berm that is then overlain with a sand buffer. Vegetation can also be utilized in hybrid dune systems to further stabilize dune structures and reduce erosion. Additional beach width and height provides an initial buffer for coastal erosion while also providing additional recreational area. The buried revetment or berm then acts as a hardened last line of defense to prevent damage to adjacent coastal resources under more severe storm events. Maintenance is required over time as the sand layer erodes naturally, though the underlying structural element reduces overall sediment requirements as compared to a pure nourishment approach.

Hybrid dune and cobble berm structures have been employed at several sites in Southern California due to their potential for multiple benefits. Projects have been fully implemented at Surfers Point in Ventura and Imperial Beach in San Diego, and construction of a hybrid dune is planned for Cardiff State Beach in 2018 and 2019 (Figure 8-11). Cobble berms also occur naturally in the region, providing evidence that such an approach can be highly compatible with natural shoreline processes.

The cost of a hybrid dune and living shoreline concept can vary significantly based on the source location of materials such as sand, cobble, and armor stone. The estimated cost of the Cardiff State Beach living shoreline project was about $2 million, which equates to a rough unit cost of about $700 per lf. Preliminary costs for a similar solution along Doheny State Beach were estimated to be significantly higher ($1300 to 2800/lf) based on the assumption all sand and cobble material would have to be imported for use in the restored dune and cobble stone revetment. If coordinated with maintenance dredging of San Juan Creek, or in combination with a regional beach nourishment project, there is an opportunity to significantly reduce the cost due to savings on mobilization and imported material.

A hybrid dune living shoreline could prove to be an effective adaptation with multiple benefits to offset adverse impacts resulting from sea level rise and beach erosion. The adaptive capacity of such a measure is heavily dependent on the amount of sand fronting the restored dune. If coupled with a regional beach nourishment program to offset the long-term erosion and future SLR this measure could be very effective for the 1.6 and 3.3-foot SLR scenarios. Without a regular nourishment program to maintain a beach fronting the restored dune system, the adaptive capacity of this measure would be significantly reduced and would be difficult to maintain under a 1.6-foot SLR scenario.

For higher SLR scenarios (4.9 and 6.6 feet) this strategy would remain effective at reducing coastal hazards if the rates of re-nourishment are sufficient to keep pace with SLR. If the rates of re-nourishment cannot keep pace with SLR then periodic and eventually permanent erosion of the restored dune system would be expected. Under these high SLR scenarios much, of the back-beach development would require some form of adaptation to preserve the existing land uses. For example, beach parking at State and County parks would have to be elevated, protected, or reconfigured to accommodate the significantly higher tide range, wave runup and beach berm. Similar adaptation measures would be required along the Capistrano Bay Community development. While a hybrid dune living shoreline alone may not be sufficient to mitigate impacts from higher SLR scenarios, it could be implemented in combination with other measures and over several cycles of adaptation.

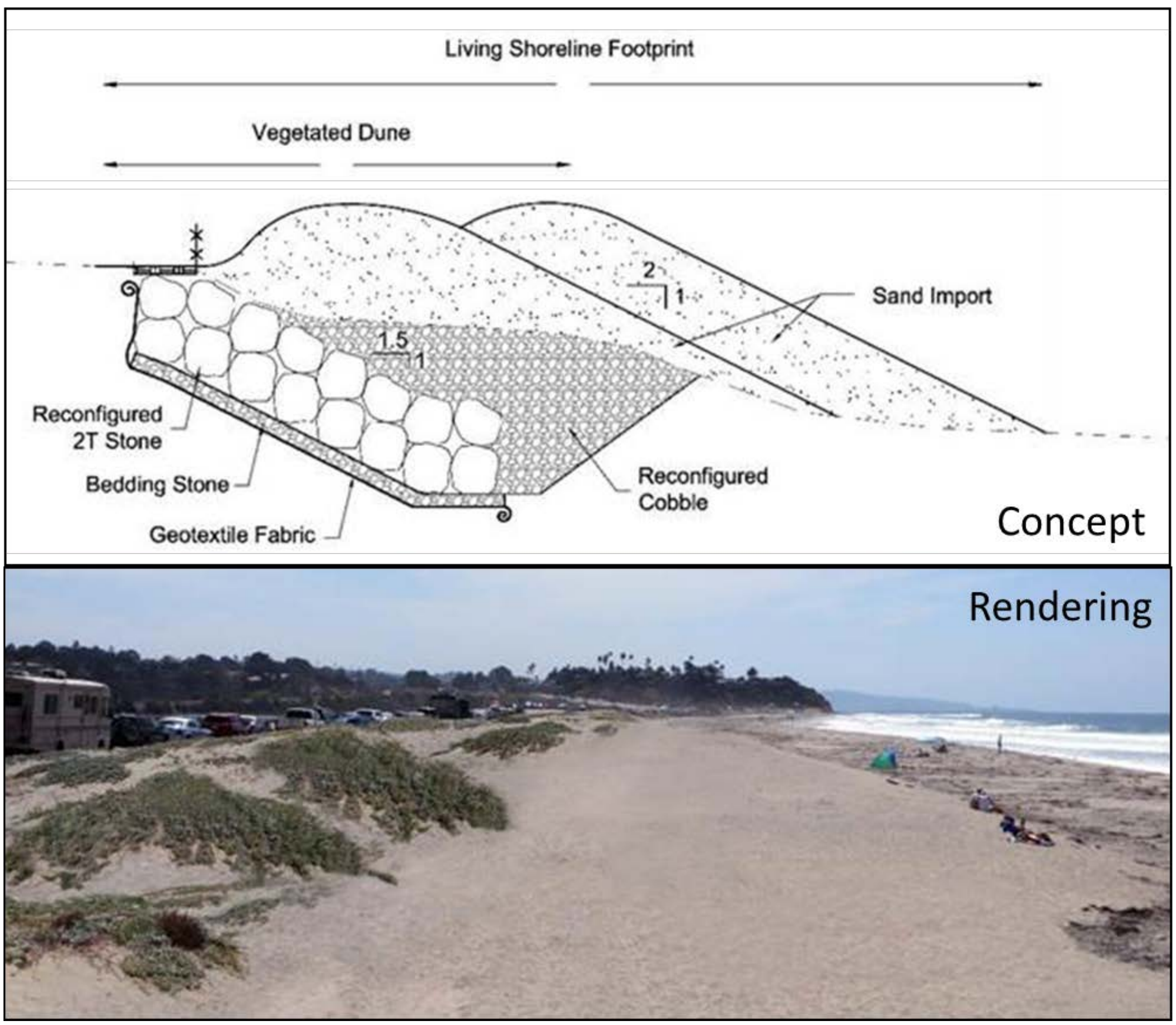


Figure 8-11: Conceptual Cross Section and Illustration of a Hybrid Dune System at Cardiff State Beach

Potential Applications

- Install hybrid dune structures along the south day-use lot of Doheny State Beach, Capistrano Beach Park, or Capistrano beachfront development.
- Utilize existing revetment structures or individual shoreline protection structures as material for the structural component of the hybrid dune.
- Align hybrid dune design with any planned beach nourishment activities.
- Develop a monitoring program to evaluate performance and maintenance needs of hybrid dune structures. This can be coordinated with potential bluff monitoring in North Dana Point.

Challenges

- Permitting challenges associated with additional structural protection elements.
- Establishment of self-sustaining dune vegetation.
- Ongoing maintenance of hybrid dune structures including sand replenishment.
- Public access to any newly formed beaches located seaward of existing private development.

9. Conclusions

This assessment identifies potentially significant impacts to coastal resources in Dana Point for a SLR scenario of 1.6 ft. 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 OPC document suggests there is a 50% probability that SLR will exceed 1.6 ft by 2080. However, the worst-case projections (H++ scenario) indicate this amount of SLR could occur as soon as 2040.

Natural resources and recreational amenities will be among the first resources impacted by SLR due to the effects of coastal squeeze. Throughout Dana Point these resources are constrained from landward migration by development such as residential housing, the LOSSAN railroad corridor, and PCH. "Coastal squeeze" can be defined as the process by which sea level-dependent physical, cultural, or biological areas are pushed landwards with SLR but are prevented from natural landward migration due to a protected or non-erodible structure such as a sea cliff or revetment. The dry beach and intertidal areas of Dana Strand, South Doheny State, and Capistrano Beaches (and resources dependent on these areas) are vulnerable to permanent loss due to coastal squeeze based on CoSMoS shoreline projections for a 1.6-ft rise in sea level.

Continued shoreline erosion, accelerated by SLR, coupled with storm-induced beach erosion has the potential to cause permanent damage to development along Capistrano Beach. With a 1.6-ft rise in sea level, over half of the parcels along Beach Road could be subject to seasonal erosion impacts, which could be problematic for structures on shallow foundations without shoreline protection. The newer structures supported on pile foundations would be less sensitive to seasonal erosion but could be subject to wave uplift forces under this scenario during an extreme coastal storm event. A 3.3-ft rise in sea level represents a significant threshold at which the everyday shoreline is at or landward of the existing development at 135 parcels indicating that 1) there is little or no dry beach remaining in front of these parcels and 2) the existing structures would be subject to regular and more intense wave action given the higher water levels of this scenario. Shoreline projections for higher SLR scenarios indicate the daily shoreline position would be landward of existing development along all of Capistrano Beach. Long-term shoreline erosion not only threatens structures, it also has the potential to eliminate the dry sandy beach areas valued by the community.

The vulnerability to some of these assets can be mitigated through adaptation measures implemented on regional, local, or site-specific scales. The adaptation measures will need to involve coordination with stakeholder groups and agencies to balance the costs, benefits, and trade-offs of these measures. Improving our understanding of the potential effects of SLR on local coastal processes through a regular monitoring program will provide valuable information that can be used to encourage responsible development within these hazard zones. This monitoring data will also inform the design and implementation of adaptation strategies aimed at reducing the adverse impacts of SLR on coastal resources.

A living shoreline approach that mimics rocky intertidal habitat, potentially in combination with restored or enhanced reef structures, could provide multiple ecological benefits for intertidal areas while reducing wave energy and erosion along the shoreline. The design of these features could also be fine-tuned to provide additional benefits such as sediment retention or potentially improved surfing conditions, and applications could vary to mimic the different nearshore rocky intertidal habitat types along Dana Point.

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 coastal squeeze on natural and man-made resources in Dana Point. However, beach nourishment, considered a “soft protection” strategy, is temporary by design and requires a regular program of re-nourishment to maintain an adequate supply of sediment to a littoral zone. Such a program requires significant financial resources that are often difficult for a single city or entity to support.

One opportunity for implementing an effective and sustainable beach nourishment program would be to engage stakeholders such as OCTA, Caltrans, the City of San Clemente, and California State Parks whose assets would also benefit from a consistent nourishment program. SANDAG may also be a potential partner in a beach nourishment program given the City is within the same littoral cell (Oceanside) as many San Diego communities. Partnering with SANDAG on future beach nourishment projects conducted in the San Diego region could prove a cost-effective option to supplement a local program.

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. For this reason, SLR hazard planning efforts should not rely on a single projection or scenario. Future SLR hazards for planning purposes should instead correspond to acceptable levels of risk based on the predicted lifespan, exposure, and vulnerability of specific coastal uses and resources. The most effective way for the City to address the vulnerabilities described in this report while accounting for the inherent uncertainties in SLR hazard planning is to implement policies and programs that are flexible and can be adapted in response to SLR, future beach conditions, and future development. Regular updates to the vulnerability assessment, potentially at 10 year intervals, would provide an opportunity to update the findings in this study with the best available science on sea level rise projections and coastal hazards. The updated assessment should also evaluate the effectiveness of the policies, programs and projects implemented by the City and other entities to mitigate the adverse effects of sea level rise.

10. References

Ballard, G., Barnard, P.L., Erikson, L., Fitzgibbon, M., Moody, D., Higgason, K., Psaros, M., Veloz, S., Wood, J., (2016). Our Coast Our Future (OCOF). [web application]. Petaluma, California. www.ourcoastourfuture.org. (Accessed: Date [April 2018]).

Barnard, P.L., O'Reilly, Bill, van Ormondt, Maarten, Elias, Edwin, Ruggiero, Peter, Erikson, L.H., Hapke, Cheryl, Collins, B.D., Guza, R.T., Adams, P.N., and Thomas, J.T., (2009.) The framework of a coastal hazards model; a tool for predicting the impact of severe storms: U.S. Geological Survey Open-File Report 2009-1073, 21 p. [http://pubs.usgs.gov/of/2009/1073/].

Burke, A., (2016). California Assembly Bill No. 2616. Ch. 578. Approved by Governor Sep. 24, 2016.

California Coastal Commission, (2015). California Coastal Commission Sea Level Rise Policy Guidance. Adopted August 12, 2015.

California Department of Fish & Wildlife, (2018). CNDDB Maps and Data. [online] Available at: https://www.wildlife.ca.gov/Data/CNDDB/Maps-and-Data#43018410-cnddb-quickview-tool [Accessed Nov. 2017].

Coastal Environments, (2014). Updated Coastal Processes and Hydraulics/Hydrology Studies for Doheny State Beach, Technical Report. September 11, 2014.

County of Orange, (2013). South Orange County Integrated Regional Watershed Management Plan. Final July 2013.

Cutter, S. L., Boruff, B. J., and Shirley, W. L., (2003). "Social Vulnerability to Environmental Hazards*." *Social Science Quarterly*, Wiley/Blackwell (10.1111), <http://onlinelibrary.wiley.com/doi/10.1111/1540-6237.8402002/full> (Jan. 2018).

Danapoint.org, (2018). "Community Services and Parks | City of Dana Point." <http://www.danapoint.org/department/community-services-and-parks> (May 10, 2018).

Doherty, (2015). Elevated Sea Levels During 2015-2016 Strong El Niño. December 2015.

Everest International Consultants. Science Applications International Corporation, King, P., (2013) Orange County Coastal Regional Sediment Management Plan (OCCRSMP).

Everts Coastal, (1995). Seacliff Erosion and Sediment Contributions: Dana Point to the San Gabriel River. November 1995.

Everts Coastal, (1997). Sediment Budget Analysis, Dana Point to Newport Bay, California. June 1997.

Hapke, C., & Reid, D., (2007). National Assessment of Shoreline Change, Part 4: Historical Coastal Cliff Retreat along the California Coast. *U.S. Geological Survey Open-File Report*. https://doi.org/10.1144/M40.9

Intergovernmental Panel on Climate Change (IPCC), (2013). *Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fifth Assessment Report of the IPCC. <https://www.ipcc.ch/report/ar5/mindex.shtml>

Judge, J., Newkirk, S., Leo, K., Heady, W., Hayden, M., Veloz, S., … Small, M., (2017). *Case Studies of Natural Shoreline Infrastructure in Coastal California*.

King, P., McGregor, A., Whittet, J., (2011). *The Economic Costs of Sea-Level Rise to California Beach Communities.* Prepared for the California Department of Boating and Waterways (DBW). San Francisco State University, San Francisco.

Kopp RE, Horton RM, Little CM, Mitrovica JX, Oppenheimer M, Rasmussen DJ, et al., (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tidegauge sites. Earth's Future. 2014; 2:383–406.

Levy, K. and Tucker, S., (2012). SANDAG shoreline management and getting to the 2012 Regional Beach Sand Project. Shore & Beach, Vol 80, No. 3, Summer 2012.

Li, H., Lin, L., Lu, C., & Shak, A., (2011). Evaluation of breakwaters and sedimentation at Dana Point Harbor, CA. *Proceedings Coastal Sediments*.

Moffatt & Nichol, (2017). *Doheny State Beach Alternatives Analysis Report, Draft*, Dana Point CA.

Moffatt & Nichol, (1985). Coastal Flood Plain Development, Orange County Coastline. January, 1985.

Moffatt & Nichol, (1993). Coastal Floodplain Development Study Update for the Capistrano Bay Community, Dana Point, California. December, 1993.

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., Van, B., Lange, M., & Burks-copes, K. A., (2016). The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. PLoS ONE, 11(5). https://doi.org/10.1371/journal.pone.0154735

National Ocean Economics Program (NOEP), (2017). *Coastal Economy Data*. http://www.oceaneconomics.org/Market/coastal/coastalEcon.asp

National Oceanic and Atmospheric Association (NOAA), (2018a). NOAA Office for Coastal Management, Sea Level Rise Viewer v 3.0.0. Accessed March 2018. https://coast.noaa.gov/digitalcoast/tools/slr.html

National Oceanic and Atmospheric Association (NOAA), (2018b). NOAA Tides and Currents. Accessed May 2018. https://tidesandcurrents.noaa.gov/waterlevels.html?id=9410230

OPC-SAT., (2018). *State of California – Sea-Level Rise Guidance – 2018 Update*. Prepared by the California Ocean Protection Council Science Advisory Team and California Natural Resources Agency.

Patsch, Kiki and Gary Griggs, (2007). Development of Sand Budgets for California's Major Littoral Cells. Institute of Marine Sciences. University of California, Santa Cruz.

Pister, B., (2009). Urban marine ecology in southern California: the ability of riprap structures to serve as rocky intertidal habitat. *Marine Biology*, *156*(5), 861–873. https://doi.org/10.1007/s00227-009-1130-4

Sutton-Grier, A. E., Wowk, K., & Bamford, H., (2015). Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. *Environmental Science and Policy*, *51*, 137–148. https://doi.org/10.1016/j.envsci.2015.04.006

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler and C.Z., (2017). Global and Regional Sea Level Rise Scenarios for the United States. 2017.

United States Army Corps of Engineers (USACE), (1991). Coast of California Storm and Tidal Waves Study, San Diego Region, Final Report, USACE Los Angeles District.

United States Army Corps of Engineers (USACE), (2002). Coast of California Storm and Tidal Waves Study, Orange County Region, Final Report, USACE Los Angeles District.

United States Army Corps of Engineers (USACE), (2012). *San Clemente Shoreline Feasibility Study Orange County, California*. United State Army Corps of Engineers, San Clemente, CA

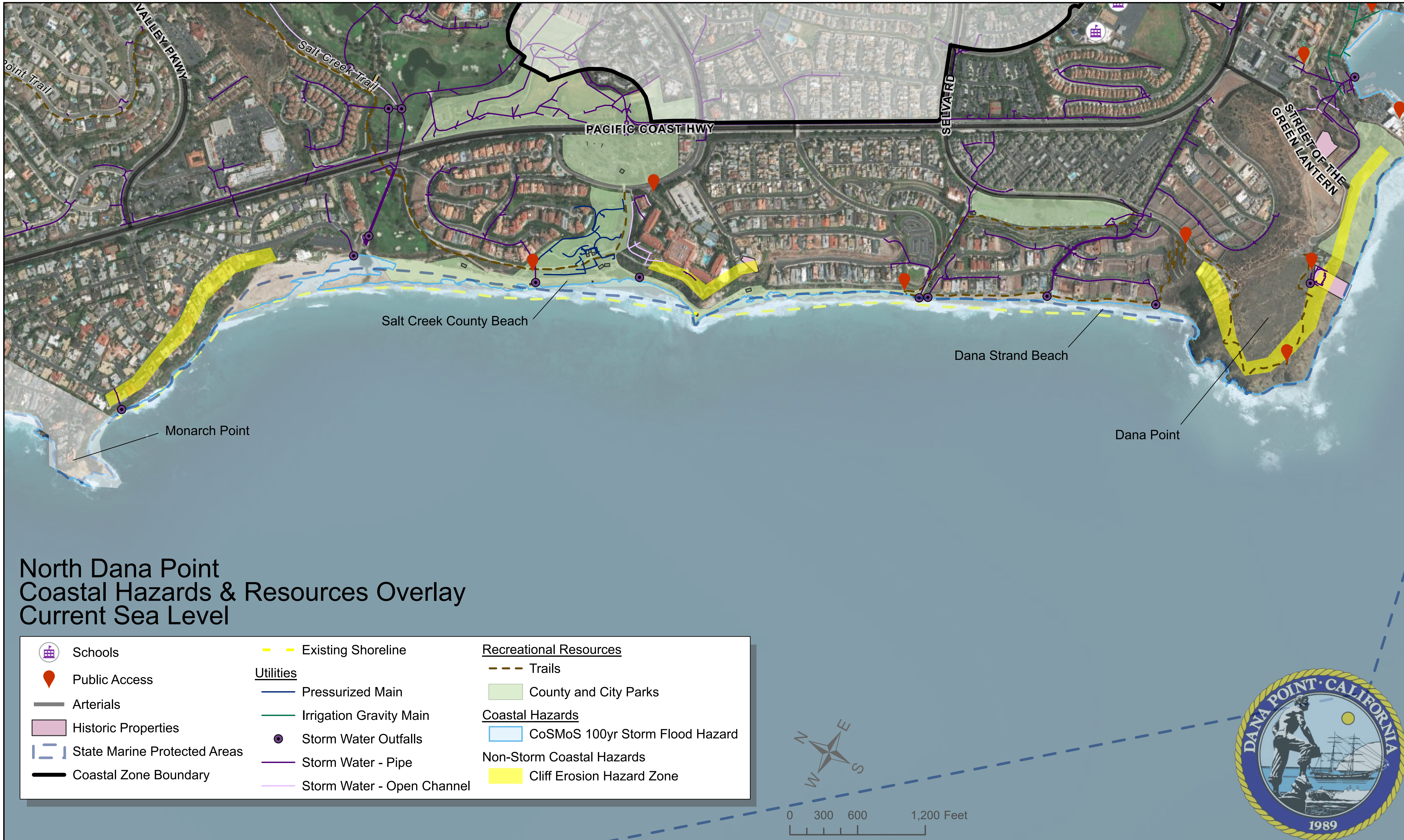
United States Army Corps of Engineers (USACE), (2015). *North Atlantic Coast Comprehensive Study.* National Planning Center for Coastal Storm Risk Management. January 2015.

University of Southern California (USC) Sea Grant Program, (2013). Sea Level Rise Vulnerability Study for the City of Los Angeles, Report prepared for the Mayor of Los Angeles.

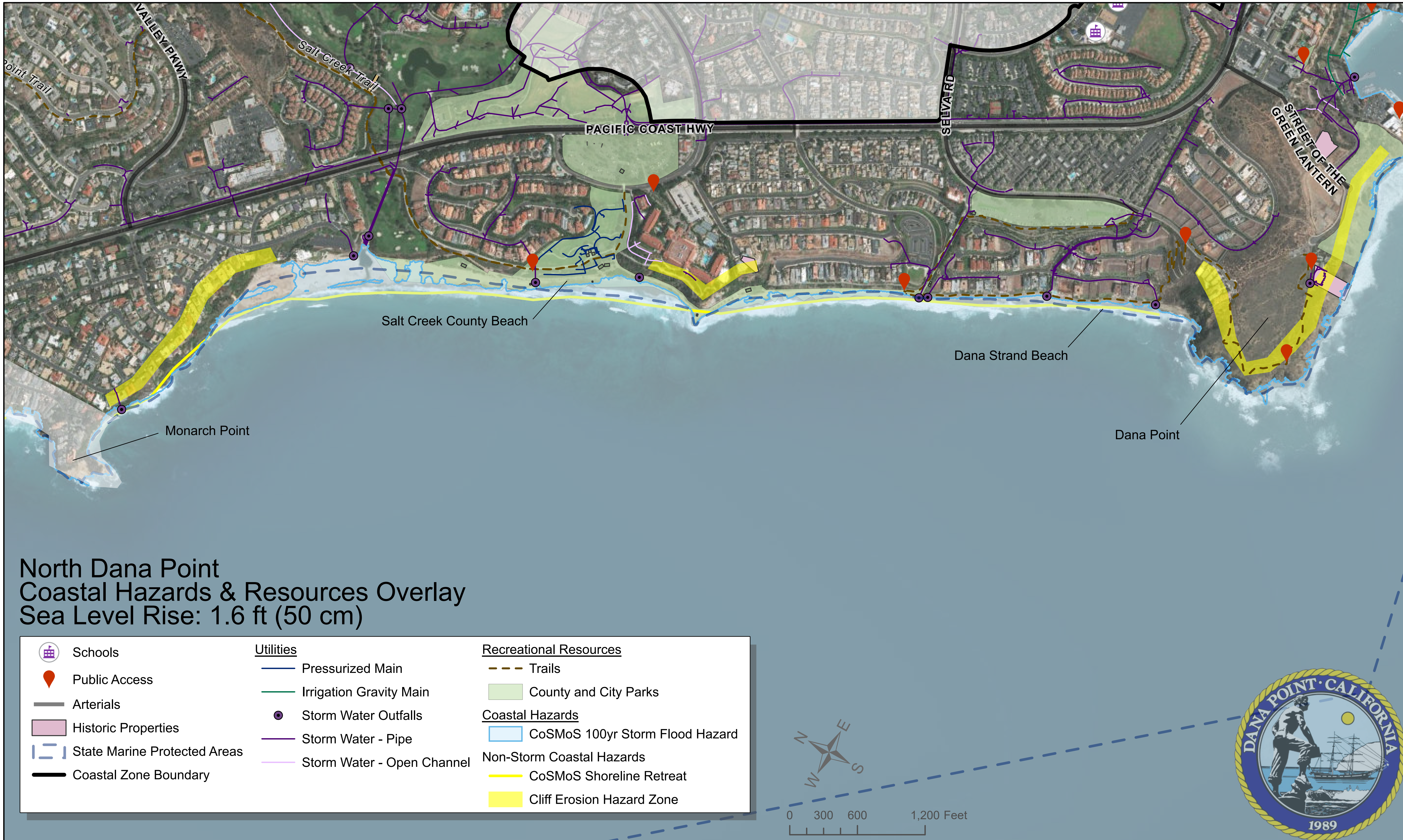
Young, A., (2018). "Decadal-scale coastal cliff retreat in southern and central California". Geomorphology, 300, 164-175.

Appendix A

Coastal Hazard and Resource Overlay Maps

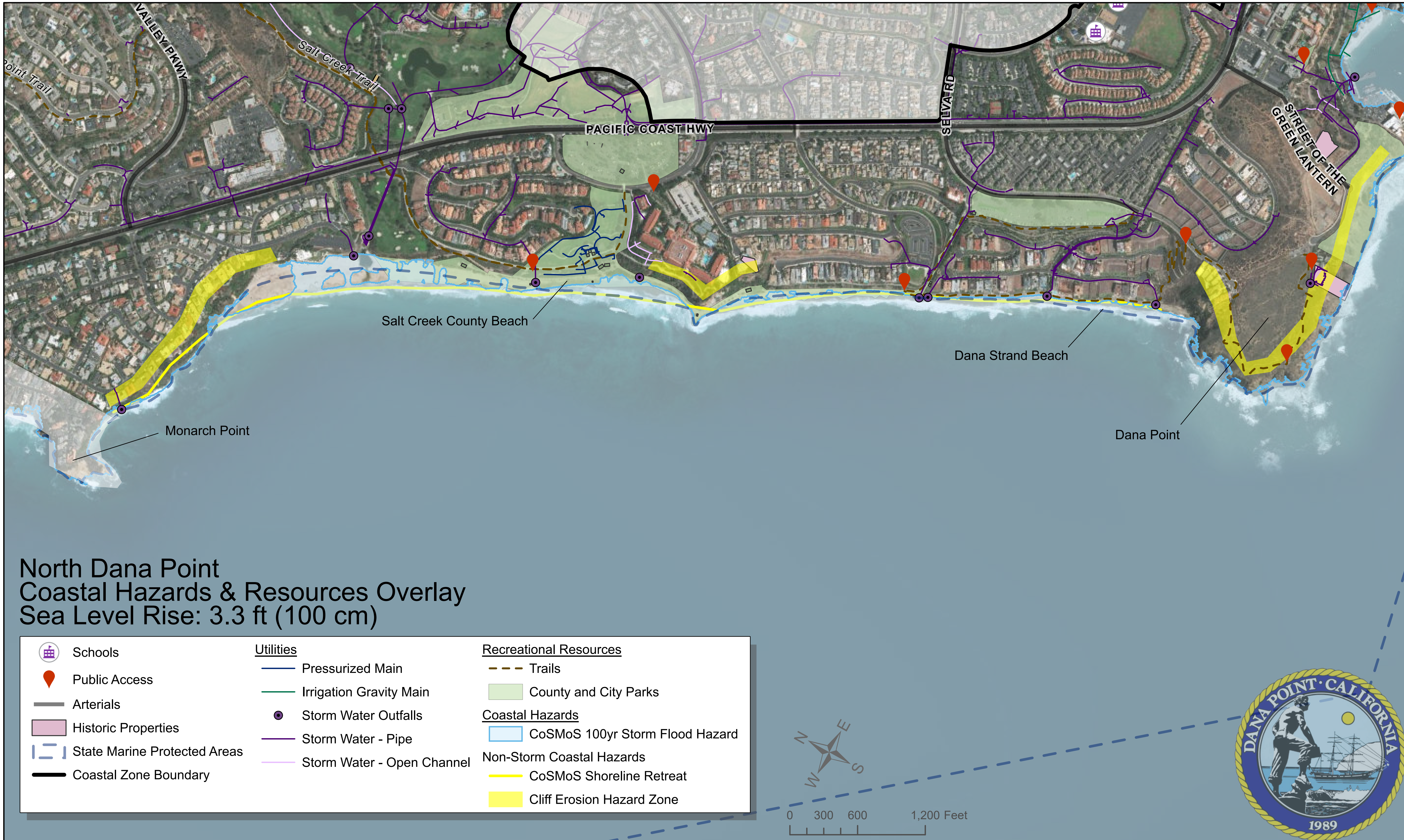


Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.

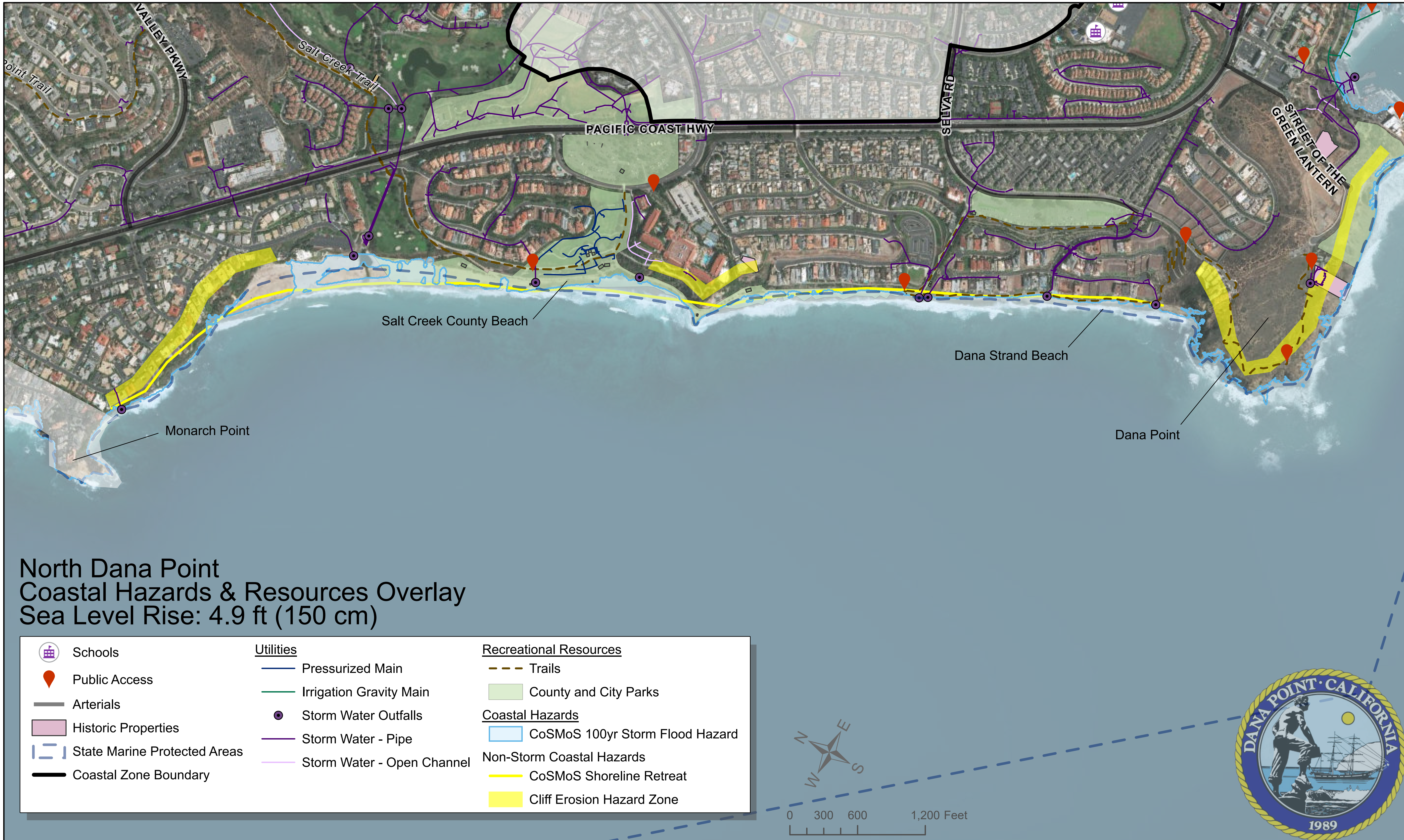


North Dana Point
Coastal Hazards & Resources Overlay
Sea Level Rise: 1.6 ft (50 cm)

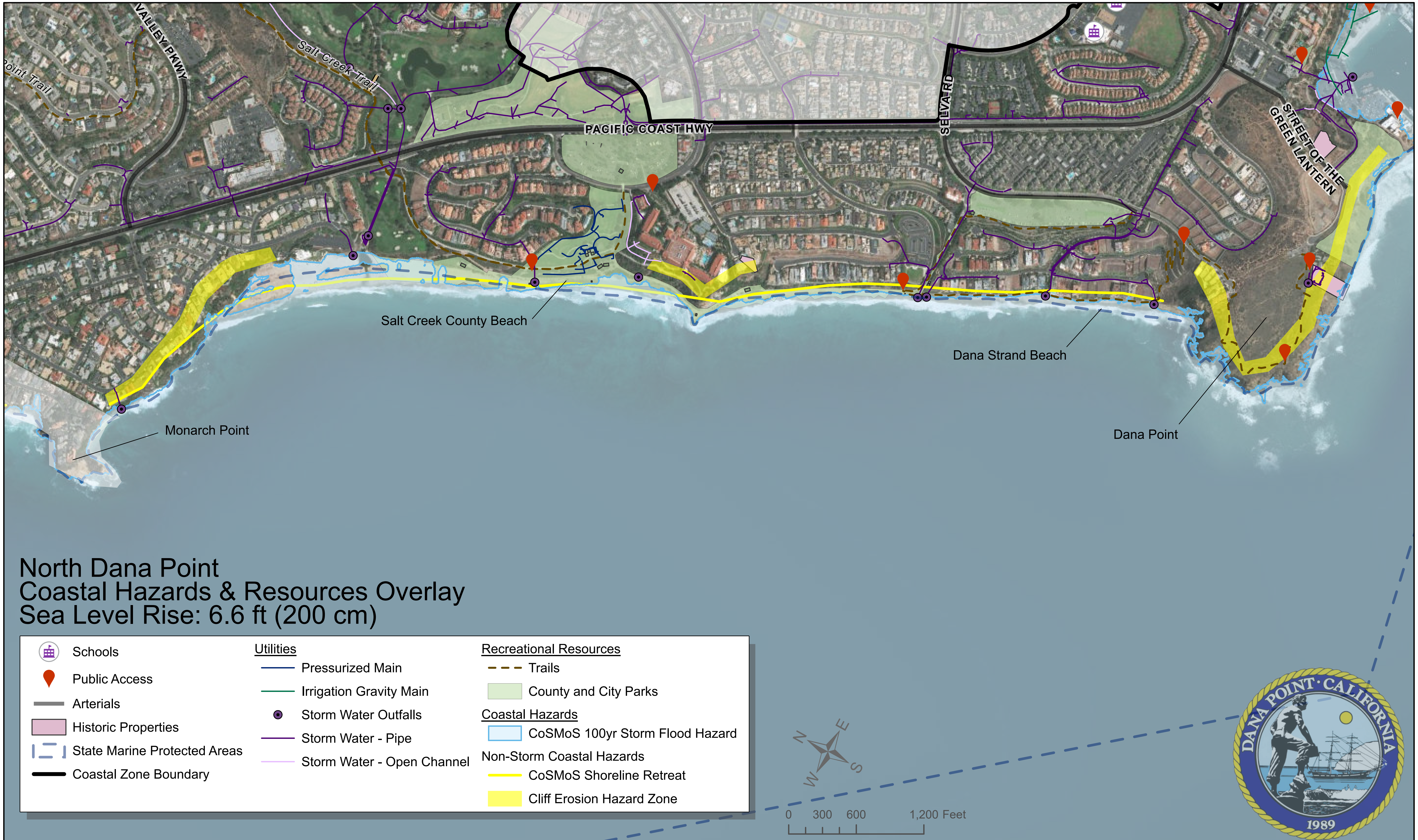
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



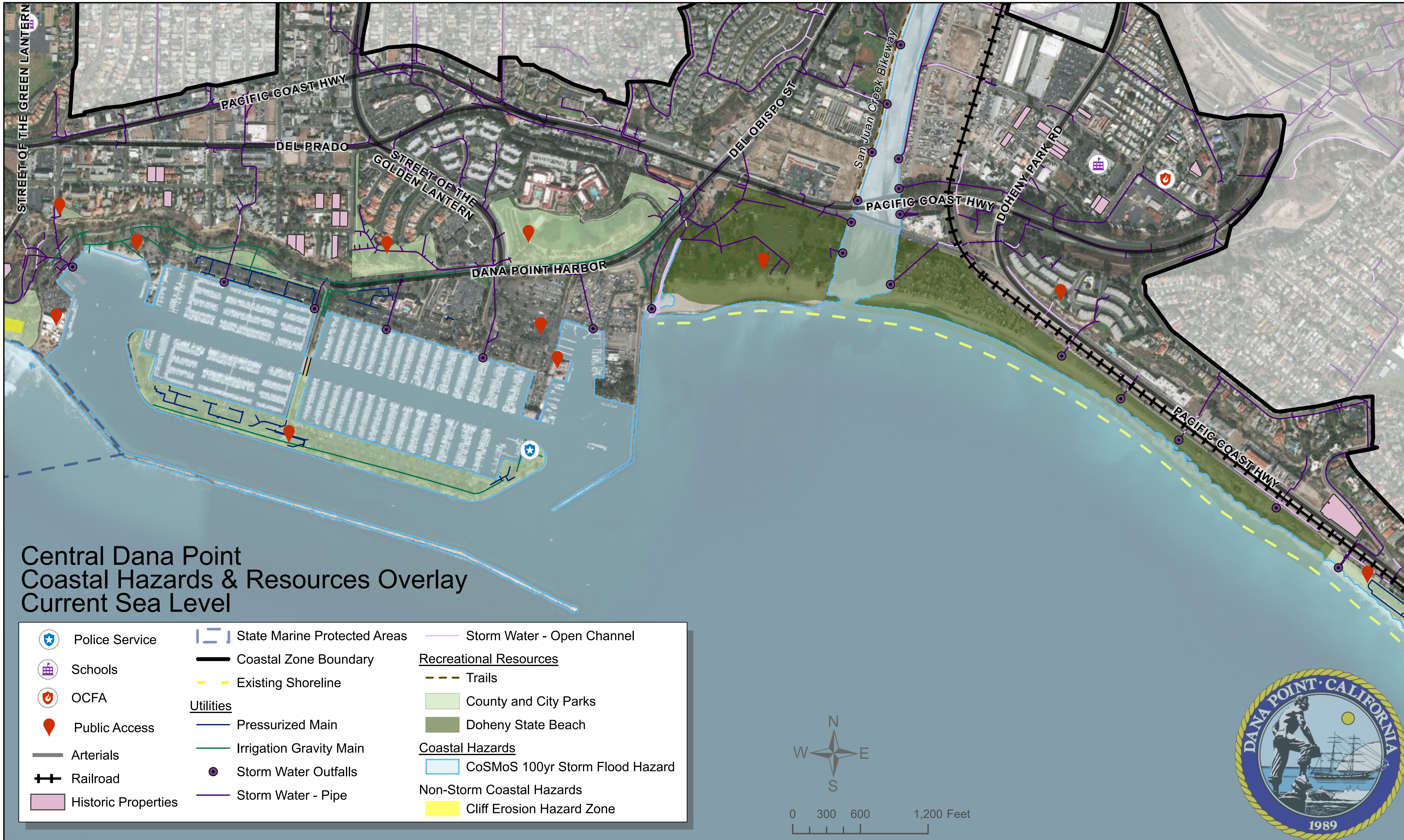
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



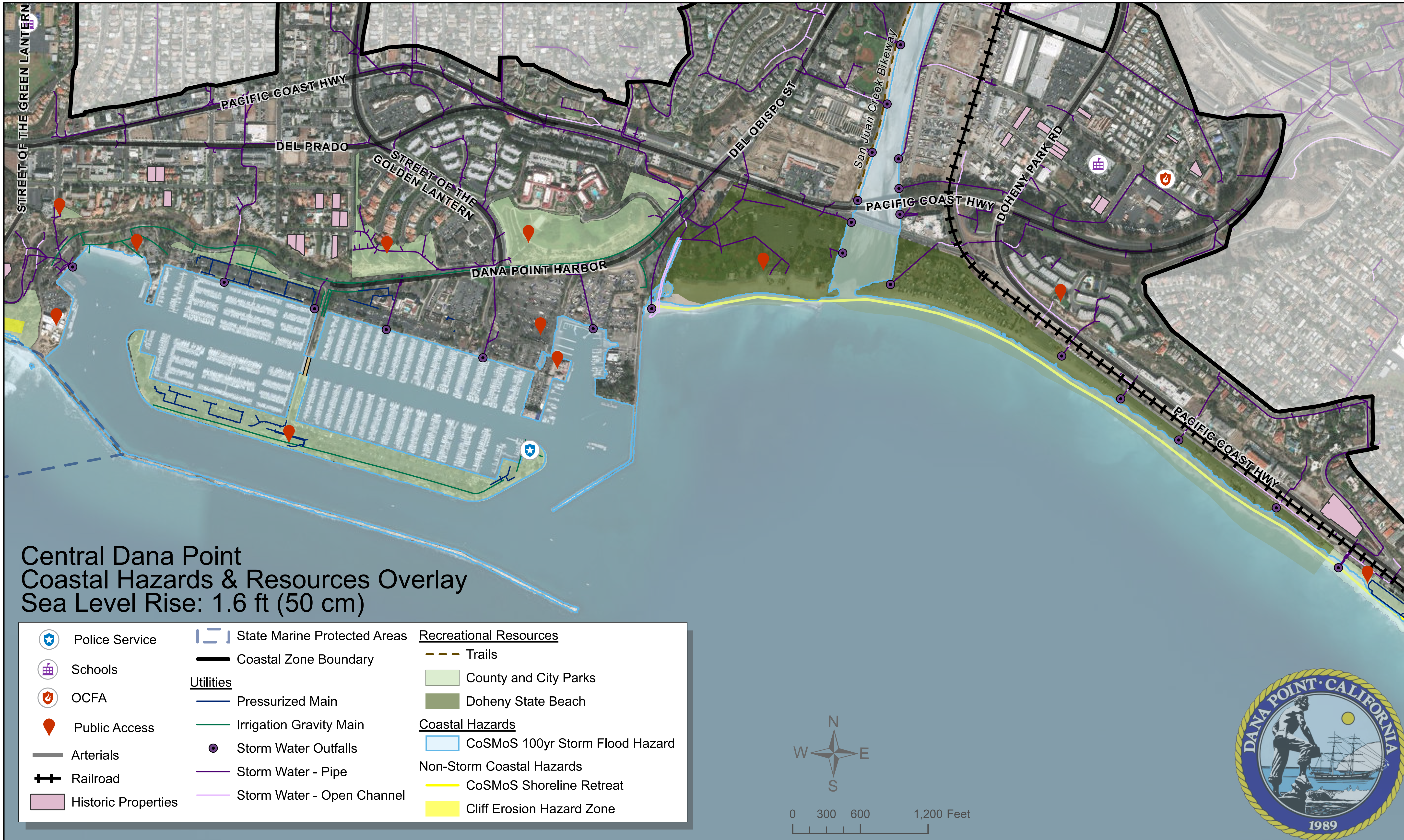
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



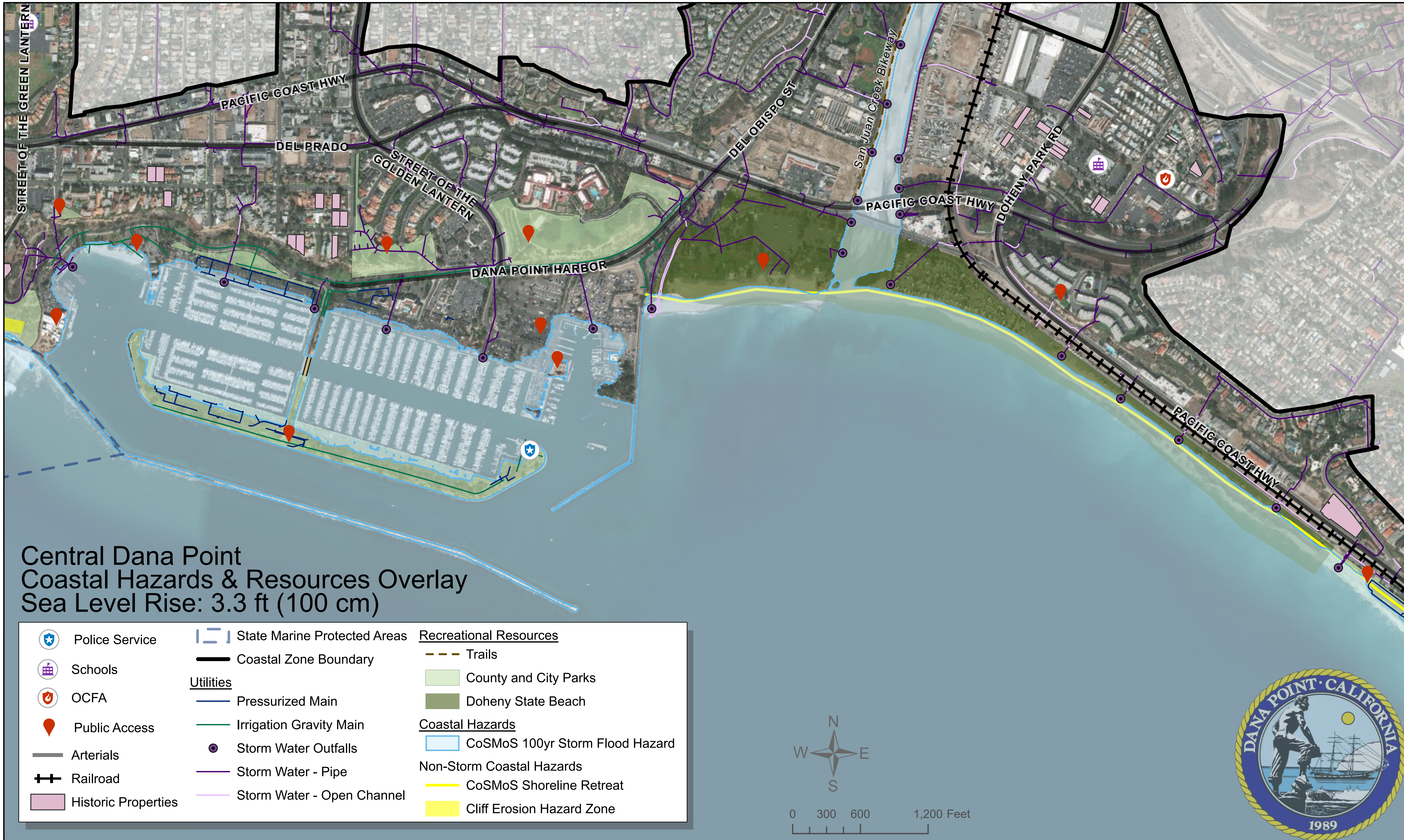
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



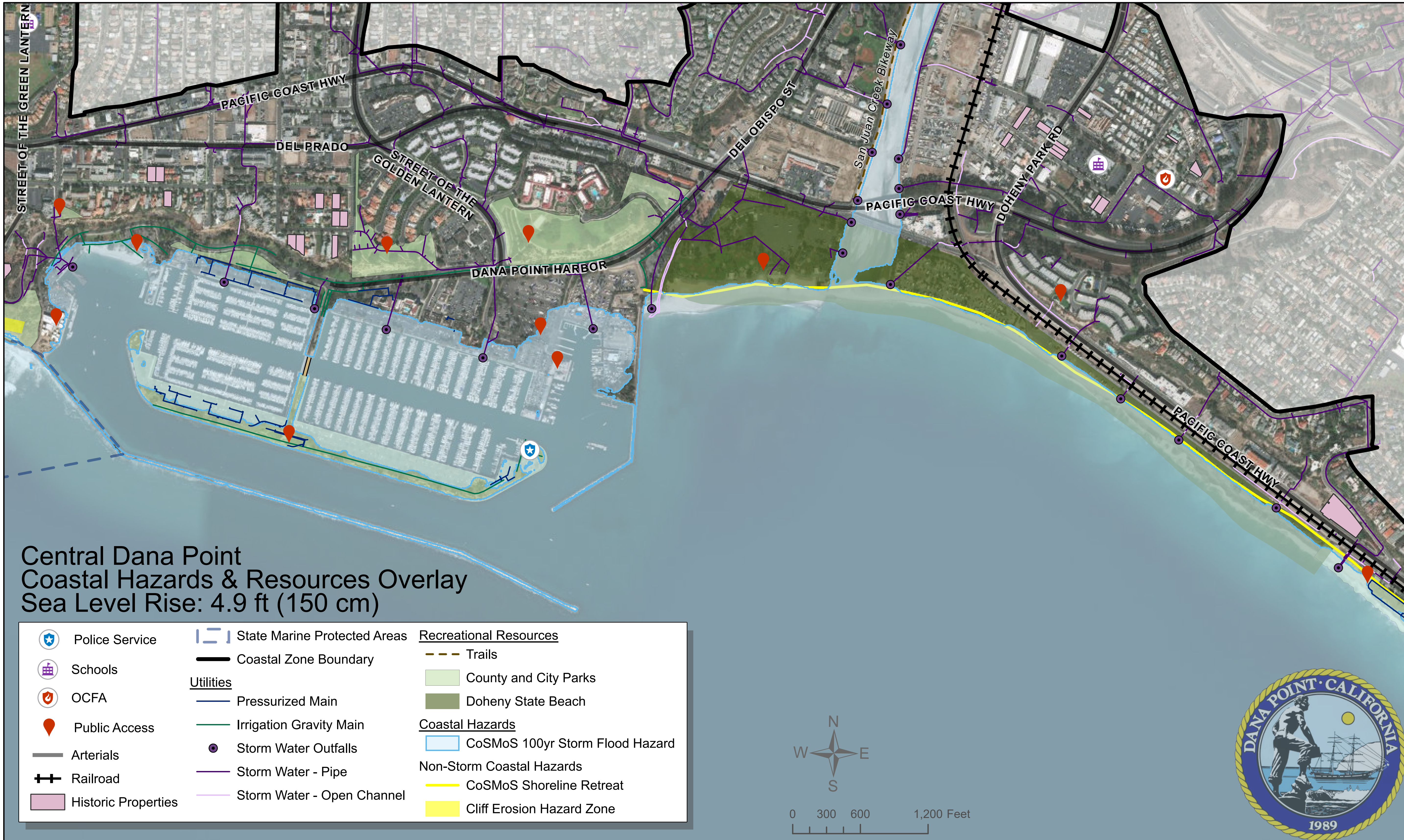
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



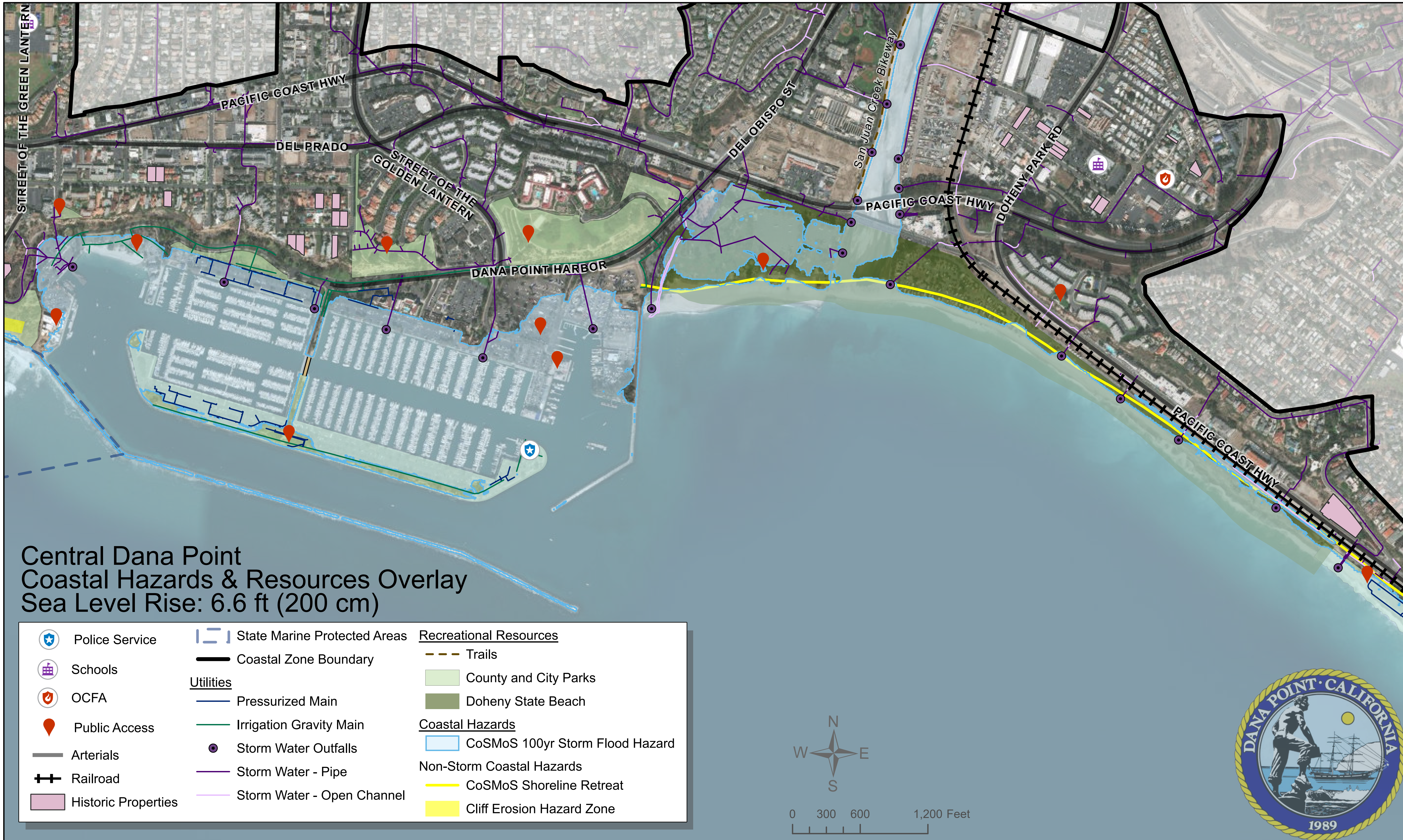
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



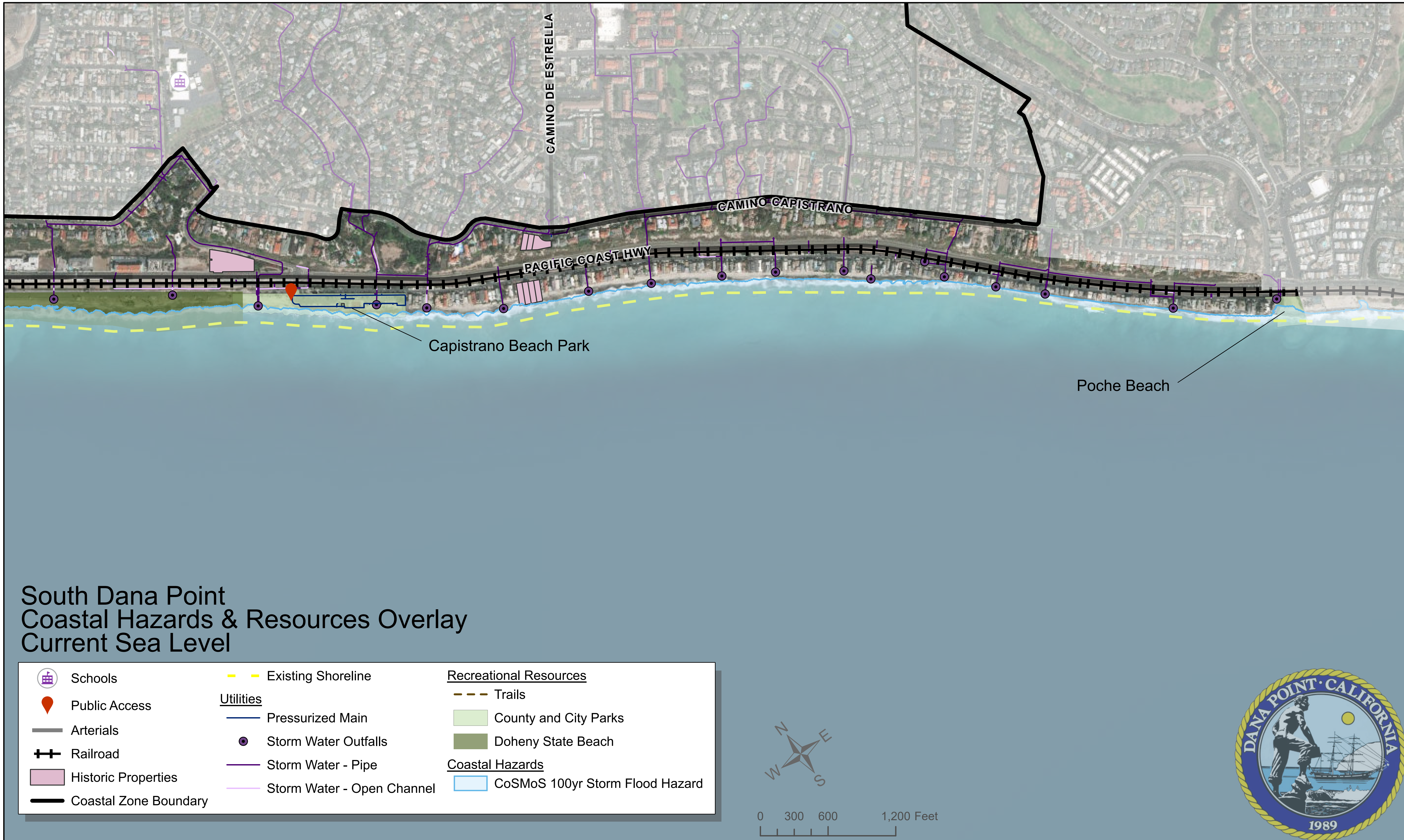
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



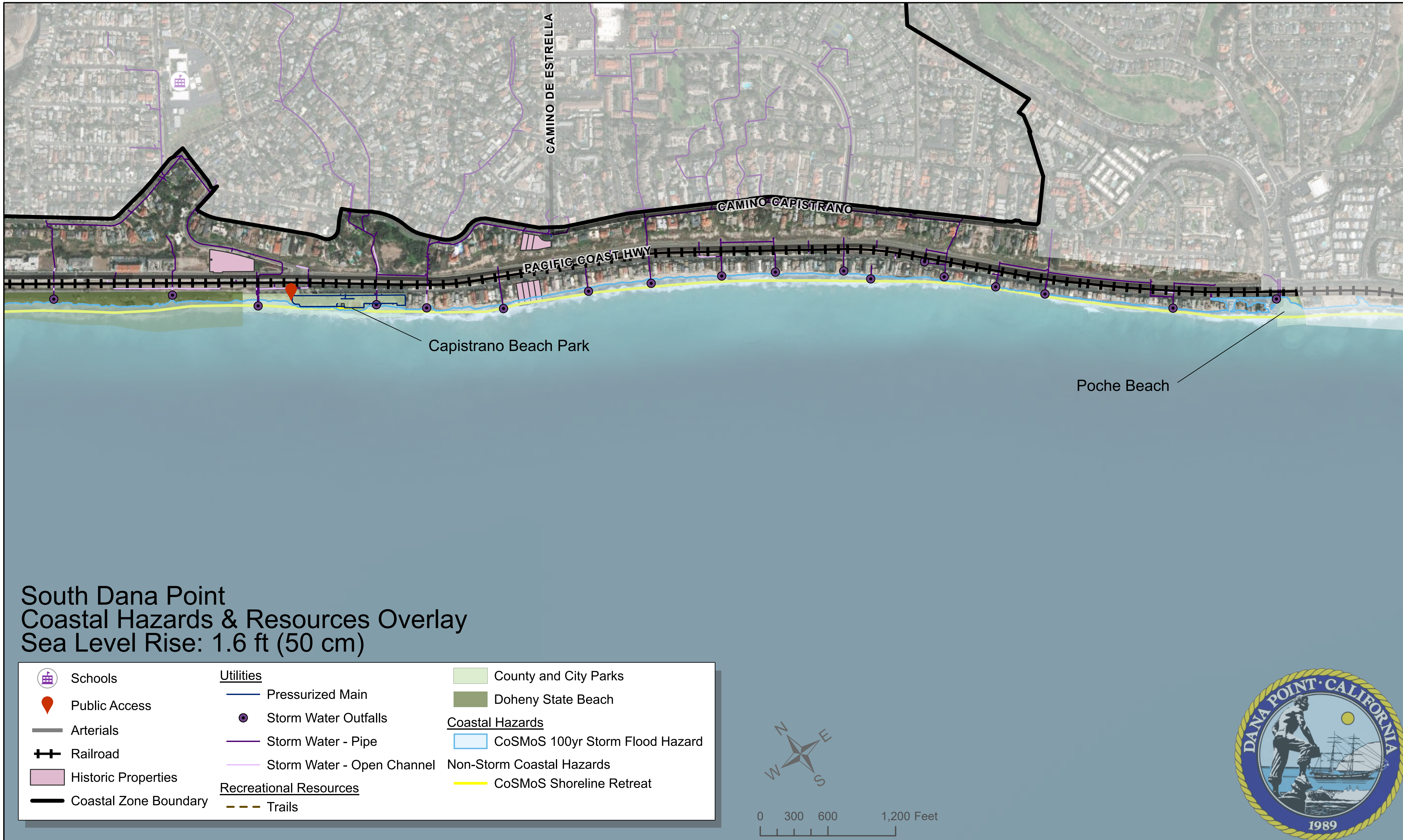
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



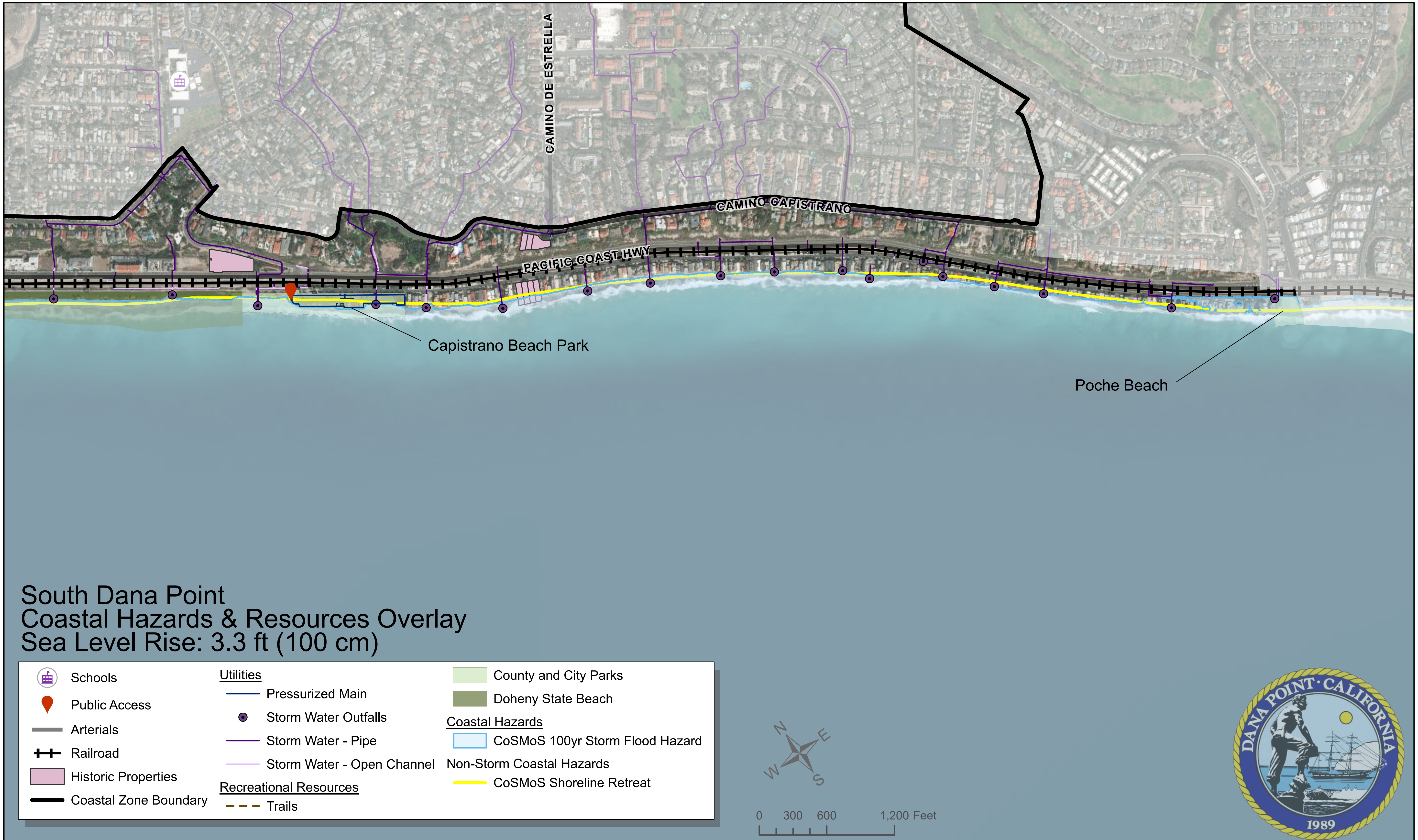
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



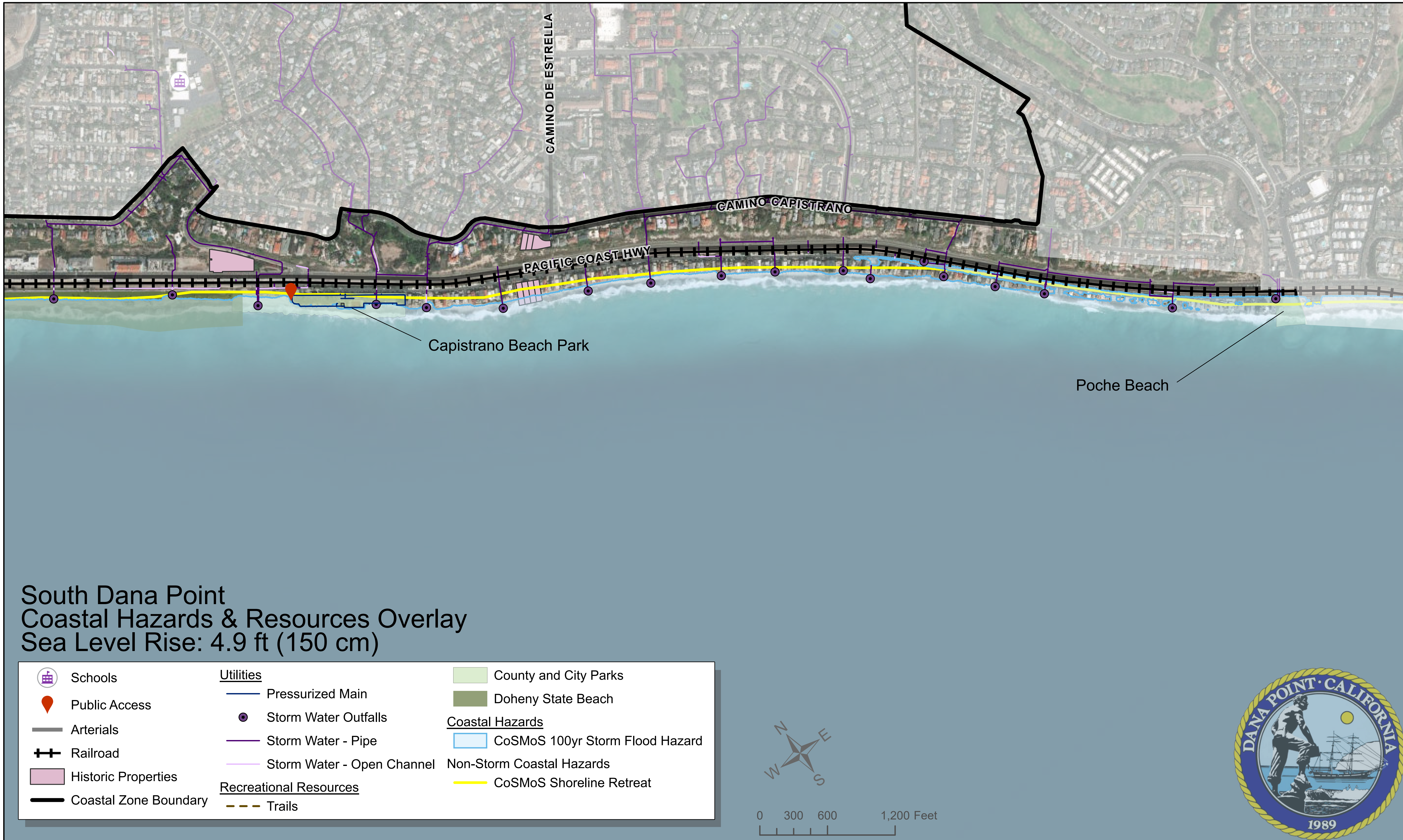
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



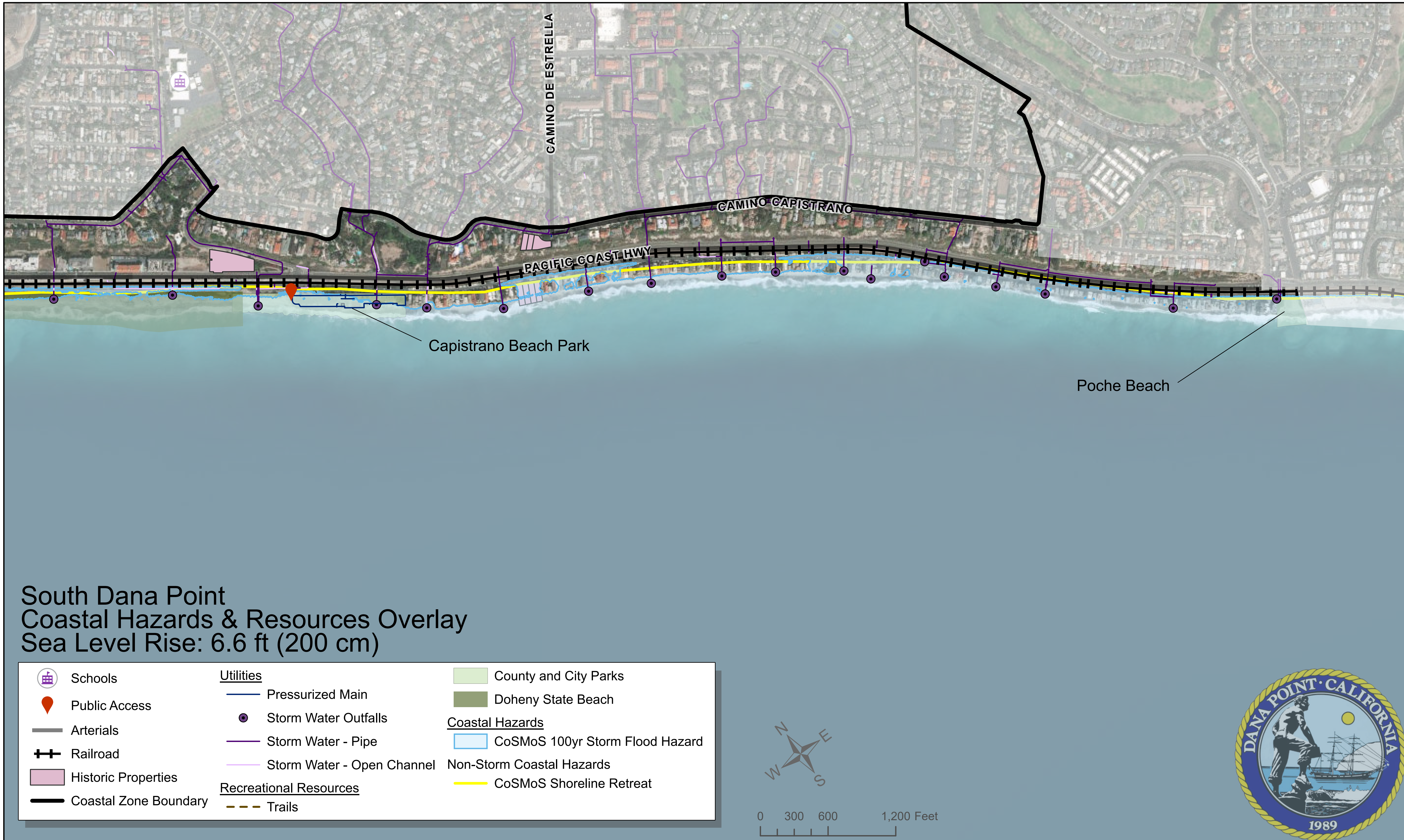
Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.



Disclaimer: Data utilized within this Vulnerability Assessment are advisory in nature and not intended as a regulatory or legal standard. Users of this product acknowledge that CoSMoS data are based on model simulations and assume all risks associated with the results and performance of the data. No warranties are made with regard to the accuracy or completeness of maps and data therein.