The City of SAN DIEGO

SEA LEVEL RISE VULNERABILITY ASSESSMENT - DRAFT

December 2019

Prepared for the City of San Diego by ICF

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ICF

Executive Summary

The City of San Diego has long recognized the need to address the risks from sea level rise, storm surge, and coastal erosion. To better understand these risks, the City has conducted this sea level rise vulnerability assessment with funding from a California Coastal Commission Local Coastal Program Local Assistance Grant.

The City undertook a five-step process to complete an initial understanding of sea level rise vulnerability, including:

1. Reviewing existing information related to climate vulnerability in San Diego;
2. Gathering the best available climate change projections and preparing maps of spatial hazards;
3. Collecting asset data on City-owned critical assets, as identified by City of San Diego departments;
4. Assessing the exposure of critical assets to sea level rise, storm surge, and coastal erosion; and
5. Characterizing the level of sensitivity and adaptive capacity of these critical assets to coastal climate hazards by conducting consultations with City department staff, reviewing departmental information, and reviewing external literature.

Together, the data revealed that the following asset types are vulnerable to coastal hazards:

- **Public safety**: fire stations, lifeguard stations, other public safety;
- **Water**: water pipes, wastewater pipes, water pump stations, wastewater pump stations, wastewater treatment plants;
- **Transportation and storm water**: bridges, major arterials, drain pump stations, outfalls;
- **Open space and environment**: recreation centers, conservation areas/open space/source water, community parks, sensitive habitat; and
- **Additional assets**: historic and cultural resources.

Ultimately, the risks identified in this assessment will depend on both the accuracy of the climate change forecasts and how the City responds to changes over the next several decades. These findings will be integrated into a broader City-wide, multi-hazard vulnerability assessment and Climate Resilient San Diego Plan.

Contents

Introduction

San Diego, located in Southern California, is home to approximately 1.4 million people. The City of San Diego (City) boasts seventeen miles of coastline and a strong economy, with key industries such as international trade, manufacturing, military and defense, and tourism.

San Diegans are a culturally diverse population: over one-quarter of residents are Hispanic or Latinx, roughly one-sixth are Asian, and less than half are white (US Census Bureau 2017). Historically, this region was home to the Kumeyaay people. The City's population is also economically diverse; approximately fifteen percent of San Diego's population lived below the federal poverty level in 2017 (US Census Bureau 2019), while nearly ten percent of households in San Diego had incomes of more than $200,000 (Esri 2018). Across the U.S., Hispanic and Latinx populations are disproportionately vulnerable to and impacted by climate change. The same is true for Native American populations, and thus likely applies to the Kumeyaay people as well. This vulnerability seems to be tied to variables such as location, employment type, income level, and access to resources (EDF, 2017; Lynn et al., 2011). Assessing vulnerability and taking proactive action to prepare for impacts from climate change is important for all San Diegans, particularly for its population of disproportionately vulnerable inhabitants.

The San Diego region is known for its impressive biodiversity and is considered a biodiversity hotspot. Many rare, threatened, and endangered plant and animal species call San Diego home, including the Torrey Pine, Southern sea otter, and Peninsular bighorn sheep.[1]

The City faces both risks and opportunities from climate change hazards. Sea level rise is occurring along the California coastline, and will lead to more extensive flooding and increased coastal erosion in the years and decades ahead. To address these hazards and better prepare for expected changes, the City is currently developing a Climate Resilient San Diego Plan (*Climate Resilient SD)*. This effort is in accordance with the City's 2015 Climate Action Plan, which identifies the need for a standalone climate adaptation plan to help the City prepare for the impacts of climate change.

The *Climate Resilient SD* Plan's primary goals are to:

- Address climate equity by prioritizing and empowering the City's most vulnerable populations to climate change, including strong consideration of communities of concern;
- Raise awareness of projected and/or potential climate change impacts to the City;
- Gain a comprehensive understanding of the City's vulnerability to climate change;
- Build City capacity for preventive and responsive action; and
- Identify potential climate adaptation and resiliency strategies.

Support for this effort comes in part from the California Coastal Commission in the form of a Local Coastal Program Local Assistance Grant. This Sea Level Rise Vulnerability Assessment Report fulfills Grant Task 2.5.

This vulnerability assessment is a technical report that presents key findings from the assessment of exposure, sensitivity, and adaptive capacity of critical built, natural, and cultural assets to coastal hazards. The focus is on City-owned assets, as the results will inform the identification of adaptation measures to protect critical City assets and services. Additionally, this assessment will inform a broader City-wide multi-

[1] San Diego State University (2005) *Overview of San Diego's Biodiversity* https://interwork.sdsu.edu/fire/resources/overview_bioderversity.htm

hazard vulnerability assessment, which includes analysis for vulnerability to additional climate hazards: precipitation driven flooding, extreme heat, and wildfires. It is anticipated the vulnerability assessment and related mapping would be updated approximately every ten years, or as necessary to address significant changes in climate change hazard projections.

Background

Under the City of San Diego's 2015 Climate Action Plan (CAP), the City has already undertaken bold steps to mitigate impacts of climate change and to reduce its greenhouse gas emissions. The CAP calls for promoting the City's prosperity and quality of life by building communities that are resilient to climate change, recognizing that some degree of climate change will occur regardless of the City's effort to reduce and mitigate greenhouse gas (GHG) emissions.

- Chapter 5 of the CAP specifically calls for the development of a standalone climate adaptation plan that will integrate and build upon the strategies and measures in the CAP. This vulnerability assessment will inform that climate adaptation plan.
- The City of San Diego's *2018 General Plan Amendments* (2018) revised the General Plan's Public Facilities, Services and Safety Element to include goals and policies that address wildfire hazard severity zones.

Other Local Efforts

- The San Diego County *Multi-jurisdictional Hazard Mitigation Plan* was last revised in 2017. The City of San Diego contributed a chapter to this plan, providing information on the City's critical facilities and potential exposures and losses related to climate change hazards including coastal storms and erosion, sea level rise, floods, rain-induced landslides, wildfire, and non-climate-related hazards such as earthquakes, dam failures, and tsunamis. The City's plan includes six hazard mitigation goals, along with objectives and prioritized action items to achieve them. The information relating to climate change hazards gathered by the City for the Hazard Mitigation Plan helped inform this vulnerability assessment.
- The ICLEI–Local Governments for Sustainability *Sea Level Rise Adaptation Strategy for San Diego Bay* (2012) provides a high-level analysis of vulnerable sectors and impacts to the San Diego Bay lands. The study focused on flooding, inundation, erosion, saltwater intrusion, and water table rise. It identified resilience strategies for both regional and local implementation, as well as strategies targeted to the sectors included in the analysis (ecosystems and critical species, contaminated sites, storm water management, wastewater, potable water, local transportation facilities, building stock, emergency response facilities, parks, recreation, and public access, regional airport operations, and vulnerable populations). The high-level vulnerability analysis helped inform this report.
- The ICLEI–Local Governments for Sustainability *San Diego Coastal Resilience Assessment* (2017) is a local sea level rise vulnerability assessment that included the coastal areas from Point Loma to Del Mar, excluding Mission Bay. The assessment identified sea level rise coastline impacts related to changes in flood frequency and extent, inundation, changes in sedimentation supply and movement, high rate of erosion, and saltwater intrusion and groundwater inundation. The assessment focused on building stock, the social sector, storm water, wastewater, water, transportation, beaches and public access, and biodiversity and habitat. These findings helped inform this vulnerability assessment with respect to coastal hazards.
- The Scripps Institute of Oceanography *Beach and Coastal Cliff Survey* (ongoing) is currently collecting data on beach sand levels from La Jolla Shores Beach to Oceanside. These data can

provide greater insight into coastal hazards, which are considered in this vulnerability assessment.

- From 2013 to 2019, the City of San Diego partnered with the U.S. Bureau of Reclamation to complete the *San Diego Basin Study*. The study uses the latest change modeling tools to perform a quantitative analysis of the uncertainties associated with climate change impacts on the San Diego Basin's local and imported fresh water supplies. A goal of this study is to assist water agencies serving the Basin and San Diego Integrated Regional Water Management planning region in adapting to climate change-related uncertainties.
- The *San Diego Regional Climate Collaborative's Resilient Coastlines Project* (ongoing) is building coastal resilience in the region by translating sea level rise and coastal storm science into planning, building local leadership, and holding living shorelines workshops.

The *Climate Resilient SD* plan will complement and build upon these existing efforts.

State Guidance and Resources

The following state guidance is applicable to the City's resilience planning efforts:

- The California Ocean Protection Council and California Natural Resources Agency's State of California Sea-Level Rise Guidance 2018 Update (2018) provides: "1) a synthesis of the best available science on sea level rise projections and rates for California; 2) a stepwise approach for state agencies and local governments to evaluate those projections and related hazard information in decision-making; and 3) preferred coastal adaptation approaches."
- The Governor's Office of Planning and Research, California Natural Resources Agency, and California Energy Commission's California's Fourth Climate Assessment (2018) was designed "to address critical information gaps that decision-makers need at the state, regional, and local levels to protect and build resilience of California's people and its infrastructure, natural systems, working lands, and waters." The City is using findings published in the Fourth Assessment that pertain to sector vulnerability, sensitivity, and adaptive capacity.
- The California Natural Resources Agency's Safeguarding California (2018) is "the State's roadmap for everything state agencies are doing and will do to protect communities, infrastructure, services, and the natural environment from climate change impacts." The City is using this resource to help coordinate adaptation with state efforts and to find examples of adaptation strategies.
- The California Coastal Commission's Sea Level Rise Policy Guidance (2018) provides the best available science on sea level rise specific to California, paired with a recommended methodology for addressing sea level rise in Coastal Commission planning and regulatory actions. The City followed this guidance in assessing its vulnerabilities to sea level rise.
- The Governor's Office of Emergency Services' California Adaptation Planning Guide (2012) provides guidance for local jurisdictions in addressing climate change impacts. The City referred to this guide when developing its framework for adaptation planning. The City is also working with the Governor's Office to inform the development of the updated California Adaptation Planning Guide planned for publication in 2020.

Vulnerability Assessment

Methods

This vulnerability assessment uses quantitative and qualitative climate hazard and asset data to analyze the three components of vulnerability—exposure, sensitivity, and adaptive capacity.

Data Collection and Consultations

This analysis began with a review of existing information on climate vulnerability in San Diego to identify information gaps, and to determine actions the City and State were already taking to prepare for and respond to climate change. Climate hazard data was collected from the best available scientific sources and consultations were conducted to identify critical assets and compile asset data.

Coastal Hazard Data

Climate change related coastal hazards in this report include sea level rise, coastal flooding, and coastal erosion. Saltwater intrusion is a secondary hazard, but there is insufficient scientific data to warrant a detailed assessment of when and where saltwater intrusion may occur. Saltwater intrusion is a hazard because it can seep into groundwater resources, such as the San Diego Formation aquifer, and can therefore impact water quality. As saltwater intrusion's effects on groundwater are not well understood at this time, further monitoring and study in conjunction with academia, is recommended.

The Coastal Storm Modeling System (CoSMoS) was used to capture sea level rise spatial data under baseline and storm scenarios for 0.25m, 0.5m, 0.75m, 1.0m, 1.5m, and 2.0m of sea level rise, assessing a total of twelve scenarios. CoSMoS is a U.S. Geological Survey model that makes "detailed predictions of coastal flooding due to both future sea level rise and storms integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat)" along the California coast (USGS n.d.).

A memorandum was developed on the selection of climate change data and scenarios and the San Diego-specific findings of these climate data and scenarios. The findings pertaining to coastal hazards are presented below.

Sea Level Rise and Storm Surge

Sea levels rose 0.71 feet in San Diego during the 20th century (NOAA 2018). By the end of the 21st century, San Diego could experience another 3.6 to 10.2 feet of sea level rise.

Coastal storms are projected to occur more frequently in the future, which will further exacerbate flooding along the coast.

Past and Present Conditions: Over the past century, mean global sea level has risen approximately 1.7 mm per year (about 0.07 inches per year) accelerating to a rate of 3.2 mm per year (about 0.13 inches per year) since 1993 (IPCC 2013). From 1906 to 2017, the tide gage at San Diego suggests a rise of around 2.17 mm per year (about 0.09 inches per year), approximately 32% higher than the global rate (see Figure 1) (NOAA 2018).

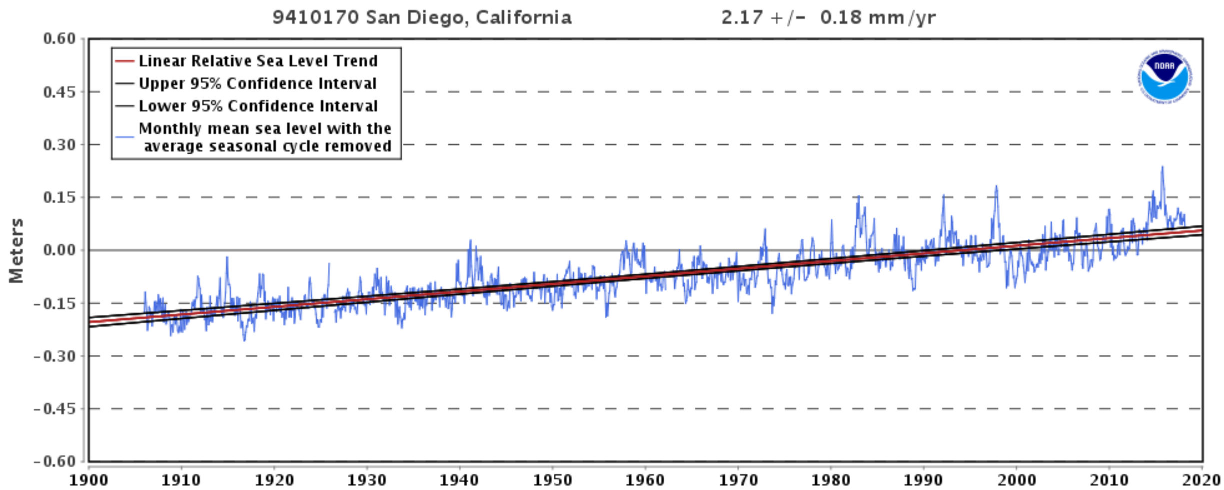


Figure 1. The relative sea level trend is 2.17 millimeters/year with a 95% confidence interval of +/- 0.18 mm/yr. based on monthly mean sea level data from 1906 to 2017; this is equivalent to an increase of 0.71 feet in 100 years (tide gauge 9410170, San Diego, CA).

Future Conditions: According to the recent California Coastal Commission Sea Level Rise Policy Guidance November 2018 update, sea levels in San Diego may rise by 0.6 to 1.1 feet by 2030, 1.2 to 2.8 feet by 2050, and 3.6 to 10.2 feet by 2100 (California Coastal Commission 2018). Similarly, Kalansky et al. (2018) found that in San Diego County, sea level is projected to rise by approximately 1 foot by mid-century, and 3 feet or more by end-of-century. This range demonstrates a level of uncertainty associated with estimating SLR in the long term, particularly in the latter half of the 21st century. The contribution of thermal expansion (i.e., ocean water volume expanding as ocean water warms) and small glaciers to SLR is relatively well-researched, whereas the impacts of climate change on large ice sheets are less understood. In general, SLR is projected to accelerate toward the second half of the century. See Table 1 for a description of the scenarios considered in this report.

Notably, a variety of factors affect local relative SLR (i.e., the SLR projections for a specific location rather than global average SLR), including vertical land movement, ocean dynamics, and changes in the Earth's gravitational and rotational fields (NRC 2012). Through 2100, San Diego is projected to subside at a rate of 1.4 mm/year, and the glacial geostatic adjustment[2] is projected to cause local relative sea level to increase by 0.4 mm/year (NRC 2012). These values are factored into SLR projections presented here for the San Diego region.

SLR and storm surge scenarios from the CoSMoS SLR and storm surge (100-year flood) modeling are being integrated into an interactive online map that will be used to explore current and future flood risks. The primary CoSMoS layers in this map are provided in Table 1. The 1.5-meter CoSMoS scenario, while not listed in the table, is also included in the analysis to provide additional insight on the timing and phasing of future flooding. The mapping tool will include daily inundation and 100-year storm events for each of the SLR

[2] The Earth's crust is still reaching a state of equilibrium after the melting of the glaciers at the end of the last ice age. This process is called glacial geostatic adjustment. Some locations that were compressed due to the huge weight of the ice are still rebounding, while areas that were near to but not covered by glaciers were pushed up during the ice age and are still subsiding.

increments (Table 1). Note that daily inundation and daily flooding mean the same thing, and both relate to SLR exposure.

Values for SLR projections come from the best available science in California, as well as official state guidance. The Coastal Commission Guidance is used in planning and regulatory actions throughout the state, and the recent science update reflects scientific studies up through 2018. Kalansky et al. (2018)'s *San Diego Summary Report* is a part of California's Fourth Climate Change Assessment and is thus also associated with official state guidelines. CoSMoS, created and run by the United States Geological Survey, has been used by multiple federal, state, and community partners throughout California. While SLR projections in these sources may change slightly in future updates due to the dynamic nature of climate change, these changes are unlikely to be significant in magnitude.

Table 1: California Coastal Commission SLR Scenarios and corresponding CoSMoS increment[3].

Year	Low Risk Scenario 17% probability SLR meets or exceeds		Medium-High Risk Scenario 0.5% probability SLR meets or exceeds		Extreme Risk Scenario H++ scenario, no assigned probability	
	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment	CCC 2018 Projection	Closest CoSMoS Increment
2030	0.6 ft.	0.25 m (0.8 ft.)	0.9	0.25 m (0.8 ft.)	1.1 ft.	0.25 m (0.8 ft.)
2050	1.2 ft.	0.25 m (0.8 ft.)	2.0 ft.	0.5 m (1.6 ft.)	2.8 ft.	0.75 m (2.5 ft.)
2100	3.6 ft.	1 m (3.3 ft.)	7.0 ft.	2 m (6.6 ft.)	10.2 ft.	2 m (6.6 ft.)

[3] The recent California Coastal Commission (CCC) Sea Level Rise Policy Guidance November 2018 update provides three sets of SLR projections: projections for low, medium-high, and extreme risk aversion. The SLR projections associated with low risk aversion should be used to inform planning for development with high adaptive capacity and relatively low associated consequences if impacted by SLR, such as temporary or seasonal development, or development that can be easily moved. The projections labeled "medium-high risk aversion" are appropriate for informing less adaptive, more vulnerable land uses that will experience medium to high consequences if impacted by SLR, including residential and commercial development. The projections labeled "extreme risk aversion" and "H++" are appropriate for development that, if impacted by SLR, would be irreversibly destroyed, would be significantly costly to repair, and/or would have considerable public health, public safety, or environmental impacts.

Extreme flood frequency is expected to increase under all projections of SLR. In addition, rising seas boost the occurrence of severe floods (such as the 500-year flood) more than moderate floods (such as the 10-year flood) along the Pacific coast of the United States (Buchanan 2017). By elevating storm tide, SLR makes it easier for waves to surpass natural barriers, increasing the relative frequency of flooding along the Pacific coast.

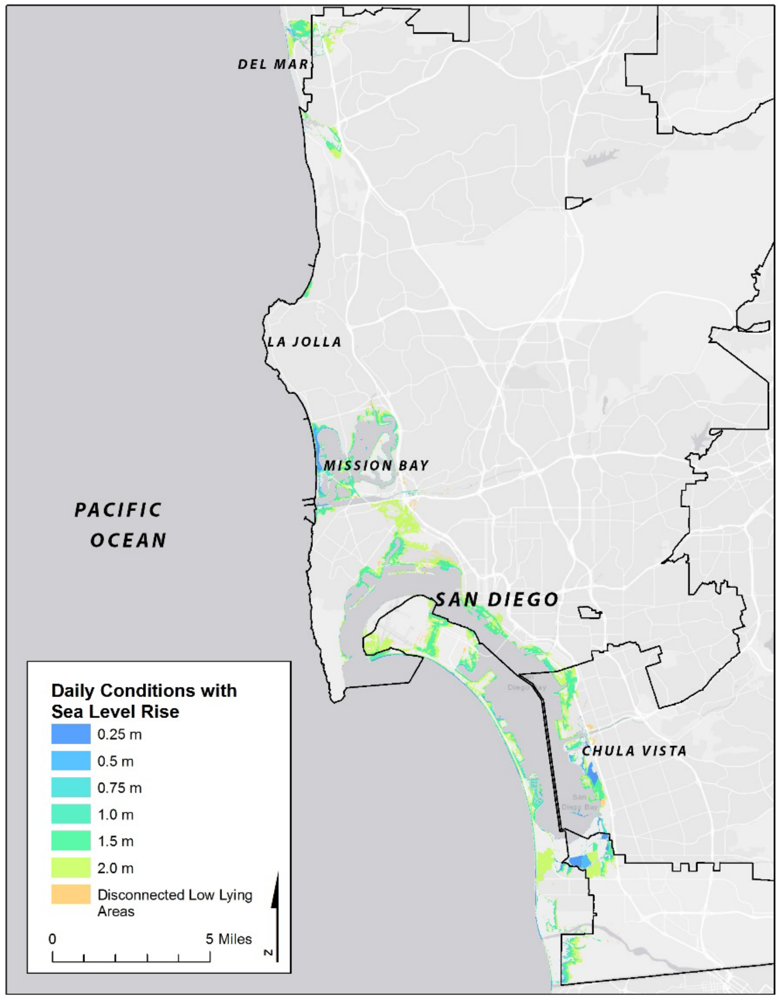


Figure 2. Exposure to daily flooding in San Diego given various levels of sea level rise. Larger versions of this map are available in the Appendix. Image source: ICF, based on SanGIS and CoSMoS data

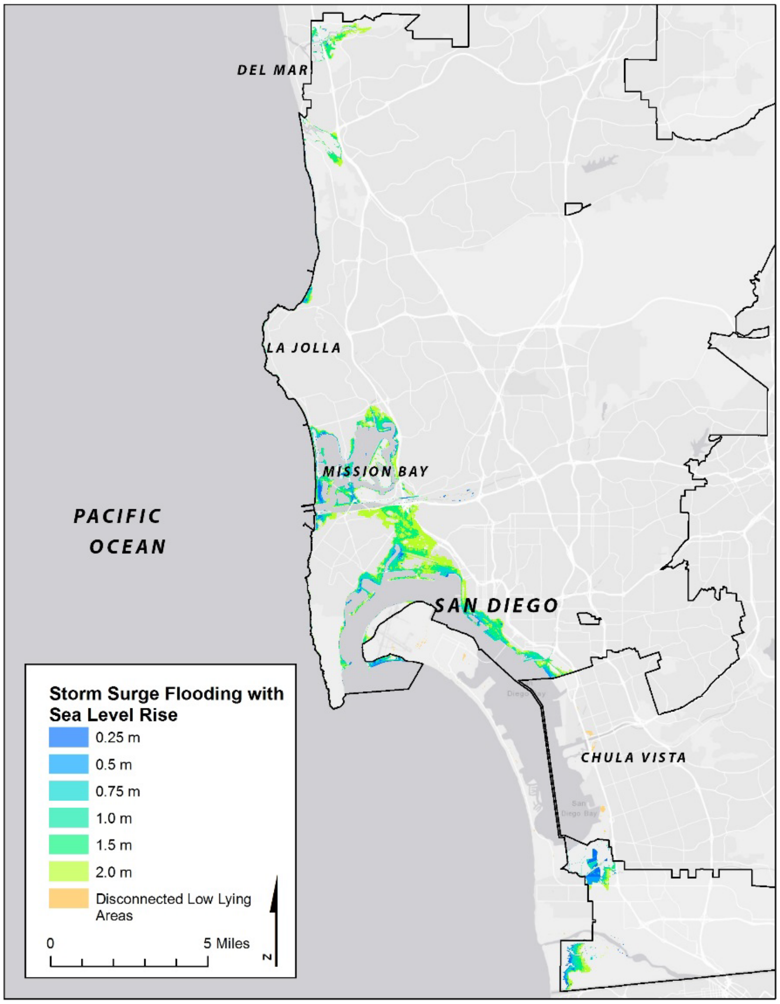


Figure 3. Exposure to storm surge flooding in San Diego given various levels of SLR. Larger versions of this map are available in the Appendix. Image source: ICF, based on SanGIS and CoSMoS data

Coastal Erosion

Coastal erosion has historically occurred along Sunset Cliffs, La Jolla Cove, and Torrey Pines. In addition, new sand placement on beaches is needed to maintain beach width. Coastal erosion is expected to increase with sea level rise and changes in storms, though there is uncertainty regarding where and when it may occur.

Past and Present Conditions: The relatively soft sandstone bluffs that are common along the San Diego coast are prone to erosion from waves and from storm water runoff. The last City-wide coastal erosion assessment, consisting of geotechnical reports, site visits, and photographic documentation of erosion, was completed in 2003 (City of San Diego 2003). That study identified eleven high-priority sites with conditions that "presented potential public hazards". These sites included:

1. Osprey Street to Adair Street (Spalding Park)

2. Hill Street to Guizot Street
3. Guizot Street to Froude Street
4. Froude Street to Osprey Street
5. Nautilus Street to Westbourne Street (Stairwell)
6. Diamond Street to Missouri Street
7. Coast Boulevard – split to Children's Beach (bluff top and sidewalk)
8. La Jolla Cove (North of 1325 Coast Blvd)
9. Mission Beach Park
10. Sun Gold Point to Cortez Place
11. Pt. Loma Ave to Bermuda Ave (Pt. Loma Ave street-end and storm drain)

Figure 4. Erosion assessment images for Hill Street to Guizot Street from 1993, 2003, and 2018. Source: ICF 2018

In 2018, the City prepared an update of the 2003 assessment (ICF 2018). This update included revisiting the sites from the 2003 assessment to take new photographs and document visual changes in the level of erosion (Figure 4). The update indicated that although the City has made improvements to both pedestrian access and safety at erosion sites, coastal erosion continues to impact the coastline. 21% of the 71 evaluated sites were ranked as high priority, meaning they pose potential pedestrian hazards, have limited pedestrian access to the site, or show signs of imminent bluff collapse.

Future Conditions: Cliff erosion is likely to increase with SLR and heavier rainfall events, but modeling when and where this will occur can be difficult. New research by the Scripps Institute of Oceanography indicates that cliffs cycle through periods of erosion and stability, meaning that historical erosion rates are not always an accurate predictor of future erosion (Young 2018). Areas that have been stable for some time may start eroding while areas that have been actively eroding may stabilize. Research, however, has not yet determined how to predict when cliff erosion may slow or accelerate.

Beach erosion is also likely to accelerate with SLR. While the City currently nourishes the beaches, it is likely that historical rates of nourishment will be insufficient to halt future beach erosion. A recent study (Vitousek 2017) found that, although subject to considerable uncertainty, significant impacts to the shoreline will occur due to accelerated SLR, with 31% of beaches in Southern California lost by 2100 under a projection of 0.93 meter (3 feet) of SLR.

To provide a preliminary understanding of the locations and potential extent of future coastal erosion risks in San Diego, the CoSMoS cliff erosion and shoreline change data (see Figure 5 and Figure 6) was assessed. The sandy beach projections include modeling of alongshore and cross-shore transport due to waves and SLR. The cliff erosion projections assume that cliffs will erode and fail as they are undermined and affected by wave action. While CoSMoS provides several scenarios to account for varying levels of investment in coastal armoring, there is still significant uncertainty in the projections due to uncertainties:

- in engineered protection structure life,
- in human behavior to protect the coast and maintain existing structures,
- surrounding potential changes in coastal policy, and
- in future rates of sand nourishment.

More information on the erosion scenarios and uncertainties is available at the CoSMoS FAQ page.

Based on this identified vulnerability, the best available spatial projections from CoSMoS for coastal erosion in the area were selected, covering shoreline and cliff retreat under a Medium-High Risk Aversion Scenario of 2.0 m of SLR by 2100 (see Table 3) for four scenarios (USGS n.d.):

- Beach erosion:
  - "No hold no nourish" assumes the shoreline is allowed to retreat unimpeded and with no human increases in sediment (i.e., beach nourishment).
  - "Hold, continued nourish" assumes the shoreline retreat is limited to an urban boundary and sediment is increased.
- Cliff retreat:
  - "Let it go" avoids coastal armoring and allows the cliff to retreat and cliff erosion rates to increase as SLRs.

For the purpose of this assessment, beach erosion considers erosion of non-cliff shorelines, while cliff retreat considers erosion of cliffs along the coastline.

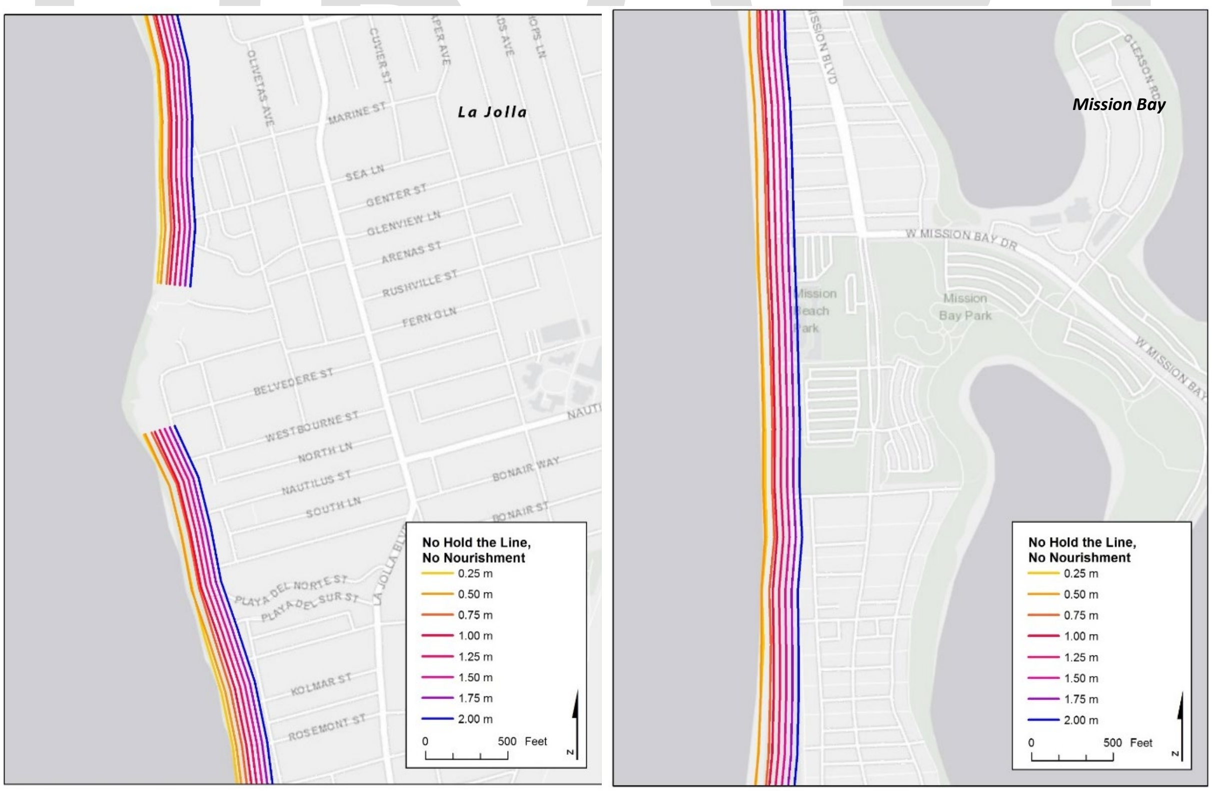


Figure 5. Coastal erosion scenarios given no protection and varying levels of SLR at La Jolla (left) and Mission Bay (right.) Larger maps are available in the Appendix. Source: ICF, based on SanGIS and CoSMoS data

In these maps, "No Hold the Line" and "No Nourishment" assumes that current coastal armoring will not be maintained, and the shoreline is allowed to retreat unimpeded and with no increases in sediment.

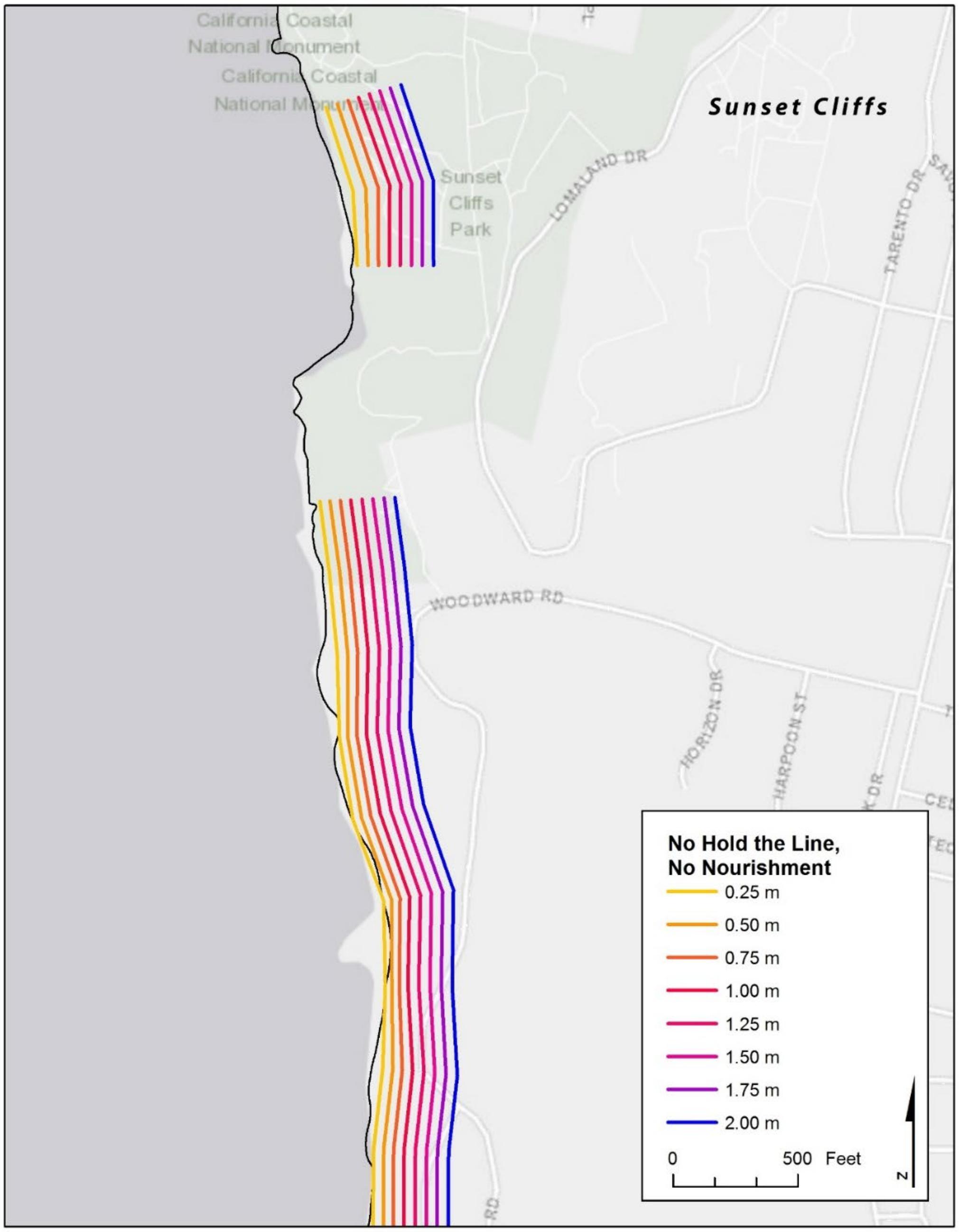


Figure 6. Coastal erosion scenarios given no protection and varying levels of SLR at Sunset Cliffs. Larger maps are available in the Appendix. Source: ICF, based on SanGIS and CoSMoS data

Selecting Critical City Assets

At the outset of this assessment, asset-owning City departments were consulted to identify which built, natural, and cultural assets owned and/or managed by the City could be considered critical. The selection criteria were:

- If the asset/resource (or its function) is necessary for continuity of important City operations;

- If the asset/resource (or its function) is a key driver in the City's economy;
- If loss of the asset/resource would present equity issues;
- If the asset/resource is critical to safeguarding biological diversity and other environmental considerations.

Table 2 provides a breakdown of the sectors under consideration, the asset-owning City department, and the identified critical. Only critical assets are included in the vulnerability assessment. Not all assets in this list were found to be exposed to coastal hazards.

Table 2. City of San Diego departments and corresponding critical assets

Sector	City Department(s)/ Divisions	Identified Critical Assets
Public Safety	Fire-Rescue, Police	• fire stations • police stations • lifeguard stations • fire trucks/engines • police patrol and specialty vehicles • other public safety (Critical Incident Management Unit equipment location (20th & B); police communications, maintenance facilities (Northern Storefront, evidence & property locations, Emergency Communications Center, Multicultural Storefront, Northern Boat Docks)
Water Infrastructure	Public Utilities	• dams • water pipes • wastewater pipes • water pump stations • wastewater pump stations • distribution reservoirs • water treatment plants • wastewater treatment plants
Transportation[4]	Transportation and Storm Water; Real Estate Assets (Airports)	• Montgomery and Brown Airports • bridges • major arterials
Storm Water	Transportation and Storm Water	• drain pump stations • outfalls
Open Space/ Environment	Parks and Recreation, Environmental Services; Public Utilities	• recreation centers • conservation areas/open space/source water • community parks • Miramar Landfill • Compressed Natural Gas (CNG) fueling station
Miscellaneous	Real Estate Assets; Planning; Development Services; Parking Organization;	• libraries • City administrative buildings • historic and cultural resources

[4] Bridges and major arterials were broken down into roadway segments as defined in the City's asset management system.

	Commission for Arts and Culture

State highways and freeways and privately held land parcels within the City were also assessed for exposure to the key climate change hazards. Vulnerability scores were not calculated for privately held land, as the City does not have insight into the sensitivities and adaptive capacities of privately managed developments.

Each private parcel was assigned one or more land use type based on the tax assessors' land use code. Seventy-two building types were identified and grouped them into seventeen land use categories: agricultural, commercial, community, cemetery, entertainment, health, hotel/motel, industrial, institutional, marina docks, office space, open space, residential, restaurant, rural, not defined, and vacant.

Compiling Asset Data

Spatial data for critical City-owned assets and climate hazard spatial data, from sources such as the City of San Diego, CalEPA, and SanGIS through the SanGIS Regional Data Warehouse, were used for this assessment.

Collecting detailed asset data across departments required collaboration and inputs from internal stakeholders followed by extensive review to understand the data and to determine the portions of the available data sets relevant to the analysis.

Overlaying Climate Hazard and Asset Data

To easily communicate exposure across City departments, an interactive online map was created that allows for toggling on and off various asset and climate hazard layers. This web map can be used to streamline data management needs for data collection, analysis, visualization, and reporting. The web application comes equipped with tools such as querying, layer filtering, and geocoding for location intelligence. The map has a selection of base maps and location-based bookmarks that enhance navigation and situational awareness. The mapping application will help the City better understand which environmental threats could affect specific assets and communities.

A screenshot of the interactive online map is presented in Figure 7.

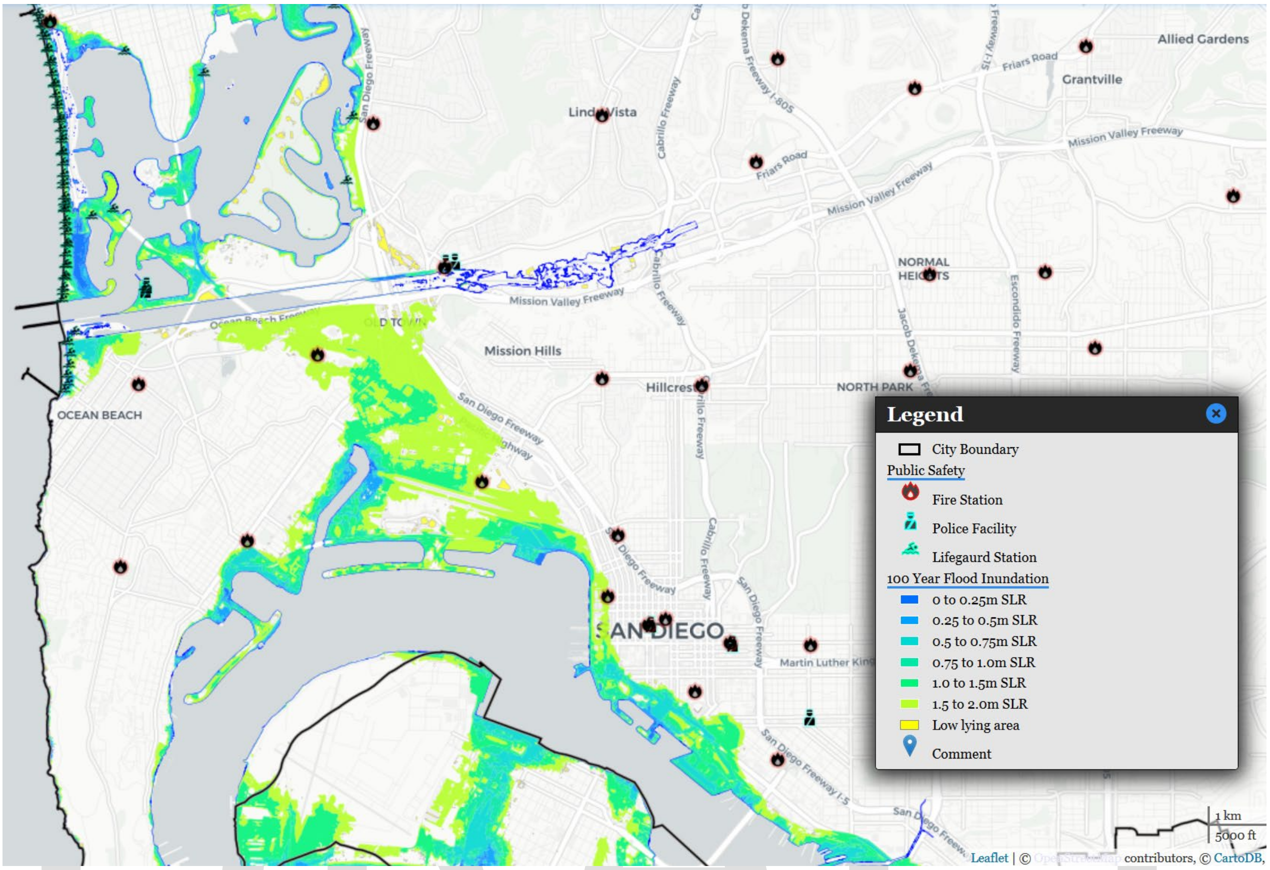


Figure 7. Map section showing public safety infrastructure assets and storm surge flooding at different levels of SLR. Source: ICF, based on SanGIS and CoSMoS data.

Analyze Exposure

After gathering information on critical assets and climate change hazards, an exposure assessment was completed. Exposure of each asset was completed by examining the spatial overlap of the primary coastal concerns and available asset location data for critical assets within the City. That information resulted in an exposure score for each asset class.

Exposure scores were determined for SLR, SLR + storm surge (100-year flood), and coastal erosion using the rubric shown in Table 3. A score was assigned to each asset class based on the highest level of exposure for the entire class (e.g., if the locations of police stations overlapped with both 0.5 m and 0.25 of SLR, then police stations were considered highly exposed.) This report uses the following classifications for scoring exposure (Table 3):

Definition of Terms

Exposure: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.

Adaptive Capacity: The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.

- **High Exposure:** Exposure to SLR and storm surge starting at 0.25 m of SLR is classified as high exposure, as San Diego could see such SLR by 2030. For coastal erosion, exposure within a 100-foot buffer of the 2 m “shoreline hold, continued nourish” scenario is classified as high.
- **Medium Exposure:** Exposure to SLR and storm surge starting at 0.5 or 0.75 of SLR is classified as medium exposure, as these levels are not likely to be reached until 2050. For coastal erosion, exposure within a 100-foot buffer of the 2 m “cliff let it go” or “shoreline no hold, no nourish” scenarios is classified as low.
- **Low Exposure:** Exposure to SLR and storm surge starting at 1, 1.5, or 2 meters of SLR is classified as low for SLR and storm surge, as these levels are not likely to be reached until 2100. For coastal erosion, no exposure is classified as low.

Table 3. Scoring for critical infrastructure exposure to coastal hazards

Hazard	Exposure Data Set	High Exposure (2030)	Medium Exposure (2050)	Low Exposure (2100)
Sea Level Rise	CoSMoS Average flood layers	0.25 m	0.5 m 0.75 m	1m 1.5 m 2 m
Sea Level Rise + Storm Surge	CoSMoS 100-year flood layers	0.25 m	0.5 m 0.75 m	1 m 1.5 m 2 m
Coastal Erosion	CoSMoS cliff and shoreline erosion scenarios	2 m “Shoreline hold, continued nourish” scenario	2 m “Cliff let it go” OR “Shoreline no hold, no nourish” scenarios	N/A (no low score for erosion)

Analyze Sensitivity

Using the same critical asset classes and hazards as in the exposure analysis, critical infrastructure sensitivity (the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli) was assessed. Several data sources were used to assess sensitivity:

- *Sensitivity literature:* Literature pertaining to the sensitivity of critical asset classes to SLR, storm surge, and coastal erosion was reviewed. This provided information used to estimate the level of impact to the asset type if exposed.
- *Department consultations*: Interviews with nineteen City departments[5] were conducted to collect information on historical damage, available documentation of damages or disruptions to service, asset/service sensitivity, and whether adaptive actions had been taken to date.
- *City documentation:* Documentation pertaining to previous emergencies and natural hazard impacts was reviewed. These documents provided information such as the type of hazard experienced, level of damage, costs incurred, and asset condition.

Sensitivity was scored based on the most sensitive asset within each asset class using the scale shown in Table 4. For example, SLR is projected to increase the frequency and baseline water level of extreme storms, which may exceed design standards for bridges. Storm surge can stress bridges due to erosion, scour, or by washing debris into bridges. The higher end of potential impacts – needing to replace bridges

[5] Parks and Recreation, Chief Operating Officer Homelessness Strategies, Office of Homeland Security, Risk Management, Debt Management, Department of Finance, City Treasurer, Sustainability, Fleet Services, Purchasing and Contracting, Human Resources, Transportation and Storm Water (TSW), Public Utilities (PUD), Public Works (PW), Environmental Services Department (ESD), Real Estate Assets (READ), Police, Fire-Rescue, and Development Services Department (DSD)

to fit a higher design standard – was used to give bridges a “high” score for sensitivity to SLR and storm surge.

Table 4. Sensitivity scoring rubric.

Score	Rationale
High	If exposed, the asset type becomes damaged beyond repair or destroyed and cannot resume normal function until replaced.
Medium	If exposed, the asset type is damaged such that repairs are necessary before it can resume full functionality.
Low	If exposed, the asset type suffers minor damage but can maintain functionality or is not damaged at all.

Analyze Adaptive Capacity

The goal of the adaptive capacity analysis was to identify actions the City has already taken or implemented to prepare for current and future natural hazards, and to understand the potential for further adaptive action. Adaptive actions are assumed to reduce vulnerability by mitigating potential sensitivity to exposure. This can occur through physical protection measures, operational changes to avoid exposure, moving the asset out of exposed areas, changing the nature of the asset so that it is less sensitive to exposure, and other strategies.

The City has a history of proactively managing extreme weather events. This includes being an active contributor to the County Hazard Mitigation Plan (HMP), which was last updated in 2017. For the HMP, City-specific goals, objectives, and actions were developed to mitigate climate hazards. Many of these actions are ongoing and already included in the City’s budget, such as updating the Land Development Code to require private development in the coastal zone to elevate storm drains above anticipated SLR and training multiple staff members for each position in the City’s Emergency Operations Center (City of San Diego 2017).

Consultations with City departments and asset management data were used to understand the ability of critical assets to adapt to climate change hazards and to determine where adaptive measures or practices are already in place or planned. To assess adaptive capacity, City departments were asked whether:

- Any assets are made of materials that are particularly susceptible to damage from climate exposure;
- The assets could be moved when extreme weather events occur;
- The department currently deploys protective measures to prevent exposure during extreme weather events; and
- Any backup assets are available to maintain functionality if some assets become damaged.

Adaptive capacity was scored based on the rubric in Table 5. Adaptive capacity has an inverse relationship with vulnerability, whereas exposure and sensitivity have a direct relationship with vulnerability. Specifically, high exposure, high sensitivity, and low adaptive capacity contribute to high vulnerability, whereas low exposure, low sensitivity, and high adaptive capacity contribute to low vulnerability.

Table 5. Rubric for scoring asset adaptive capacity

Score	Rationale
High	The asset can easily be protected from climate impacts (e.g., there are already protective measures in place that adequately prevent impacts; assets can be moved during an event; there are backups available).
Medium	The asset can be protected with some effort (e.g., there are potential protective measures but they are not yet in place; the asset needs to be retrofitted or upgraded to withstand impacts; backups need to be acquired from other jurisdictions during an event).
Low	The assets cannot be protected (e.g., they are located within an exposed area and would be difficult to move; there is no level of protection that can fully prevent damage; they are made of sensitive materials and cannot be upgraded; there are no backups available).

Limitations

Due to data limitations and the hundreds of thousands of assets across many City departments, vulnerability scores were developed for groups or types of assets rather than for individual assets. The exposure of individual assets was analyzed, but the sensitivity and adaptive capacity of the assets were developed at the asset type level, and therefore the final vulnerability scores are also at the asset type level. The scores for sensitivity and adaptive capacity were based on a combination of literature review, expert knowledge, and department consultations. As such, the scores do not capture the nuanced and full range of vulnerability represented by each individual asset within the City. The asset type vulnerability scores do not represent an average or summary of individual asset scores. They are meant to provide a relative understanding of the risk that select climate change hazards could pose to the asset category.

Bringing it all Together to Assess Asset Vulnerability

Vulnerability is a function of exposure, sensitivity, and adaptive capacity. Scores for these three components were combined to determine a vulnerability score for each type of critical asset for each coastal hazard (that is, scores were assigned to the asset class level and not to individual assets). If all three components contributed to low vulnerability (low exposure, low sensitivity, high adaptive capacity), then the vulnerability score was low. If all three contributed to high vulnerability (high exposure, high sensitivity, and low adaptive capacity), then the vulnerability score was high. If all were medium, then the vulnerability score was medium. Two component scores that contributed to high vulnerability warranted a high vulnerability score. Two component scores that contributed to low vulnerability warranted a low vulnerability score if the third component was medium, and a medium vulnerability score if the third component contributed to high vulnerability.

Vulnerability Findings

The findings from the exposure scoring exercise provided insight into which geographic areas and asset types may be vulnerable to coastal climate change hazards. The following section details these findings, describing the level of exposure experienced by each asset class to the various coastal hazards. These findings are organized by sector (listed in Table 2).

This section also provides preliminary findings on the sensitivity and adaptive capacity of these asset classes to coastal hazards. These elements add more nuance to the understanding of exposure and help to frame the sectors as more or less vulnerable. This analysis will be carried forward to consider the sensitivity and adaptive capacity of selected individual assets to obtain a more granular look at vulnerability and to direct the development of targeted adaptation strategies.

The following asset types were found to be vulnerable to coastal hazards:

- **Public safety**: fire stations, lifeguard stations, other public safety;
- **Water**: water pipes, wastewater pipes, water pump stations, wastewater pump stations;
- **Transportation and storm water**: bridges, major arterials, drain pump stations, outfalls;
- **Open space and environment**: recreation centers, conservation areas/open space/source water, community parks, sensitive habitat; and
- **Additional assets**: historic and cultural resources.

The results of the vulnerability assessment are presented in Table 6 below. "N/A" is used to indicate that the assets were not found to be exposed to the hazard, so sensitivity and adaptive capacity were not assessed, and the asset types were deemed not vulnerable.

Table 6. Summary vulnerability scores for City of San Diego critical assets[6]

Sector	Critical Asset	Sea Level Rise	SLR + Storm Surge (100-year flood)	Erosion
Public Safety	Fire Stations	N/A	Low	N/A
	Police Stations	N/A	N/A	N/A
	Lifeguard Stations	High	Medium	High
	Fire Trucks/ Engines	N/A	N/A	N/A
	Maintenance Facilities	N/A	N/A	N/A
	Police Patrol and Specialty Vehicles	N/A	N/A	N/A
	Other Public Safety	Medium	Medium	N/A
Water	Dams	N/A	N/A	N/A
	Water Pipes	Medium	Medium	High
	Wastewater Pipes	Medium	Medium	High
	Water Pump Stations	N/A	N/A	High
	Wastewater Pump Stations	Medium	Medium	High
	Distribution Reservoirs	N/A	N/A	N/A
	Water Treatment Plants	N/A	N/A	N/A
	Wastewater Treatment Plants	N/A	N/A	N/A
	Airports	N/A	N/A	N/A
	Bridges	High	High	High
	Major Arterials	High	Medium	Medium

[6] The vulnerability scores were calculated using a combination of spatial asset data provided by the City of San Diego or SanGIS, the best available spatial projections for the chosen climate hazard scenarios, and an assumption of asset type-level (general) of sensitivity and adaptive capacity based on literature reviews and high-level department consultations. The scores reported here do not reflect the vulnerability of specific, individual assets, but rather an assumption of asset type vulnerability.

Sector	Critical Asset	Sea Level Rise	SLR + Storm Surge (100-year flood)	Erosion
Transportation and Storm Water	Drain Pump Stations	High	High	N/A
	Outfalls	High	High	High
Open Space and Environment	Recreation centers	High	Medium	N/A
	Conservation Areas/Open Space/Source Water	High	High	N/A
	Community Parks	High	Medium	High
	Miramar Landfill	N/A	N/A	N/A
	CNG Fueling Station	N/A	N/A	N/A
	Sensitive habitat	High	Medium	High
	Beaches	High	Medium	High
Additional Assets	Libraries	N/A	N/A	N/A
	City Administrative Buildings	N/A	N/A	N/A
	Historic and Cultural Resources	High	High	High

Public Safety

Public safety assets include those managed by the Fire-Rescue and Police departments and the Office of Homeland Security. The following assets are considered critical: fire stations, police stations, lifeguard stations, fire trucks and engines, police patrol and specialty vehicles, and other public safety assets (e.g., Critical Incident Management Unit equipment location, police communications, maintenance facilities, evidence and property locations, and the emergency communications center).

Only three public safety critical asset types are exposed to coastal hazards: fire stations, lifeguard stations, and other public safety assets. Lifeguard stations and other public safety assets are vulnerable to chronic flooding through SLR, all three are vulnerable to periodic flooding through SLR + storm surge (100-year flood), and only lifeguard stations are vulnerable to erosion.

The results of the vulnerability assessment of public safety assets to SLR, SLR + storm surge, and coastal erosion are shown in Table 7, Table 8, and Table 9, respectively. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these assets to coastal hazards.

Table 7. Public safety asset vulnerability to SLR[6]

Sea Level Rise (SLR)	Fire Stations	Lifeguard Stations	Fire Trucks/ Engines	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Not exposed	High	Not exposed	Not exposed	Not exposed	Not exposed	Low
Sensitivity	N/A	High	N/A	N/A	N/A	N/A	High
Adaptive Capacity	N/A	Medium	N/A	N/A	N/A	N/A	Medium

Sea Level Rise (SLR)	Fire Stations	Lifeguard Stations	Fire Trucks/ Engines	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Vulnerability	**N/A**	**High**	**N/A**	**N/A**	**N/A**	**N/A**	**Medium**

Table 8. Public safety asset vulnerability to SLR + storm surge[6]

SLR + Storm Surge	Fire Stations	Lifeguard Stations	Fire Trucks/ Engines	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Low	High	Not exposed	Not exposed	Not exposed	Not exposed	Low
Sensitivity	Medium	Low	N/A	N/A	N/A	N/A	High
Adaptive Capacity	Medium	High	N/A	N/A	N/A	N/A	Medium
Vulnerability	**Low**	**Medium**	**N/A**	**N/A**	**N/A**	**N/A**	**Medium**

Table 9. Public Safety asset vulnerability to coastal erosion[6]

Coastal Erosion	Fire Stations	Lifeguard Stations	Fire Trucks/ Engines	Maintenance Facilities	Police Stations	Police Patrol and Specialty Vehicles	Other Public Safety
Exposure	Not exposed	High	Not exposed	Not exposed	Not exposed	Not exposed	Not exposed
Sensitivity	N/A	High	N/A	N/A	N/A	N/A	N/A
Adaptive Capacity	N/A	Medium	N/A	N/A	N/A	N/A	N/A
Vulnerability	**N/A**	**High**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Exposure

Most public safety assets are not exposed to SLR, as shown in Figure 8. However, lifeguard stations and other public safety assets may face exposure to inundation from SLR. Lifeguard stations face a high level of exposure, with 7 percent of assets located within the zone of 0.25 meters of SLR (by approximately 2030) and between forty and seventy-eight percent of assets facing exposure to inundation by 2100. The "other public safety assets" are much less exposed; just one asset faces exposure to inundation starting at 1 meter of SLR (by approximately 2100).

> **Sea Level Rise Projections for San Diego**
>
> 2030: 0.25 m
>
> 2050: 0.5-0.75 m
>
> 2100: 1.0-2.0 m

Figure 9 shows that more public safety assets may be exposed to a SLR with storm surge than are projected to be exposed to SLR alone. Over a third of lifeguard stations could be exposed to SLR starting at 0.25 meters of SLR with a storm surge (2030), and sixty-seven to ninety-two percent of these stations may be exposed by 2100. SLR with storm surge also brings some fire stations into the inundation zone: at 2.0 meters of SLR, three fire stations may be exposed to SLR with storm surge. Other public safety assets face exposure starting at 0.75 meters of SLR (approximately 2050) with a storm surge.

As Figure 10 shows, only lifeguard stations face exposure to cliff erosion. Fourteen percent of lifeguard stations may be affected if cliffs retreat and erode. Figure 10 also shows that only lifeguard stations may be exposed to beach erosion. Lifeguard stations may be much more exposed to beach erosion than to cliff erosion, with fifty-seven percent of stations exposed even with continued beach nourishment.

The figures below show public safety asset exposure to SLR, SLR plus storm surge, and erosion, respectively. The value after each asset name indicates the total number of assets in that asset type. The colored bars for each increment show how many additional assets become exposed under that SLR or erosion scenario.

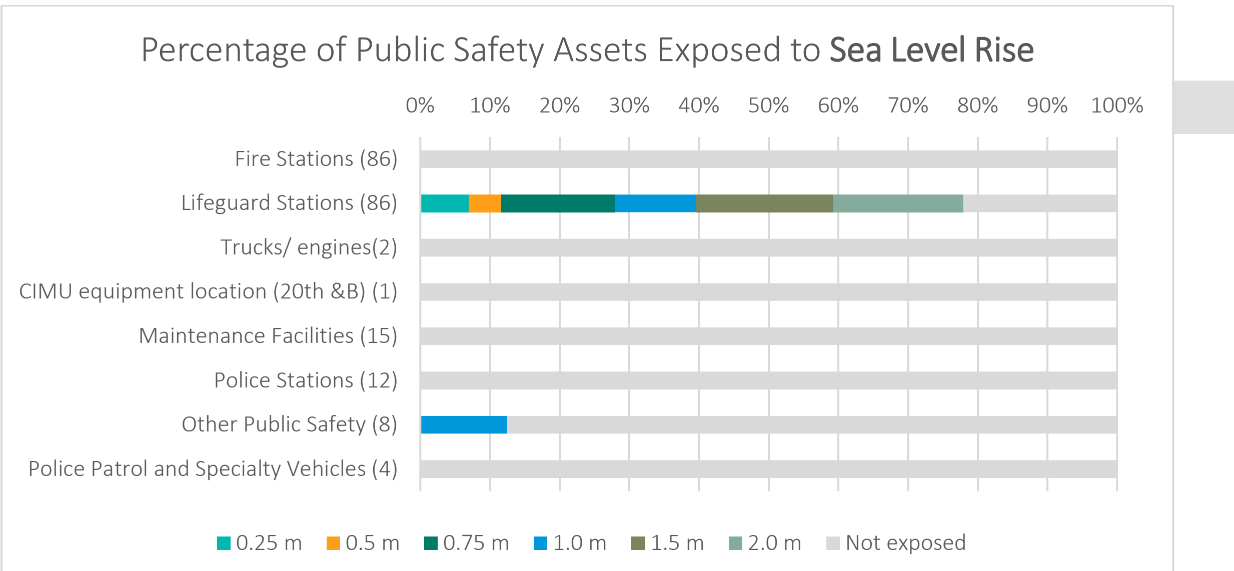


Figure 8. Public safety assets exposed to SLR.

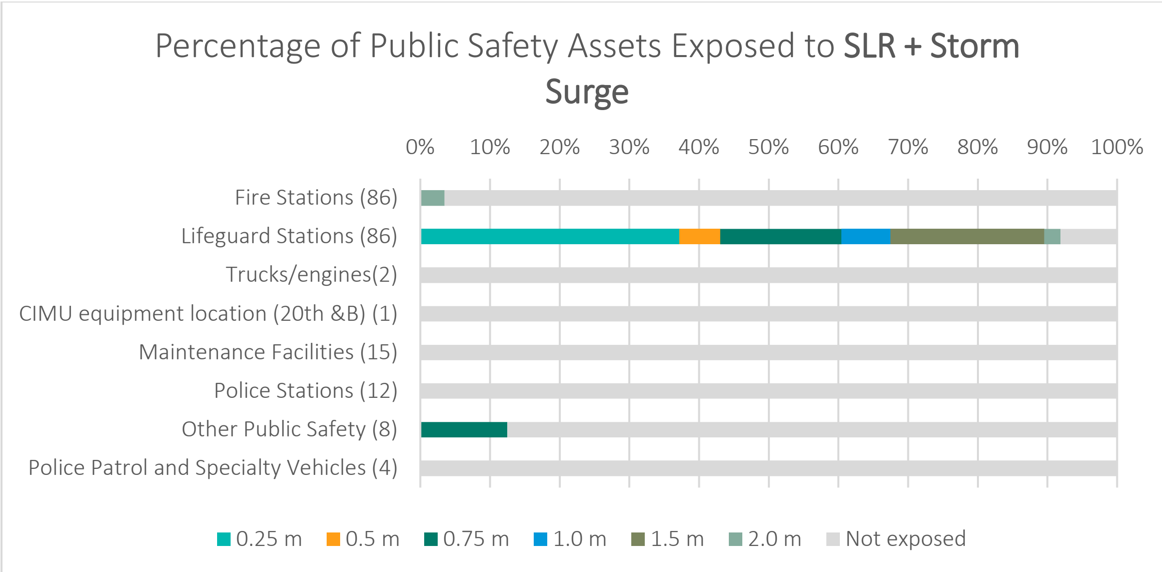


Figure 9. Public safety assets exposed to storm surge; this includes the 100-year storm on top of SLR. Storm surge + SLR encompasses a larger flood area than sea level rise alone, so more assets in this graph tend to be exposed under lower sea level rise amounts than in the graph above showing only sea level rise exposure.

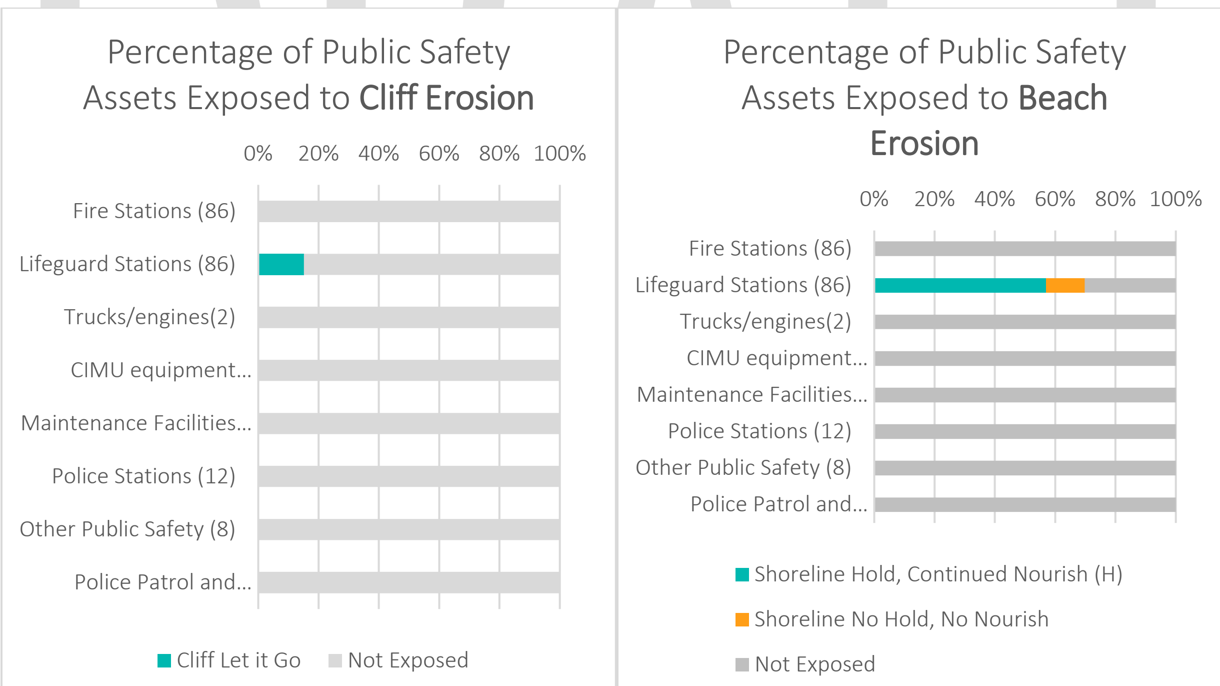


Figure 10. Public safety assets exposed to erosion. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion. "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair, while "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair.

Sensitivity and Adaptive Capacity

Based on their exposure, fire stations, lifeguard stations, and other public safety assets were included in the sensitivity and adaptive capacity analysis. The ratings and corresponding rationale for these assets are shown in Table 10.

Table 10. Sensitivity and adaptive capacity of public safety asset types exposed to coastal hazards

Fire Stations	
Sea Level Rise (SLR) Sensitivity: Not exposed	*Sea Level Rise (SLR) Adaptive Capacity: Not exposed*
SLR with storm surge Sensitivity: Medium Exposure of fire stations to storm flooding events could, over time, increase wear and tear on buildings. Storm-induced flooding could temporarily limit access to and use of a station (USAID 2014).	*SLR with storm surge Adaptive Capacity: Medium* Short term solutions exist for flood protection (e.g., sandbags); longer-term adaptation is more difficult and costly.
Erosion Sensitivity: Not exposed	*Erosion Adaptive Capacity: Not exposed*
Lifeguard Stations	
SLR Sensitivity: High Sea level rise can permanently inundate buildings within the projected sea level rise zone, can increase the erosion of structures, and can damage or destroy buildings and equipment (USAID 2014).	*SLR Adaptive Capacity: Medium* Short term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation for flooding is more difficult.
SLR with Storm Surge Sensitivity: Low Mobile towers can easily be brought back into service after experiencing flooding, assuming they do not wash away.	*SLR with Storm Surge Adaptive Capacity: High* The City has plans to build new stations to accommodate storm-based inundation (by locating all facilities on the second floor). In existing towers, equipment will be relocated to the second floor (City of San Diego Fire-Rescue Department, 2019).
Coastal Erosion Sensitivity: High If coastal erosion were to threaten the building structure of a permanent lifeguard station, the facility would need to be moved.	*Coastal Erosion Adaptive Capacity: Medium* Mobile lifeguard towers can be moved to safer locations; however, permanent lifeguard stations cannot easily be moved. Short-term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation for flooding and erosion is more difficult.
Other Public Safety	
Sea Level Rise (SLR) Sensitivity: High The Police Department's evidence and property building is currently in vulnerable condition and would be highly sensitive to flooding (City of San Diego Police Department, 2019). SLR can permanently inundate buildings within the projected SLR zone; can increase the erosion of structures; and can damage or destroy buildings and equipment (USAID 2014).	*Sea Level Rise (SLR) Adaptive Capacity: Medium* Longer-term adaptation may be necessary if chronic flooding within the coastal zone becomes a highly likely scenario (City of San Diego Police Department, 2019).
SLR with Storm Surge Sensitivity: High The Police Department's evidence and property building is currently in vulnerable condition and would be highly sensitive to flooding (City of San Diego Police Department, 2019).	*SLR with Storm Surge Adaptive Capacity: Medium* Short-term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation is more difficult and costly (City of San Diego Police Department, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*

Water Infrastructure

Water infrastructure assets include those managed primarily by the Public Utilities Department (though some pump stations are managed by other City departments such as Transportation and Storm Water). This department considers the following assets to be critical: dams, water pipes, wastewater pipes, water pump stations, wastewater pump stations, water treatment plants, wastewater treatment plants, and distribution reservoirs. "Water pipes" refers to transmission and distribution mains.

Water pipelines, wastewater pipelines, and wastewater pump stations show medium vulnerability to coastal flooding. Both water and wastewater pipes and pump stations show high vulnerability to coastal erosion. Flooding will not have a severe impact on underground pipes or pump stations, but erosion can compromise the functionality of the system. All erosion scenarios assume 2.0 meters of SLR.

The results of the vulnerability assessment of water assets to coastal hazards are shown in Table 11, Table 12, and Table 13. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these assets to coastal hazards. In particular, Table 14 provides the rationale for the sensitivity and adaptive capacity scores.

Table 11. Vulnerability of water assets to SLR[6]

Sea Level Rise (SLR)	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Dist. Reservoirs	Water Treatment Plants	Waste-water Treatment Plants
Exposure	Not exposed	High	High	Not exposed	High	Not exposed	Not Exposed	Not Exposed
Sensitivity	N/A	Low	Low	N/A	Low	N/A	N/A	N/A
Adaptive Capacity	N/A	Medium	Medium	N/A	High	N/A	N/A	N/A
Vulnerability	**N/A**	**Medium**	**Medium**	**N/A**	**Medium**	**N/A**	**N/A**	**N/A**

Table 12. Vulnerability of water assets to SLR + storm surge[6]

SLR With Storm Surge	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Dist. Reservoirs	Water Treatment Plants	Waste-water Treatment Plants
Exposure	Not exposed	High	High	Not exposed	High	Not exposed	Not exposed	Not Exposed
Sensitivity	N/A	Low	Low	N/A	Low	N/A	N/A	N/A
Adaptive Capacity	N/A	Medium	Medium	N/A	High	N/A	N/A	N/A
Vulnerability	**N/A**	**Medium**	**Medium**	**N/A**	**Medium**	**N/A**	**N/A**	**N/A**

Table 13. Vulnerability of water assets to erosion[6]

Coastal Erosion	Dams	Water Pipes	Waste-water Pipes	Water Pump Stations	Waste-water Pump Stations	Dist. Reservoirs	Water Treatment Plants	Waste-water Treatment Plants
Exposure	Not exposed	High	High	Medium	High	Not exposed	Not exposed	Not exposed
Sensitivity	N/A	High	High	High	High	N/A	N/A	N/A
Adaptive Capacity	N/A	Low	Low	Low	Low	N/A	N/A	N/A
Vulnerability	**N/A**	**High**	**High**	**High**	**High**	**N/A**	**N/A**	**N/A**

Exposure

Sea Level Rise Projections for San Diego

2030: 0.25 m

2050: 0.5–0.75 m

2100: 1.0–2.0 m

Of all water assets, wastewater pump stations face the highest relative exposure to SLR: two percent of wastewater pump stations face exposure starting at 0.25 meters of SLR (2030 timeframe), twenty-two percent face exposure at 0.75 meters of SLR (high end of the 2050 timeframe), and eighty-five percent may be inundated by 2100 (1.0-2.0 m SLR). Water pipes and wastewater pipes face less exposure: less than five percent of water pipes and less than forty percent of wastewater pipes are projected to be exposed to SLR by 2100 (Figure 11).

Water and wastewater pipes and wastewater pump stations also face flooding from SLR with storm surge (100-year flood), (Figure 12). In this case, eighteen percent of wastewater pump stations may be exposed starting at 0.25 meters of SLR (2030), with thirty-five to forty-five percent of wastewater pump stations potentially exposed to flooding from SLR with storm surge by 2100 (1.0- 2.0 m SLR). Less than five percent of water pipes but forty-eight percent of wastewater pipes may be exposed to SLR with storm surge.

Water pipes, wastewater pipes, water pump stations, and wastewater pump stations face limited exposure to cliff erosion (Figure 13). Cliff erosion poses the greatest risk for wastewater pump stations—nineteen locations, or six percent of total wastewater pump stations, may be exposed to cliff erosion.

A small portion of water pipes, wastewater pipes, and wastewater pump stations may be exposed to beach erosion (Figure 13). As with cliff erosion, wastewater pump stations face the greatest relative exposure to beach erosion, with roughly three percent of these assets facing exposure. The figures below show water asset exposure to SLR, SLR plus storm surge, and erosion, respectively. The value after each asset name indicates the total number of assets in that asset type. The colored bars for each increment show how many additional assets become exposed under that sea level rise or erosion scenario.

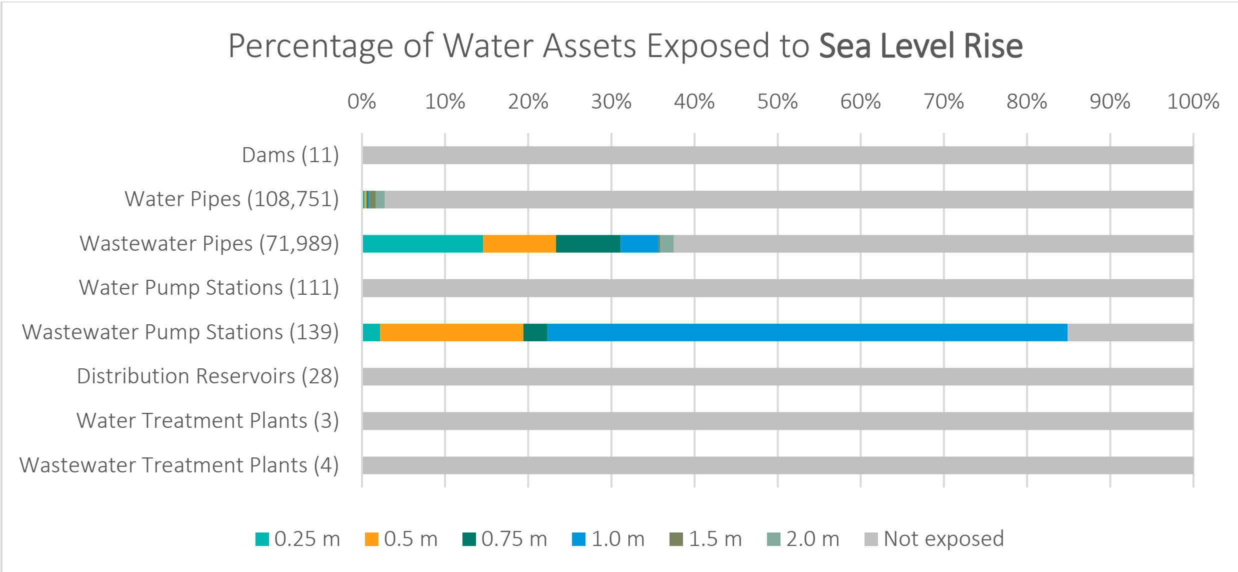


Figure 11: Water assets exposed to sea level rise.

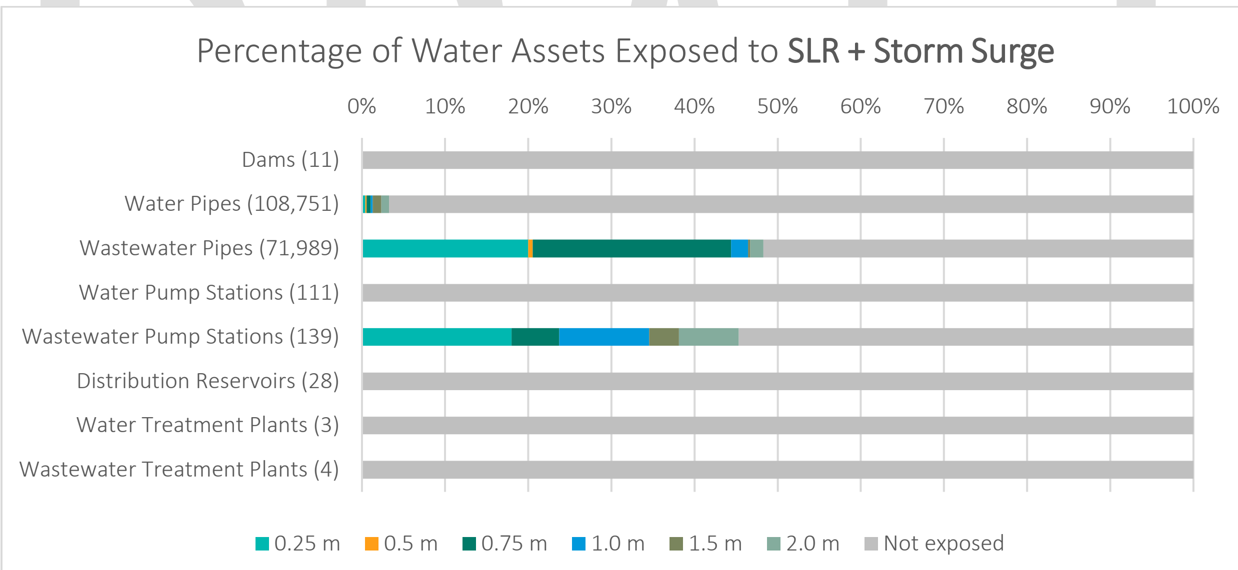
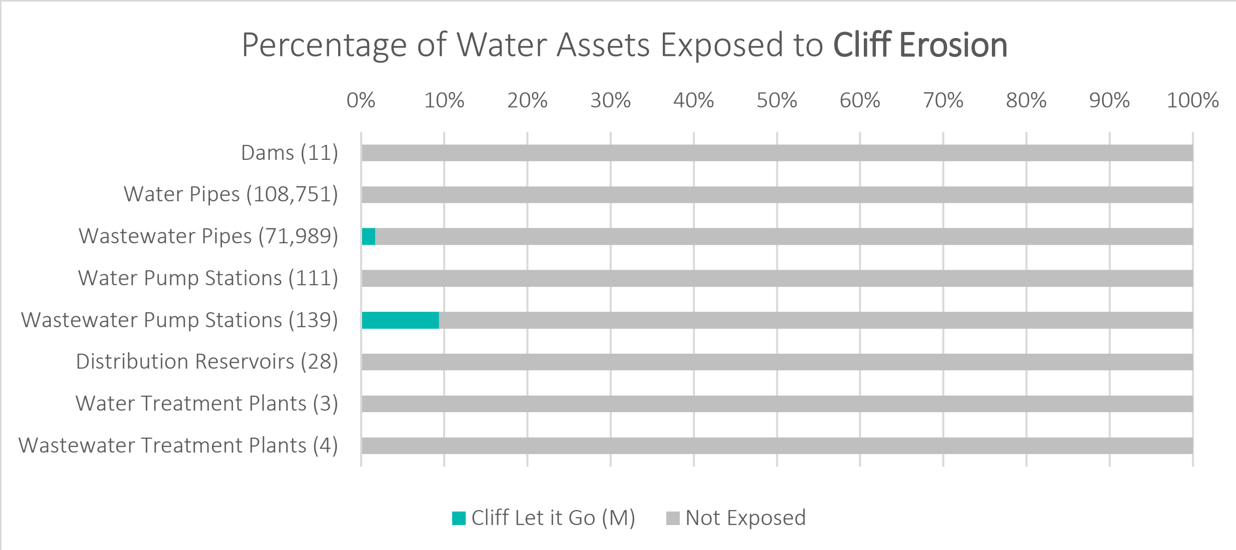


Figure 12: Water assets exposed to storm surge; this includes the 100-year storm on top of sea level rise. Storm surge + SLR encompasses a larger flood area than sea level rise alone; more assets in this graph tend to be exposed under lower sea level rise amounts than in Figure 12, showing only sea level rise exposure.



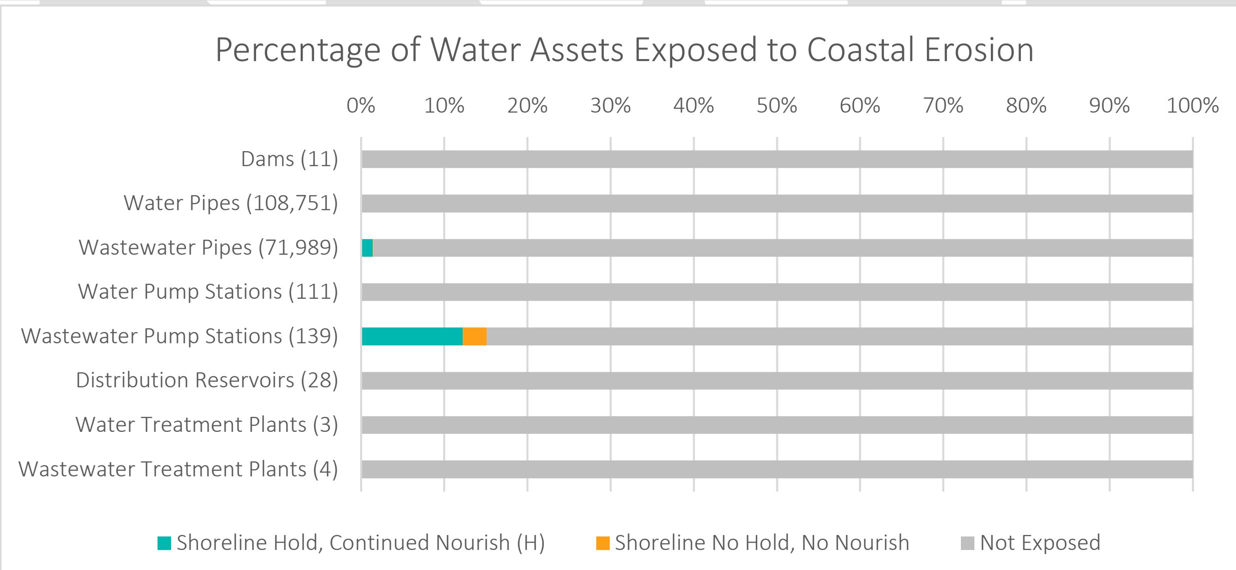


Figure 13: Water assets exposed to erosion. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion. "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair, while "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair.

Sensitivity and Adaptive Capacity

Based on the exposure assessment, the sensitivity and adaptive capacity of pipes, pump stations, and treatment plants to coastal flooding and erosion. The results of this analysis are shown in Table 14.

Table 14. Sensitivity and adaptive capacity of water assets to coastal hazards

Water and Wastewater Pipes	
SLR Sensitivity: Low Since pipes are buried underground, they will likely suffer little damage from flooding (ICLEI 2017).	*SLR Adaptive Capacity: Medium* A majority of the City's pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's

	timeframe (to 2100). The cost to replace pipes can be expensive, however PUD has planned within the department's Capital Improvements Program (CIP) to rehabilitate and replace pipes as necessary (City of San Diego 2019).
SLR with storm surge Sensitivity: Low Since pipes are buried underground, they will likely suffer little damage from flooding (ICLEI 2017).	*SLR with storm surge Adaptive Capacity: Medium* A majority of the City's pipes are still within their useful life, though they might require routine rehabilitation and replacement within this study's timeframe (to 2100). The cost to replace pipes can be expensive, however PUD has planned within the department's Capital Improvements Program (CIP) to rehabilitate and replace pipes as necessary (City of San Diego 2019).
Coastal Erosion Sensitivity: High Pipes are sensitive to erosion, as this hazard can compromise the functionality of the system (ICLEI 2017).	*Coastal Erosion Adaptive Capacity: Low* Pipes have low adaptive capacity as coastal erosion that impacts one location can have implications for the system overall (ICLEI 2017). The San Diego PUD is currently engaging in a study on this topic to further investigate the issue.
Water Pump Stations	
SLR Sensitivity: Not exposed	*SLR Adaptive Capacity: Not exposed.*
SLR with storm surge Sensitivity: Not exposed	*SLR with storm surge Adaptive Capacity: Not exposed.*
Coastal Erosion Sensitivity: High Erosion can severely impact the system and compromise its functionality (ICLEI 2017).	*Coastal Erosion Adaptive Capacity: Low* There is little that can be done to maintain a system that is faced with erosion (ICLEI 2017).
Wastewater Pump Stations	
SLR Sensitivity: Low Exposure to flooding will have little impact on pump stations (ICLEI 2017).	*SLR Adaptive Capacity: High* Impaired components may be isolated for repair if necessary without significant disruption to the system (ICLEI 2017). Each pump station has an emergency plan in place with a complete redundancy plan (City of San Diego PUD, 2019).
SLR with storm surge Sensitivity: Low Exposure to flooding will have little impact on pump stations (ICLEI 2017).	*SLR with storm surge Adaptive Capacity: High* Impaired components may be isolated for repair if necessary without significant disruption to the system (ICLEI 2017). Each pump station has an emergency plan in place with a complete redundancy plan (City of San Diego PUD, 2019).
Coastal Erosion Sensitivity: High Erosion can severely impact the system and compromise its functionality (ICLEI 2017).	*Coastal Erosion Adaptive Capacity: Low* There is little that can be done to maintain a system that is faced with erosion (ICLEI 2017).
Wastewater Treatment Plants	
SLR Sensitivity: Medium Wastewater treatment plants are designed for contingencies such that the plant can stay	*SLR Adaptive Capacity: Medium* The current design of wastewater treatment plants and requirement of on-site backup generators

functional even if some parts fail. Backup generators are always available in the event of an outage. Coastal plants (such as Point Loma) are designed for coastal impacts, so all equipment is marine rated (e.g., units are housed to prevent corrosion). However, chronic inundation could pose a threat to access and plant longevity (City of San Diego PUD, 2019).	means that these facilities are well-prepared for coastal impacts. However, if inundation becomes chronic additional engineering solutions and site improvements will be evaluated.
SLR with storm surge Sensitivity: Low Wastewater treatment plants are designed for contingencies such that the plant can stay functional even if some parts fail. Backup generators are always available in the event of an outage. Coastal plants (such as Point Loma) are designed for coastal impacts, so all equipment is marine rated (e.g., units are housed to prevent corrosion) (City of San Diego PUD, 2019).	*SLR with storm surge Adaptive Capacity: High* The current design of wastewater treatment plants and requirement of on-site backup generators means that these facilities are well-prepared for coastal storms (City of San Diego PUD, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed.*

Transportation and Storm Water

Transportation and storm water assets include those managed by the City's Transportation and Storm Water department and Real Estate Assets department. The following assets are considered critical: City-operated airports, bridges, major arterials, drain pump stations, and storm water outfalls. This assessment includes the City-operated airports Brown Field Municipal Airport (KSDM) and Montgomery-Gibbs Executive Airport (KMYF). It does not include the privately-owned San Diego International Airport, which completed its own climate resilience plan.

Bridges often have mixed ownership between the City and State: there are 126 bridges in the City, for which the City is responsible for maintenance of the bridge deck, railing, streetlights, and improvements above the superstructure of the bridge, while Caltrans is responsible for the maintenance of the superstructure and substructure of the bridge. Bridges and major arterials are broken down into roadway segments as defined in the City's asset management system.

All transportation and storm water critical asset types, except airports, are highly vulnerable to SLR and have medium to high vulnerability to SLR with storm surge (100-year flood). Bridges, major arterials, and outfalls show vulnerability to coastal erosion. All erosion scenarios assume 2.0 meters of SLR.

The results of the vulnerability assessment of transportation and storm water assets to coastal hazards are shown in Table 15, Table 16, and Table 17. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these assets to coastal hazards.

Table 15. Vulnerability of transportation and storm water asset types to SLR[6]

Sea Level Rise (SLR)	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls
Exposure	N/A	High	High	High	High
Sensitivity	N/A	High	High	High	High

Sea Level Rise (SLR)	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls
Adaptive Capacity	N/A	Medium	Medium	Low	Low
Vulnerability	**N/A**	**High**	**High**	**High**	**High**

Table 16. Vulnerability of transportation and storm water asset types to SLR + storm surge[6]

SLR with storm surge	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls
Exposure	Not exposed	High	High	High	High
Sensitivity	N/A	High	Low	Medium	Medium
Adaptive Capacity	N/A	Medium	High	Low	Low
Vulnerability	**N/A**	**High**	**Medium**	**High**	**High**

Table 17. Vulnerability of transportation and storm water asset types to erosion[6]

Coastal Erosion	Airports	Bridges	Major Arterials	Drain Pump Stations	Outfalls
Exposure	Not exposed	High	Medium	Not exposed	High
Sensitivity	N/A	High	High	N/A	High
Adaptive Capacity	N/A	Low	Medium	N/A	Low
Vulnerability	**N/A**	**High**	**Medium**	**N/A**	**High**

Exposure

A small portion of the critical transportation assets may be exposed to SLR and SLR with storm surge (100-year flood), whereas a large percentage of storm water assets face exposure to coastal hazards (Figure 15, Figure 16, Figure 17).

Sea Level Rise (SLR) Projections for San Diego

2030: 0.25 m SLR

2050: 0.5–0.75 m SLR

2100: 1.0–2.0 m SLR

Across all transportation assets, less than five percent may be exposed to sea level rise; however, there is local exposure in select coastal neighborhoods (Figure 15). Of the transportation elements analyzed, major arterial segments showed the greatest exposure in the near term (thirty-two segments at .25 m in 2030). Over time, more significant portions of the major arterial network—up to 247 segments at 1.0 to 2.0 m (2100)—may be exposed to SLR. With .25 m SLR (2030), four bridges will already face exposure to sea level rise, with up to eleven more becoming exposed by the end of the century (1.0 to 2.0 m SLR). Compared with transportation assets, a greater proportion of storm water assets may be exposed to SLR. Seven percent of drain pump stations may be exposed starting at 0.25 m SLR (2030), and thirty-six to fifty-seven percent of drain pump stations may be exposed by 2100 (1.0-2.0 m SLR). Twenty-seven percent of outfalls may be exposed starting at 0.25 m SLR (2030), and thirty-nine to fifty-one percent of outfalls may be exposed by 2100 (1.0-2.0 m SLR).

With storm surge and sea level rise scenarios, where SLR vulnerability is compounded by storm surge, assets become exposed across a broader spectrum of sea level rise ranges. Under these scenarios a few additional transportation assets face flooding, but the proportion still stays below five percent, with a total of up to 426 major arterial road segments exposed to a storm surge event in 2100 (1.0-2.0 m SLR) (Figure 16). Major arterial segments will be the most exposed with the addition of storm surge to sea level rise:

forty-four segments face projected exposure in 2030, increasing to 123 to 323 segments by 2100. More storm water assets may also become exposed to inundation. Thirty-six percent of drain pump stations may be exposed starting at 0.25 meters (2030), and between forty-three and eighty-six percent of drain pump stations may face flooding from SLR with storm surge by 2100. Similar to drain pump stations, thirty-six percent of outfalls may be exposed to SLR with storm surge starting at 0.25 meters of SLR (2030), and fifty to fifty-nine percent may be exposed by 2100.

For cliff erosion, bridges are not exposed, one major arterial segment may be exposed, and fifteen percent of storm water outfalls are exposed to cliff erosion (Figure 17).

For beach erosion, a single bridge and one major arterial segment face exposure and eight percent of storm water outfalls may be exposed. No drain pump stations are expected to be exposed to erosion.

Figure 14. A coastal storm water outfall in San Diego.

The figures below show transportation and storm water asset exposure to SLR, SLR plus storm surge, and erosion, respectively. The value after each asset name indicates the total number of assets in that asset type. For bridges and major arterials, the value signifies the number of roadway segments as defined in the asset management system. The colored bars for each increment show how many additional assets become exposed under that SLR or erosion scenario.

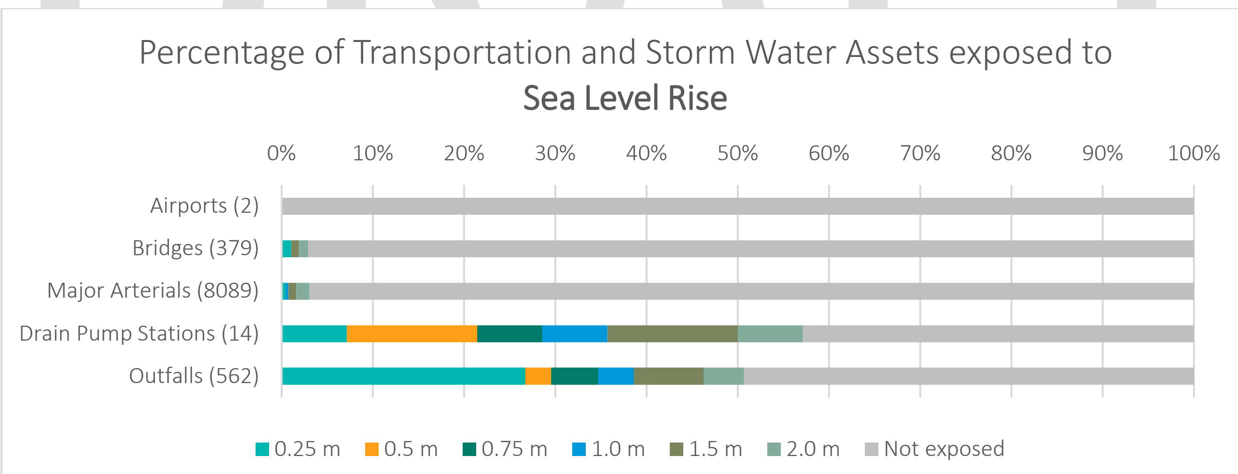


Figure 15: Transportation and storm water assets exposed to SLR.

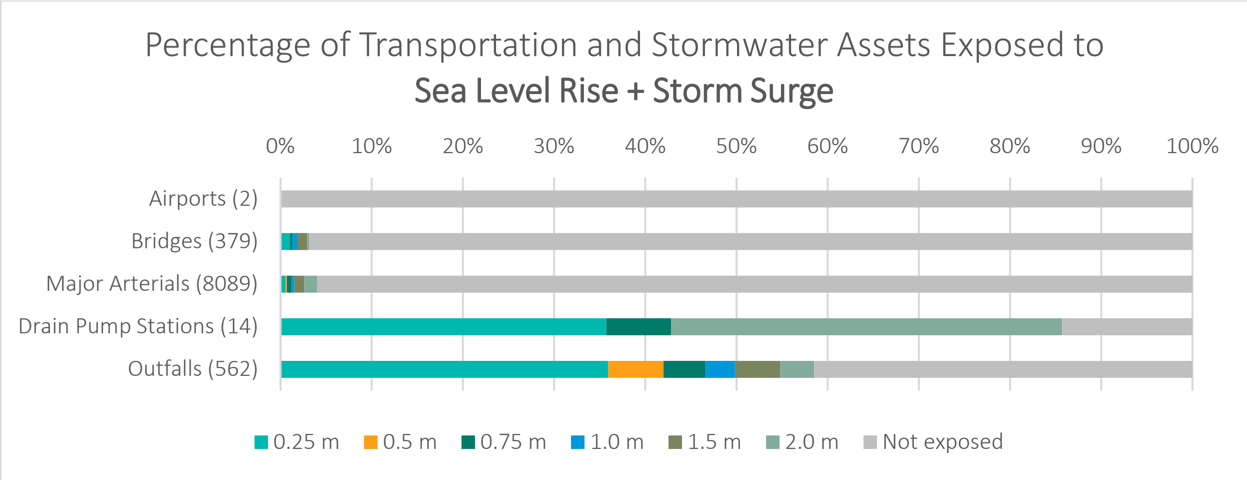
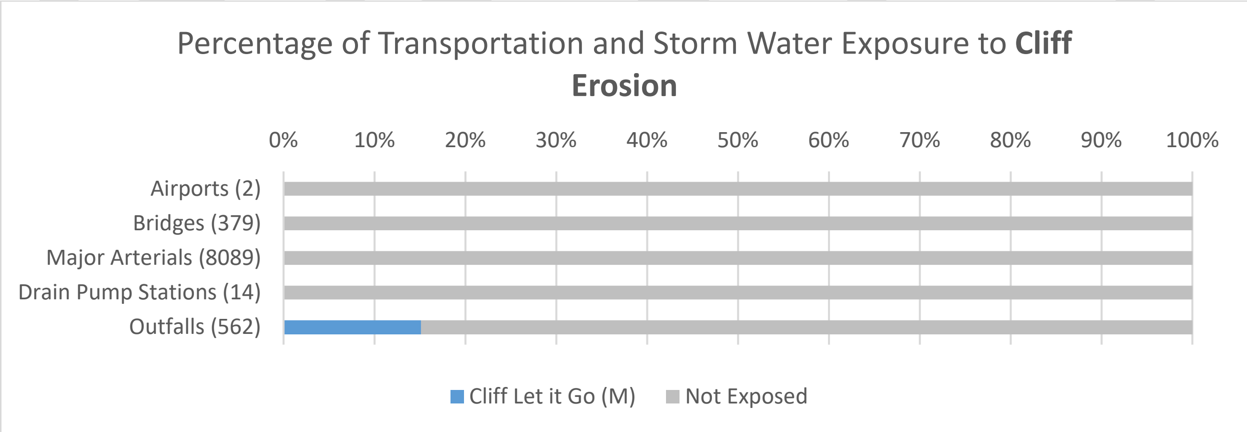


Figure 16: Transportation and storm water assets exposed to storm surge. Storm surge + SLR encompasses a larger flood area than sea level rise alone, so more assets in this graph tend to be exposed under lower sea level rise amounts than in the graph above showing only sea level rise exposure.



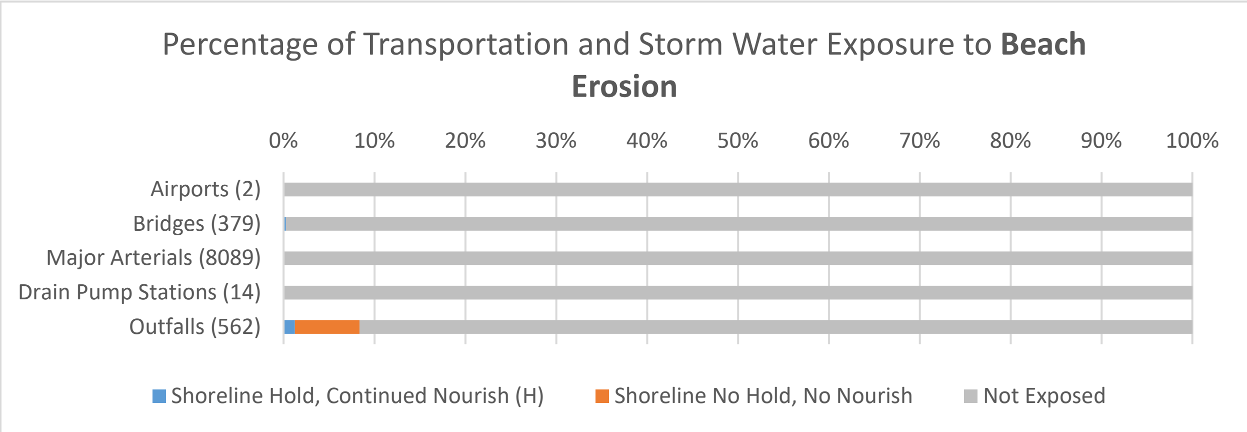


Figure 17: Transportation and storm water assets exposed to erosion. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion. "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair, while "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair.

Sensitivity and Adaptive Capacity

Based on the exposure analysis, the sensitivity and adaptive capacity of all transportation and storm water critical asset types to coastal hazards was assessed. The results of this analysis are shown in Table 18 below.

Table 18. Sensitivity and adaptive capacity of transportation and storm water asset types to coastal hazards

Bridges	
SLR Sensitivity: High Daily inundation can cause structural damage to assets and cut off access from flooded routes.	*SLR Adaptive Capacity: Medium* There is lower redundancy in the bridge network. Daily flooding could require the creation of alternate routes outside of inundation zones. If priority safety-related repair is needed, the City addresses the repair. State funds can be applied for to address issues that Caltrans finds during its inspections and are categorized as capital improvement plan (CIP) work, though this is a limited pool that may only cover one to two bridges every few years (City of San Diego Transportation and Storm Water Department, 2019).
SLR with Storm Surge Sensitivity: High Sea level rise is projected to increase the frequency and baseline water level of extreme storms, which may exceed design standards for bridges. Storm surge can stress bridges via erosion and scour, and by washing debris into bridges.	*SLR with Storm Surge Adaptive Capacity: Medium* Typically, bridge and roadway drainage design standards are for a 100-year storm. For bridges that cross over a channel or river rather than a roadway, the design standard may change to suit needs (e.g., West Mission Bay Drive is designed to a 500-year tsunami). There is lower redundancy in the bridge network. If priority safety-related repair is needed, the City addresses the repair. State funds can be applied for to address issues that Caltrans finds during its inspections and are categorized as CIP work, though this is a limited pool that may only cover one to two bridges every few years (City of San Diego TSWD, 2019).
Coastal Erosion Adaptive Capacity: High Roads and bridges are highly sensitive to erosion and have already begun to suffer impacts. If major routes become eroded, new routes must be created (ICLEI 2017) (City of San Diego TSWD, 2019).	*Coastal Erosion Adaptive Capacity: Low* There is lower redundancy in the bridge network. If priority safety-related repair is needed, the City addresses the repair. State funds can be applied for to address issues that Caltrans finds during its inspections and are categorized as CIP work, though this is a limited pool that may only cover one to two bridges every few years (City of San Diego TSWD, 2019).

Major Arterials	
SLR Sensitivity: High Daily inundation can cause structural damage to assets and cut off access from flooded routes.	*SLR Adaptive Capacity: Medium* Policy- and planning-based decisions are needed for long term solutions (City of San Diego TSWD, 2019).
SLR with storm surge Sensitivity: Low Roads are not very sensitive to occasional flooding.	*SLR with storm surge Adaptive Capacity: High* The Transportation and Storm Water Department can close flood gates, put in pumps, and build berms to protect against periodic flooding (City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: High Roads are highly sensitive to erosion and have already begun to suffer the impacts. If major routes become eroded, new routes must be created (ICLEI 2017).	*Coastal Erosion Adaptive Capacity: Medium* Permanent impacts from erosion pose a more significant challenge for adaptation (ICLEI 2017). However, there is significant redundancy in the roadway network. Of the road types assessed, major arterials have the lowest traffic demand. Thus, rerouting traffic through a detour or temporarily limiting service on affected roads would affect fewer travelers than on state-owned routes (e.g., state highways and freeways).
Drain Pump Stations	
SLR Sensitivity: High Storm water assets may become inundated from floods and higher groundwater levels. Inundation of the system would cause the pumps to continuously run without making progress, resulting in potential pump failure and burnout.	*SLR Adaptive Capacity: Low* It is relatively difficult to adapt drain pump stations (by increasing elevation, adding backflow valves, and/or installing additional pumps). There are spatial and topographical constraints to elevating drain pump stations, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of a station. Pumps may have to be reconfigured for a greater strength or capacity.
SLR with storm surge Sensitivity: Medium Storm water assets may become inundated from floods and higher groundwater levels. Periodic flooding from storm surge, however, would be less detrimental than chronic inundation.	*SLR with storm surge Adaptive Capacity: Low* It is relatively difficult to adapt drain pump stations (by increasing elevation, adding backflow valves, and/or installing additional pumps). There are spatial and topographical constraints to elevating drain pump stations, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of a station (City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*
Outfalls	

SLR Sensitivity: High Storm water assets may become inundated from floods and higher groundwater levels, and a redesign would be necessary to accommodate changing sea level elevations (e.g., outfall elevation).	*SLR Adaptive Capacity: Low* There are outfalls with elevation that would be chronically inundated/submerged. It is relatively difficult to adapt outfalls (by increasing elevation and/or adding backflow valves). There are spatial and topographical constraints to elevating outfall pipes, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (City of San Diego TSWD, 2019).
SLR with storm surge Sensitivity: Medium Storm water assets may become inundated from floods and higher groundwater levels.	*SLR with storm surge Adaptive Capacity: Low* There are outfalls with elevation that would be chronically inundated/submerged. It is relatively difficult to adapt outfalls (by increasing elevation and/or adding backflow valves). There are spatial and topographical constraints to elevating outfall pipes, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: High Erosion could compromise the functionality of the system.	*Coastal Erosion Adaptive Capacity: Low* It is relatively difficult to adapt outfalls (by increasing elevation and/or adding backflow valves). There are spatial and topographical constraints to elevating outfall pipes, which add to the time and cost of required engineering. There are also the spatial constraints of other existing structures and easement widths when considering the relocation of an outfall (City of San Diego TSWD, 2019).

Open Space and the Environment

Open space and environment assets include those managed by the City's Parks and Recreation Department, Environmental Services Department, Public Utilities Department, and Real Estate Assets Department. The following assets are considered critical: recreation centers, conservation areas/open space/source water, community parks, the Miramar landfill, the City's Compressed Natural Gas (CNG) fueling station, sensitive habitat, and beaches.

The City found that recreation centers, community parks, sensitive habitat, and beaches are vulnerable to both coastal flooding and erosion. All erosion scenarios assume 2.0 meters of SLR. Conservation areas/open space/source water are highly vulnerable to coastal flooding, but not erosion.

The results of the vulnerability assessment of open space and environment assets to coastal hazards are shown in Table 19, Table 20, and Table 21. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these assets to coastal hazards.

Table 19. Vulnerability of open space and environment asset types to SLR[6]

Sea Level Rise (SLR)	Rec Centers	Community Parks	Conservation Areas/Open Space/Source Water	Miramar Landfill	CNG Fueling Station	Sensitive Habitat	Beaches
Exposure	Low	High	High	Not exposed	Not exposed	High	High
Sensitivity	High	High	High	N/A	N/A	High	High
Adaptive Capacity	Low	Low	Low	N/A	N/A	Medium	Low
Vulnerability	High	High	High	N/A	N/A	High	High

Table 20. Vulnerability of open space and environment asset types to SLR + storm surge[6]

SLR with storm surge	Rec Centers	Community Parks	Conservation Areas/Open Space/Source Water	Miramar Landfill	CNG Fueling Station	Sensitive Habitat	Beaches
Exposure	Low	High	High	Not exposed	Not exposed	High	High
Sensitivity	Medium	Medium	High	N/A	N/A	Low	Medium
Adaptive Capacity	Medium	Medium	Medium	N/A	N/A	High	Medium
Vulnerability	Low	Medium	High	N/A	N/A	Medium	Medium

Table 21. Vulnerability of open space and environment asset types to erosion[6]

Coastal Erosion	Rec Centers	Community Parks	Conservation Areas/Open Space/Source Water	Miramar Landfill	CNG Fueling Station	Sensitive Habitat	Beaches
Exposure	Not Exposed	High	Not exposed	Not exposed	Not exposed	High	High
Sensitivity	N/A	High	N/A	N/A	N/A	High	High
Adaptive Capacity	N/A	Low	N/A	N/A	N/A	Medium	Medium
Vulnerability	N/A	High	N/A	N/A	N/A	High	High

Exposure

A specific subset of open space and environment critical assets may be exposed to coastal hazards. The landfill and CNG fueling station are not exposed. Of the habitat areas, the forest; grasslands, vernal pools, and meadows; scrub and chaparral; and woodland areas are not exposed. The remaining open space and environment areas face some degree of inundation from daily flooding and storm surge (100-year flood).

> **Sea Level Rise Projections for San Diego**
>
> 2030: 0.25 m
>
> 2050: 0.5–0.75 m
>
> 2100: 1.0–2.0 m

Salt marsh areas face the highest proportional exposure from sea level rise: forty-three percent of salt marsh acres may be inundated under 0.25 meters of sea level rise (approximately by 2030), and forty-five to sixty-two percent are projected to be exposed to sea level rise by 2100 (Figure 18). However, these areas are already partially submerged during high tides, so exposure is expected. Beaches face similar levels to exposure: thirty-nine percent of beach area is projected to be exposed to sea level rise by 2030, and up to seventy-one percent of beach area is projected to be exposed to sea level rise by 2100. Other assets are not highly exposed to sea level rise. Dune community areas face fifteen percent exposure and riparian and bottomland habitat areas and community parks face less than ten percent exposure to sea level rise, but most of the exposure begins to occur at 0.25 meters of sea level rise (2030). Only one recreation center (out of fifty-seven total) faces exposure from sea level rise beginning in 2100.

The number of assets and acres brought into flooding zones under sea level rise with storm surge does not increase significantly; however, assets are exposed earlier in time to storm surges than they are top sea level rise alone (Figure 19). Fifty-two percent of salt marsh areas and sixty percent of beach areas and twelve percent of dune community areas become flooded due to storm surge under 0.25 meters of sea level rise (2030). Recreation centers, community parks, and conservation areas/open space/source water still face very little exposure to sea level rise with storm surge flooding. Riparian and bottomland habitat areas have five to eight percent of their area potentially exposed to sea level rise with storm surge flooding with most of the acres becoming exposed at 0.25 meters of sea level rise (2030).

Different assets and habitat types may become exposed to cliff erosion by 2100, but beaches face the greatest proportional exposure to cliff erosion (Figure 20). Fifteen percent of beach area may be exposed if no adaptive action is taken. This is beach area that currently abuts cliffs, such as along Torrey Pines or Sunset Cliffs Natural Park.

As with cliff erosion, beaches face the greatest exposure to beach erosion: up to twenty percent of beach area may be exposed (Figure 20). Most of this erosion may occur regardless of whether beach nourishment or sea wall repairs occur.

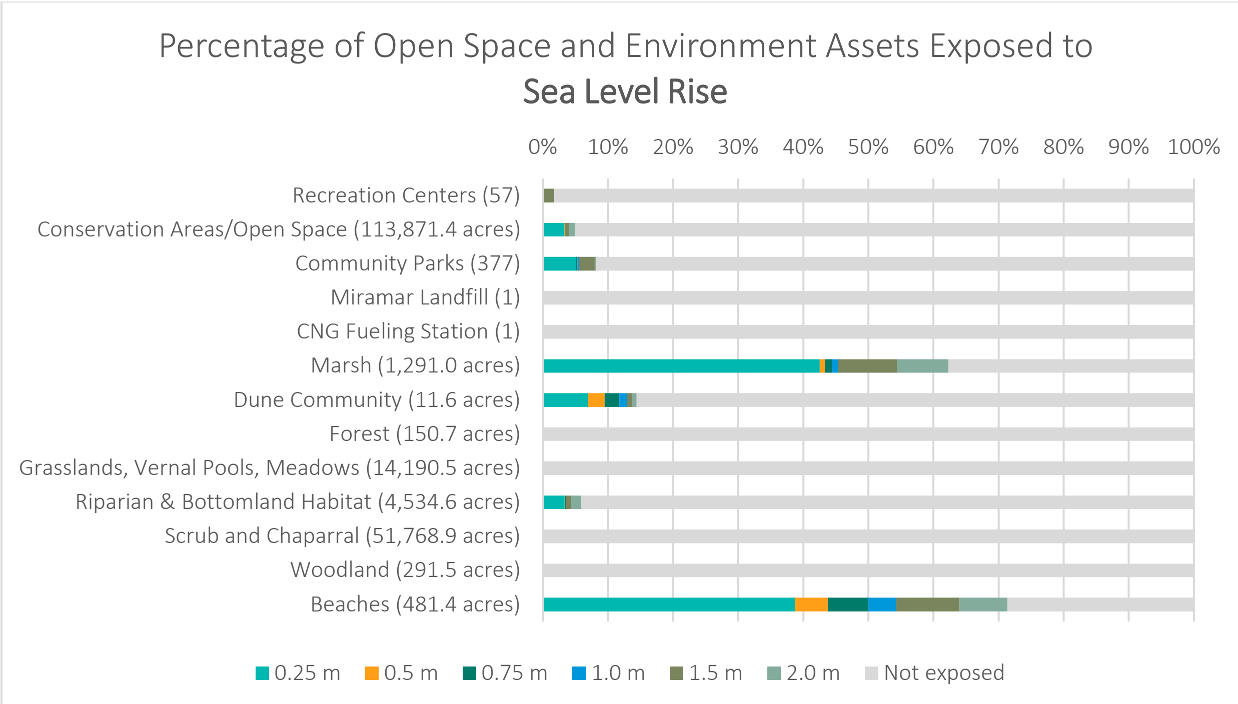


Figure 18: Open space and environment assets exposed to SLR.

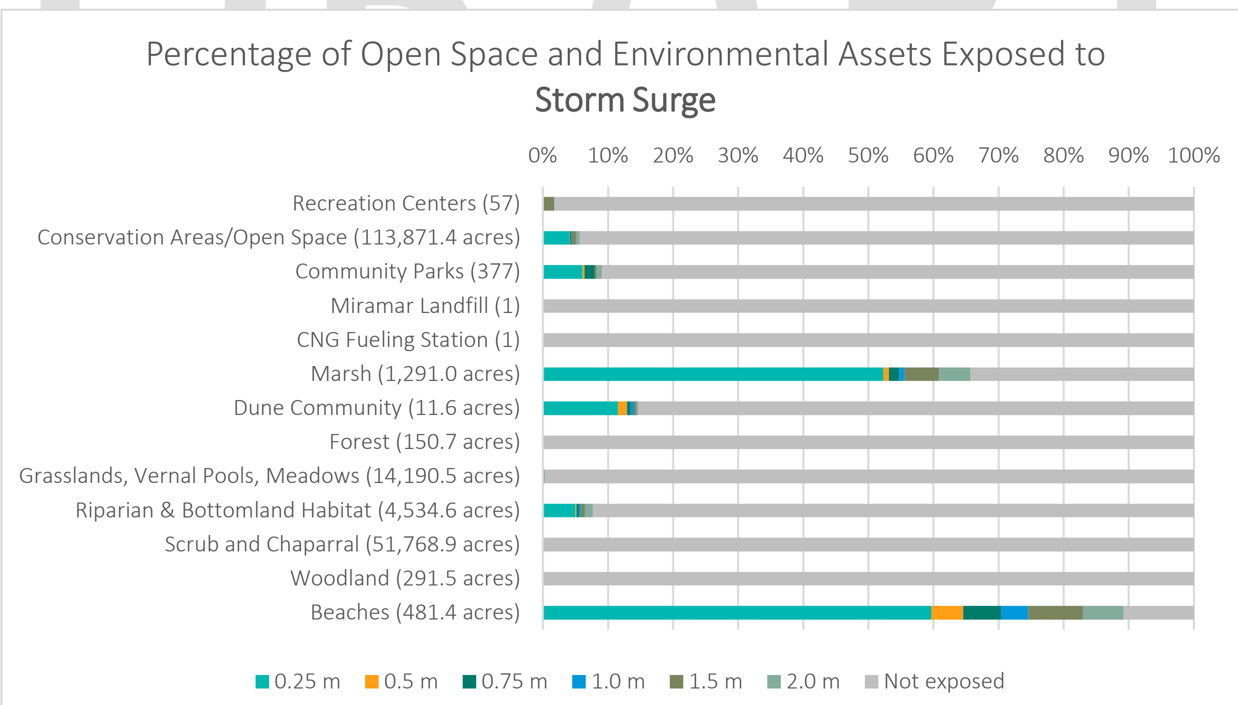
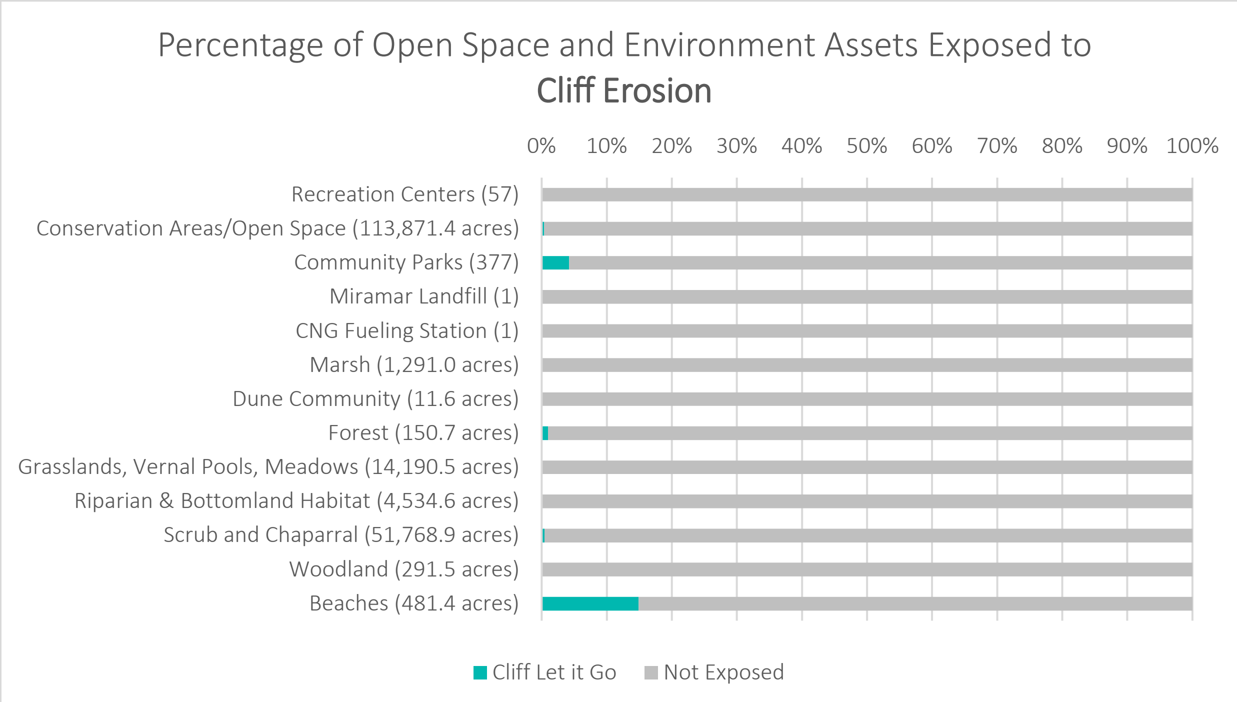


Figure 19: Open space and environment assets exposed to storm surge; this includes the 100-year storm on top of SLR. Storm surge + SLR encompasses a larger flood area than sea level rise alone, so more assets in this graph tend to be exposed under lower sea level rise amounts than in the graph above showing only sea level rise exposure.



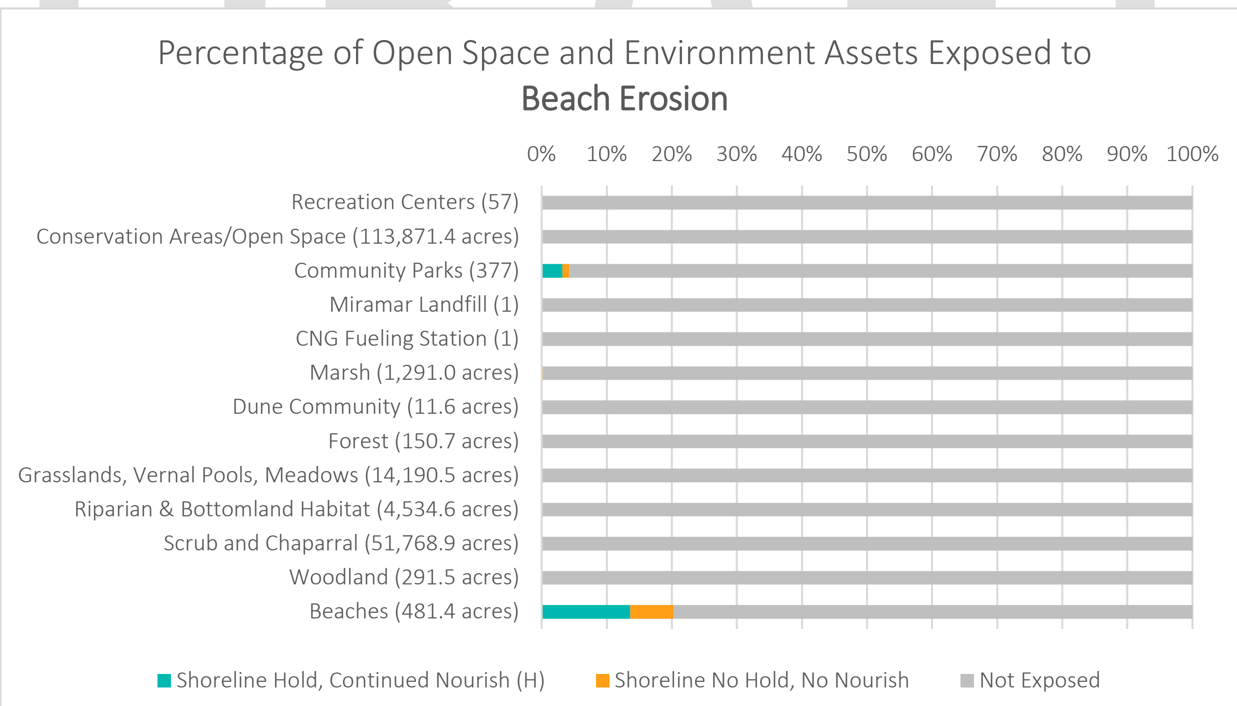


Figure 20: Open space and environment assets exposed to erosion. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion. "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair, while "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair.

Sensitivity and Adaptive Capacity

Based on the exposure assessment, the sensitivity and adaptive capacity of recreation centers, conservation areas/open space/source water, community parks, sensitive habitats, and beaches to coastal hazards was analyzed. The results of this analysis are presented in Table 22.

Table 22. Sensitivity and adaptive capacity of open space and environment asset types to coastal hazards

Recreation Centers	
SLR Sensitivity: High Sea level rise can permanently inundate buildings within the projected sea level rise zone; can increase the erosion of structures; and can damage or destroy buildings and equipment (USAID 2014).	*SLR Adaptive Capacity: Low* Longer-term adaptation (e.g., intensive, such as building relocation) may be necessary if chronic flooding within the coastal zone becomes a highly likely scenario. In some areas, this may occur as soon as 2030 (with 0-0.25 m of SLR); other areas may start to experience chronic flooding around 2050 (0.5-0.75 m SLR) or 2100 (1-2 m SLR).
SLR with storm surge Sensitivity: Medium Recreation centers might have to be temporarily closed in the event of a flood, and flood damages would have to be repaired before the facilities could be fully functional again.	*SLR with storm surge Adaptive Capacity: Medium* Short term solutions exist for flood protection (e.g., sandbags), but longer-term adaptation is more difficult.
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*
Community Parks	
SLR Sensitivity: High Chronic flooding may limit access to and use of parks and fundamentally change habitat types. Chronic flooding can also pose a threat to public safety.	*SLR Adaptive Capacity: Low* There are not currently protective measures in place to protect parks from coastal flooding (City of San Diego Parks and Recreation Department, 2019).
SLR with storm surge Sensitivity: Medium Periodic flooding may temporarily limit access to parks, but once flood waters recede, the park should be useable again with limited clean up (City of San Diego Parks and Recreation Department, 2019).	*SLR with storm surge Adaptive Capacity: Medium* There is high redundancy in the park network in the City, which increases the overall adaptive capacity of the park system.
Coastal Erosion Sensitivity: High Erosion can render the recreational functions of parks useless and pose a threat to public safety.	*Coastal Erosion Adaptive Capacity: Low* There are not currently protective measures in place to protect parks from erosion (City of San Diego Parks and Recreation Department, 2019).
Conservation Areas/Open Space/Source Water	
SLR Sensitivity: High Conservation areas could experience complete damage if exposed to chronic flooding. Based on department interviews, the project team found that many species (including endangered) may become locally extirpated if certain habitats in	*SLR Adaptive Capacity: Low* If there is sufficient available space, some habitats may be able to migrate inland to reduce exposure to chronic flooding. However, not all habitat types or species will be able to keep pace with sea level rise.

conservation areas and parks are lost (City of San Diego Parks and Recreation Department, 2019).	
SLR with storm surge Sensitivity: High Temporary flooding from storms may temporarily disrupt conservation areas, but due to the natural features, water can likely be absorbed into the ground. However, the Rare Plant Working Group has identified several rare species that are a high priority for regional conservation and are threatened by more frequent storm surges. In addition, as storm surges push salinity further upstream into traditionally freshwater areas, freshwater species further inland may be threatened and habitat areas may shift (City of San Diego Parks and Recreation Department, 2019).	*SLR with storm surge Adaptive Capacity: Medium* Most natural areas are able to recover from periodic flooding. However, certain species – including those rare priority species identified by the Rare Plant Working Group – may not be able to adapt to shifting storm surge regimes and/or greater salinity content being pushed further upstream and inland (City of San Diego Parks and Recreation Department, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed*
Sensitive Habitat	
SLR Sensitivity: High The changes to ecosystems that come with sea level rise impacts—changes in sediment, nutrient availability, and salinity—can lead to shifts in habitat locations and may cause certain habitats to shrink or disappear (ICLEI 2017).	*SLR Adaptive Capacity: Medium* There is little that habitats can do to respond to the changes brought on by sea level rise. Inland migration might be possible, though most of these habitats abut human or natural barriers. Humans may have to assist with moving sensitive plants with very limited distribution to more appropriate areas as habitats shift inland. Banking seed from sensitive plant species now (while they are still here) can help ensure the future persistence of these species. The City can also proactively identify future areas that would be suitable for these species should sea levels rise, resulting in loss of current habitat.
SLR with storm surge Sensitivity: Low Temporary flooding from storms may temporarily disrupt conservation areas, but due to the natural features, water can likely be absorbed into the ground.	*SLR with storm surge Adaptive Capacity: High* Most natural areas are able to recover from periodic flooding.
Coastal Erosion Sensitivity: High Erosion can impact habitable land, making it difficult for sensitive habitats to remain functional. The changes to ecosystems that come with sea level rise impacts—changes in sediment, nutrient availability, and salinity—can lead to shifts in habitat locations and may cause certain habitats to shrink or disappear (ICLEI 2017).	*Coastal Erosion Adaptive Capacity: Medium* Sea level rise can impact habitat viability. In some cases inland migration might be possible, however many habitats abut human or natural barriers. Humans may have to assist with moving sensitive plants with very limited distribution to more appropriate areas as habitats shift inland. Banking seed from sensitive plant species now (while they

Coastal bluffs such as those at Point Loma and La Jolla are home to sensitive species that might be lost if there is more coastal erosion. The Torrey Pines Bluffs are also a conserved sensitive area that could be severely impacted by erosion (City of San Diego Parks and Recreation Department, 2019).	are still here) can help ensure the future persistence of these species.
Beaches	
SLR Sensitivity: High Narrowing sandy areas can limit a beach's ability to provide valuable recreational and ecological services. Current beaches may shrink or even disappear as sea levels rise.	*SLR Adaptive Capacity: Low* If allowed, beaches will move landwards as sea levels rise. However, beaches will erode as sea levels rise when they are constrained from landwards movements either by coastal protection structures, or by natural coastal bluffs (Spiegel 2016). In San Diego, most beaches abut an area of urban development and therefore have limited space for inland migration as sea levels rise. The adaptive capacity of beaches to sea level rise is enhanced by beach nourishment that provides an additional buffer to beach erosion in the short term.
SLR with storm surge Sensitivity: Medium Periodic flooding has the potential to limit access to beaches and wash away sand. Once the floods recede the beach can generally resume functionality, albeit with reduced long-term functionality as sea levels rise.	*SLR with storm surge Adaptive Capacity: Medium* The adaptive capacity of beaches to storm surge and sea level rise is enhanced by beach nourishment that provides an additional buffer to beach erosion. There are measures the City can take to mitigate flood damage to beaches from storm surge (e.g., living shorelines, beach nourishment). However, long term sea level rise will lead to long term changes in the shoreline over time as sea levels rise and storm surge impacts reach farther inland (Spiegel 2016).
Coastal Erosion Sensitivity: High By definition, coastal erosion is the inland migration of the shoreline as beaches and cliffs are eroded into the ocean. Thus, beaches can be highly impacted by coastal erosion.	*Coastal Erosion Adaptive Capacity: Medium* Beach nourishment is a common and available approach to combating erosion and has been widely used in San Diego (Brennan 2018). Nourishment provides an additional buffer to beach erosion in the short term. Common hard infrastructure protection such as sea walls and bulkheads can increase rates of erosion at the infrastructure's edge (Spiegel 2016).

Additional Assets

Additional assets include those managed by the Real Estate Assets, Planning, Development Services, Parks and Recreation, and Public Utilities departments along with the Commission for Arts and Culture and the

Parking Organization. The following assets are considered critical: libraries, administrative buildings, and historic and cultural resources.[7]

For this category of critical assets, only historic and cultural resources may be exposed to coastal hazards. These assets are highly vulnerable to both coastal flooding and erosion, given their exposure to these hazards starting at just 0.25 m of SLR (projected to occur by 2030) and their high sensitivity to impacts. SLR and storm events can damage or destroy built assets, permanently inundate coastal assets, and increase erosion of assets. Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable) and repairs can be difficult and/or costly. All erosion scenarios assume 2.0 meters of SLR.

The results of the vulnerability assessment of additional assets to coastal hazards are shown in Table 23, Table 24, and Table 25. The following sections provide greater detail on the exposure, sensitivity, and adaptive capacity of these assets to coastal hazards.

Table 23. Vulnerability of Additional Asset types to SLR[6]

Sea Level Rise (SLR)	Libraries	City Administrative Buildings	Historic and Cultural Resources
Exposure	Not exposed	Not exposed	High
Sensitivity	N/A	N/A	High
Adaptive Capacity	N/A	N/A	Low
Vulnerability	**N/A**	**N/A**	**High**

Table 24. Vulnerability of Additional Asset types to SLR + storm surge[6]

SLR + Storm Surge	Libraries	City Administrative Buildings	Historic and Cultural Resources
Exposure	Not exposed	Not exposed	High
Sensitivity	N/A	N/A	High
Adaptive Capacity	N/A	N/A	Low
Vulnerability	**N/A**	**N/A**	**High**

Table 25. Vulnerability of Additional Asset types to erosion[6]

Coastal Erosion	Libraries	City Administrative Buildings	Historic and Cultural Resources
Exposure	Not exposed	Not exposed	High
Sensitivity	N/A	N/A	High
Adaptive Capacity	N/A	N/A	Low
Vulnerability	**N/A**	**N/A**	**High**

[7] The number of assets under historic and cultural resources (1,375 assets) is conservative; some of these "assets" are in fact historic districts composed of multiple assets. The conservative number was used as this is the official count of assets under that historic designation. Additionally, while the discussion of the vulnerability of these assets is limited to this section of the report, the assets themselves may fall under the other sectors discussed in this report: some bridges, dams, recreation centers, libraries, and other asset types are also designated historic and cultural resources in the City.

Exposure

Of the additional assets, only historic and cultural resources may be exposed to SLR and SLR + storm surge (100-year flood), as shown in Figure 21 and Figure 22. Seven historical and cultural resources may become exposed to SLR starting at 0.25 meters of SLR (approximately 2030), and seventeen historical and cultural resources may become exposed under 2 meters of SLR (Figure 21).

> **Sea Level Rise Projections for San Diego**
>
> 2030: 0.25 m
>
> 2050: 0.5-0.75 m
>
> 2100: 1.0-2.0 m

SLR with storm surge brings eleven historic and cultural resources into flooding zones at 0.25 meters of SLR (2030) and an upper end of twenty-five resources into flooding zones in 2100 (Figure 22). Eight of these twenty-five resources do not face exposure to SLR with storm surge until the highest level (2 meters) of SLR.

Libraries and administrative buildings are not exposed to cliff erosion. There are six historical and cultural resources that face exposure to cliff erosion and seven that face exposure to beach erosion (assuming no beach nourishment or seawall improvements) (Figure 23).

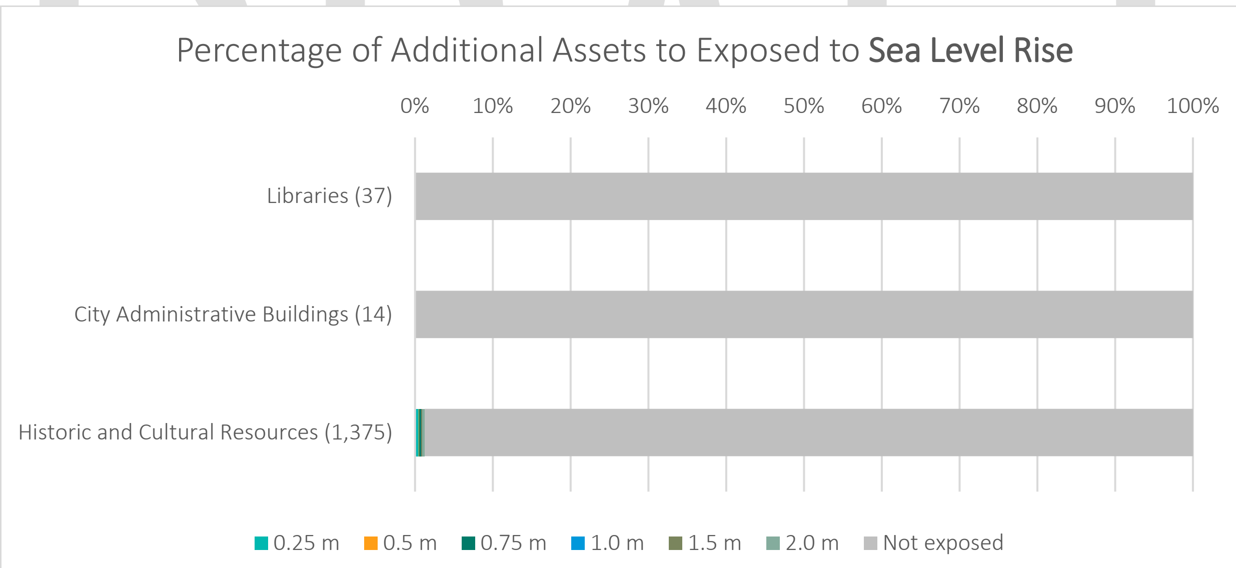


Figure 21: Additional assets exposed to SLR.

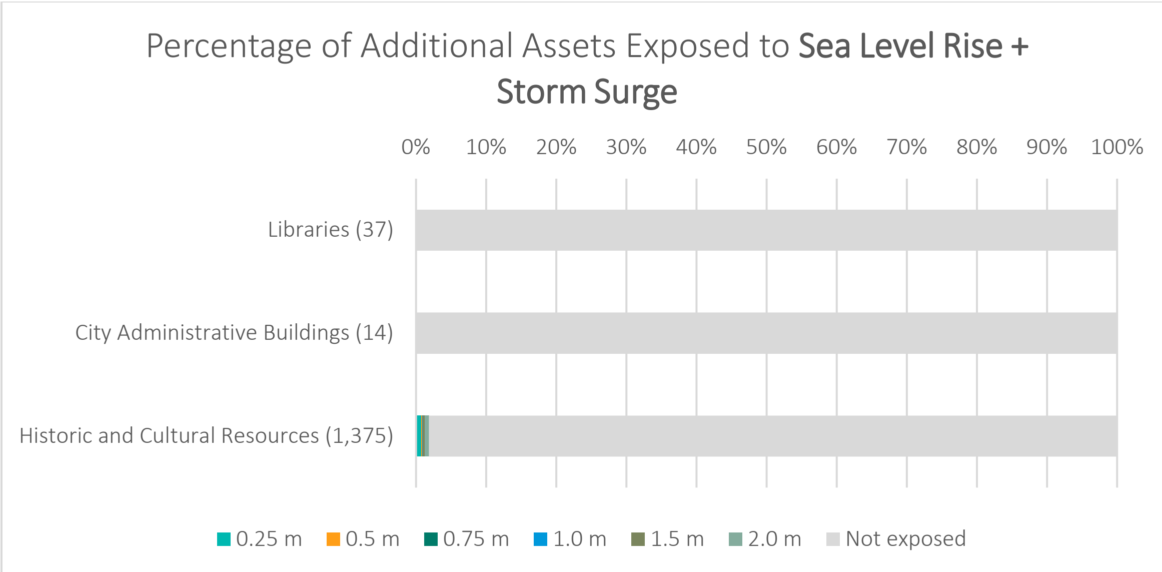


Figure 22: Additional assets exposed to storm surge; this includes the 100-year storm on top of SLR. Storm surge + SLR encompasses a larger flood area than sea level rise alone, so more assets in this graph tend to be exposed under lower sea level rise amounts than in the graph above showing only sea level rise exposure.

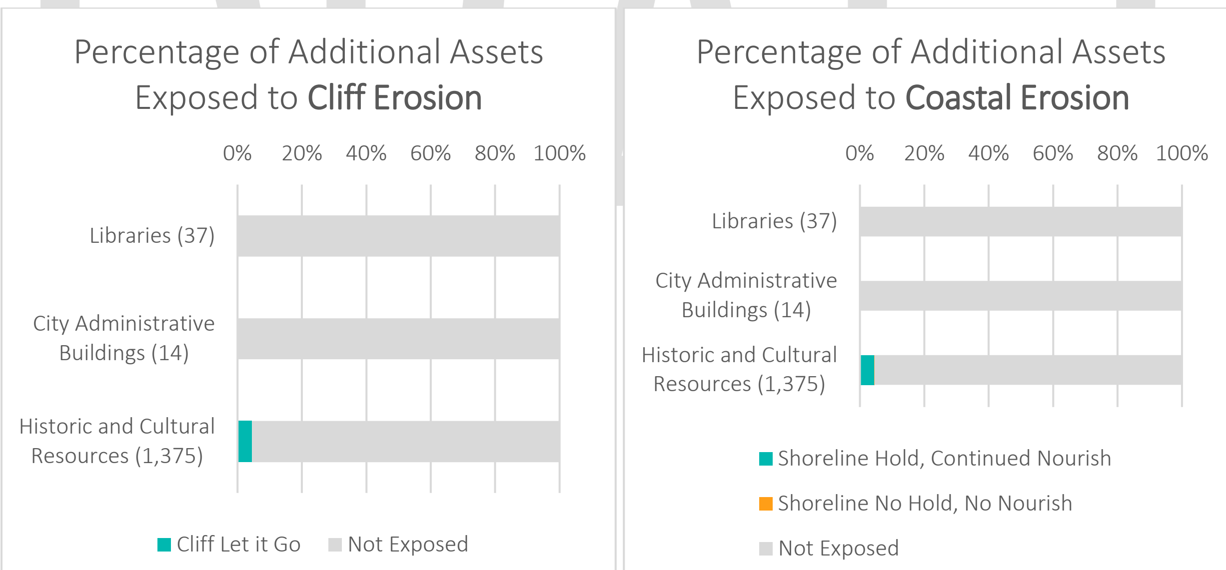


Figure 23: Additional assets exposed to erosion. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion. "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair, while "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair.

Sensitivity and Adaptive Capacity

Based on the exposure assessment, the sensitivity and adaptive capacity only of historic and cultural resources to coastal hazards were analyzed. The results of this analysis are presented in Table 26.

Table 26. Sensitivity and adaptive capacity of historic and cultural resources to coastal hazards

Historic and Cultural Resources	
SLR Sensitivity: High Chronic flooding can limit access to, damage, or destroy historic and cultural resources.	*SLR Adaptive Capacity: Low* Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable), and repairs can be difficult and/or costly. Relocation of any resource would require a Site Development Permit, Process 5 and associated environmental review and mitigation.
SLR with storm surge Sensitivity: High Periodic flooding from storms can damage or destroy these resources.	*SLR with storm surge Adaptive Capacity: Low* Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable), and repairs can be difficult and/or costly. Relocation of any resource would require a Site Development Permit, Process 5 and associated environmental review and mitigation.
Coastal Erosion Sensitivity: High If coastal erosion were to threaten the physical structure of historic or cultural resource, the asset would have to be moved. However, this is not always possible for assets that have place-based significance.	*Coastal Erosion Adaptive Capacity: Low* Because these assets are critical for their historic and cultural value, they are not easily replaced (and in some cases irreplaceable), and repairs can be difficult and/or costly. Relocation of any resource would require a Site Development Permit, Process 5 and associated environmental review and mitigation.

Non-City Owned Assets

State-Owned

Though state highways and freeways are not owned or managed by the City, these assets are part of the transportation infrastructure network within the City and were included in this vulnerability assessment to provide a complete view of the transportation network that services the City. Like bridges and major arterials, these two asset types are broken down into roadway segments as defined in the City's asset management system.

State Highways and Freeways Vulnerability to Coastal Hazards

Coastal hazards include sea level rise, storm surge (100-year flood), and erosion. Daily flooding was used to estimate exposure to chronic inundation and represents the extent of flooding that would occur at high tide each day assuming each sea level rise scenario. Storm surge (100-year storm) flooding was used to estimate exposure to more severe but periodic flooding and represents the extent of flooding that would occur during a 100-year (one percent annual chance) storm assuming each sea level rise scenario. The storm surge flooding scenario is not additive to the daily flooding scenario; rather, they represent two separate modeling scenarios.

Both state highways and freeways are highly vulnerable to sea level rise and have medium to high vulnerability to sea level rise with storm surge. State highways are also vulnerable to coastal erosion. All erosion scenarios assume 2.0 meters of sea level rise (which is projected to occur by 2100).

The results of the vulnerability assessment of state highway and freeways critical assets to coastal hazards are shown in Table 27, Table 28, and Table 29. The sections below provide greater detail on these assets' exposure, sensitivity, and adaptive capacity to coastal hazards.

Table 27. Vulnerability of State Highways and Freeways to Sea Level Rise[6]

SLR	State Highways	Freeways
Exposure	High	High
Sensitivity	High	High
Adaptive Capacity	Medium	Medium
Vulnerability	**High**	**High**

Table 28. Vulnerability of State Highways and Freeways to Sea Level Rise with Storm Surge[6]

SLR with storm surge	State Highways	Freeways
Exposure	High	High
Sensitivity	Low	Low
Adaptive Capacity	High	High
Vulnerability	**Medium**	**Medium**

Table 29. Vulnerability of State Highways and Freeways to Coastal Erosion[6]

Coastal Erosion	State Highways	Freeways
Exposure	High	Not exposed
Sensitivity	High	N/A
Adaptive Capacity	Medium	N/A
Vulnerability	**High**	**N/A**

State Highway and Freeway Exposure to Coastal Hazards

A significant portion of the critical freeway and highway assets may be exposed to sea level rise and sea level rise with storm surge (100-year flood). State highways will be more significantly vulnerable to coastal erosion whereas freeways will not (Figure 24, Figure 25, Figure 26, and Figure 27).

Sea Level Rise (SLR) Projections for San Diego
2030: 0.25 m
2050: 0.5–0.75 m
2100: 1.0–2.0 m

Less than two percent of critical state highway and freeway assets may be exposed to sea level rise; however, there are significant local exposure concerns in select coastal neighborhoods (Figure 24). Of the two asset types analyzed, freeway segments showed the most exposure in the near term (twenty-three segments in 2030).

A few additional state highway and freeway critical assets face exposure to flooding with sea level rise and storm surge, but the proportion remains below 5 percent, with a total of up to 104 state highway and freeway road segments exposed to a 2100 storm surge event (Figure 25). In a storm surge scenario, assets become exposed across a broader spectrum of sea level rise ranges. Neither state highways nor freeways are exposed to cliff erosion (Figure 26). As Figure 27 shows, four state highway segments may be exposed to beach erosion.

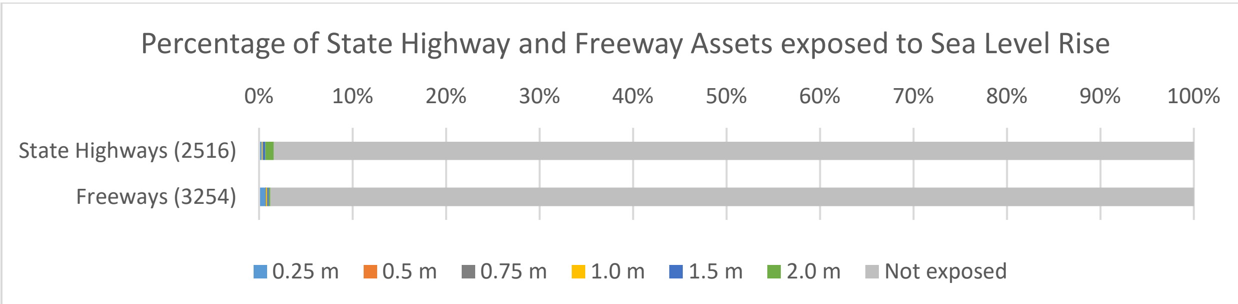


Figure 24. State Highway and Freeway critical assets exposed to sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario.

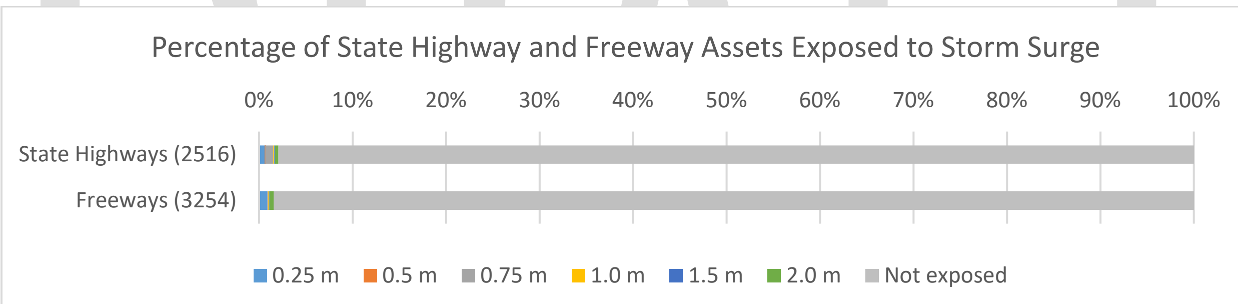


Figure 25. State Highway and Freeway critical assets exposed to sea level rise with storm surge; this includes the 100-year storm on top of sea level rise. The value after each asset name indicates the asset count. The colored bars for each increment of sea level rise show how many additional assets become inundated in each sea level rise scenario. Assets will be exposed to storm surge prior to being exposed to daily *flooding, so more assets in this graph tend to be exposed under lower sea level rise amounts.*

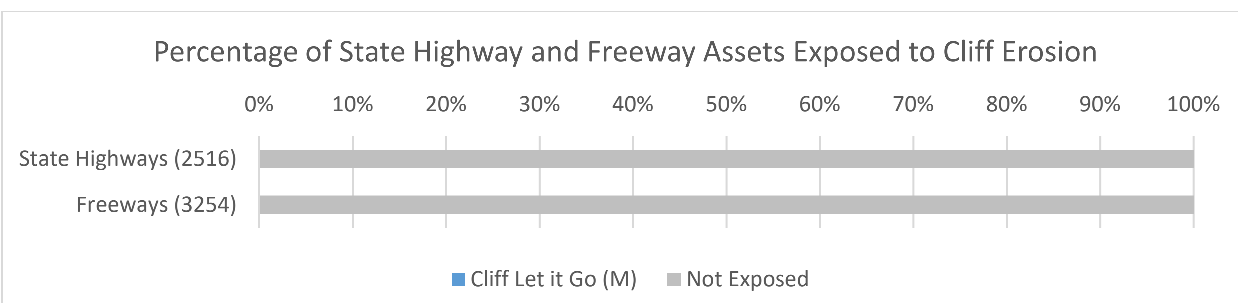


Figure 26. State Highway and Freeway critical assets exposed to cliff erosion. The value after each asset name indicates the asset count. "Cliff let it go" represents the number of assets exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

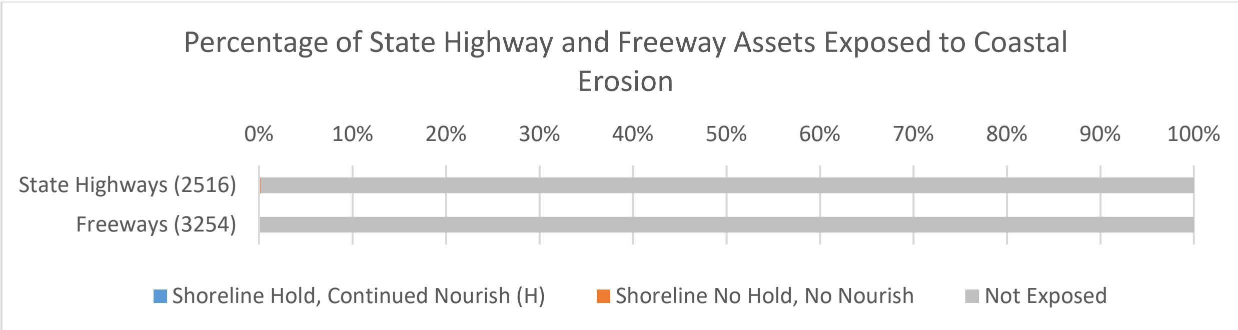


Figure 27. State Highway and Freeway critical assets exposed to beach erosion. The value after each asset name indicates the asset count. "Shoreline hold, continued nourish" represents the number of assets exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the number of assets exposed if the City were to stop beach nourishment and seawall repair.

State Highway and Freeway Sensitivity and Adaptive Capacity to Coastal Hazards

Based on the exposure analysis, the sensitivity and adaptive capacity of state highway and freeway critical asset types to coastal hazards were assessed. The results of this analysis are shown in Table 30 below.

Table 30. Vulnerability of State Highways and Freeways to Coastal Hazards

State Highways	
SLR Sensitivity: High Daily inundation can cause structural damage to assets and cut off access from flooded routes (U.S. DOT 2018).	*SLR Adaptive Capacity: Medium* Policy and planning-based decisions are needed for long term solutions (City of San Diego TSWD, 2019).
SLR with storm surge Sensitivity: Low Roads are not very sensitive to occasional flooding (U.S. DOT 2018).	*SLR with storm surge Adaptive Capacity: High* The Transportation and Storm Water Department can close flood gates, put in pumps, and build berms to protect against periodic flooding (City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: High Roads are highly sensitive to erosion and have already begun to suffer the impacts. If major routes become eroded, new routes must be created (ICLEI 2017) (City of San Diego TSWD, 2019).	*Coastal Erosion Adaptive Capacity: Medium* Permanent impacts from erosion pose a more significant challenge for adaptation (ICLEI 2017). However, there is significant redundancy in the roadway network. Of the road types assessed, state highways have moderate traffic demand.
Freeways	
SLR Sensitivity: High Daily inundation can cause structural damage to assets and cut off access from flooded routes (U.S. DOT 2018).	*SLR Adaptive Capacity: Medium* Policy- and planning-based decisions are needed for long term solutions (City of San Diego TSWD, 2019).
SLR with storm surge Sensitivity: Low Roads are not very sensitive to occasional flooding (U.S. DOT 2018).	*SLR with storm surge Adaptive Capacity: High* The Transportation and Storm Water Department can close flood gates, put in pumps, and build

	berms to protect against periodic flooding (City of San Diego TSWD, 2019).
Coastal Erosion Sensitivity: Not exposed	*Coastal Erosion Adaptive Capacity: Not exposed.*

Non-City Owned Assets

Land and/or assets not owned by the City of San Diego will also face exposure to coastal hazards. For this assessment, each parcel was assigned one or more land use types based on the tax assessors' land use code. Seventy-two unique land use types were grouped into seventeen categories: agricultural, commercial, community, cemetery, entertainment, health, hotel/motel, industrial, institutional, marina docks, office space, open space, residential, restaurant, rural, not defined, and vacant.

Category	Land Use Types
Agricultural	1-10 acres non-irrigated; 41-160 acres non-irrigated; 161-360 acres non-irrigated; 361 acres and up non-irrigated; agricultural preserve (under contract); avocado; citrus; irrigated crops other vegetable, floral, feeding (hay or seed crops); livestock; misc. agricultural; trees misc. (other than citrus or avocado)
Commercial	Auto sales/service agency; automotive repair garages; car wash; community shopping center; garage parking lot/used car; generic commercial office retail 1-3 stories; generic – radio station/bank/misc.; grocery/drug store large chain generic; neighborhood shopping center; regional shopping center; service station - generic
Community	Church; church rectory, parking and other church related use; co-op generic; meeting hall, gym – generic; public building (school, firehouse, library, etc.); theater - generic
Cemetery	Cemetery; mausoleum; mortuary
Entertainment	Bowling alley; golf course
Health	Generic – medical/dental office; hospital; rest home/convalescent hospital (sic)
Hotel/motel	Hotel/motel
Industrial	Factory/heavy manufacturing; factory/light manufacturing; industrial condos; misc. industrial/special land; natural resources – mining, extractive, processing cement/silica products, rock and gravel; storage bulk chemical/oil refinery; warehouse – processing/storage/distribution
Institutional	Institutional
Marina docks	Marina docks
Office space	Generic – 4 and more story office building; office condominiums
Open space	Open space
Residential	Condominiums and other residential classifications; duplex – generic; manufactured home in park – not specified; single family residential – generic; time share generic; trailer park
Restaurant	Restaurant/night club/tavern
Rural	Rural land other
Not defined	Information parcel – generic; miscellaneous/special; multiple 2 to 4 units – generic; multiple 5 to 15 units – generic; multiple 16 to 60 units – generic; multiple 61 units and up – generic; non-taxable; special – sliver, small parcel

Vacant	Institutional – vacant; irrigated farm vacant water available; vacant industrial; vacant land commercial; vacant recreational; vacant residential – generic; vacant taxable govt. owned property (sic)

For Non-City owned assets or land, the City is unable to assess the sensitivity and adaptive capacity to coastal hazards since the specifics of the building construction, maintenance, emergency plans, and other details are unknown. However, assessing exposure to coastal hazards provides insights into the potential scope of future concerns.

The land use category with the greatest exposure to sea level rise is marina docks—due to the waterfront location, 91 percent of these parcels are currently exposed (Figure 28). By definition, marina docks are waterfront and exposed to the sea. Four to 6 percent of entertainment, hotel and motel, and restaurant parcels may be exposed to sea level rise by 2030. The number of exposed parcels does not increase significantly between 2030 and 2050.

By 2100, between 5 percent and 62 percent of hotel and motel parcels may be exposed to sea level rise. Up to 11 percent of entertainment and restaurant parcels may also be exposed to sea level rise by 2100. Other land use categories may not experience significant exposure by 2100 (about five percent or fewer of the remaining asset types may be exposed by 2100).
Up to 5,550 residential parcels may face exposure to sea level rise and almost 9,000 residential parcels may face exposure to sea level rise with storm surge (100-year flood) by 2100. While this is a low percentage of the overall housing stock, it represents a vulnerability for those residential parcels.

With storm surge considered in combination with sea level rise, the most notable difference in exposure is that a large number of hotel and motel parcels may be exposed much earlier—between five and 58 percent of these parcels may face exposure by 2050 (compared to up to five percent by 2050 with sea level rise alone) (Figure 29). Almost 95 percent of marina dock parcels may be exposed to storm surge by 2030, most of which already face exposure.

Very few parcels are exposed to cliff erosion (Figure 30). No cemetery, health, marina docks, office space, open space, or rural land parcels face exposure, and a very small percentage (less than five percent) of other land use categories face exposure to cliff erosion. About 2,500 residential parcels face exposure to cliff erosion assuming 2.0 meters of sea level rise (which is projected to occur by 2100).

Similarly, even if the City were to stop beach nourishment and seawall repair, very few parcels would be exposed to beach erosion (Figure 31). Community, cemetery, health, industrial, marina dock, office space, open space, and rural land parcels face no exposure to beach erosion, and other land use categories face very small (less than 5 percent) exposure to beach erosion.

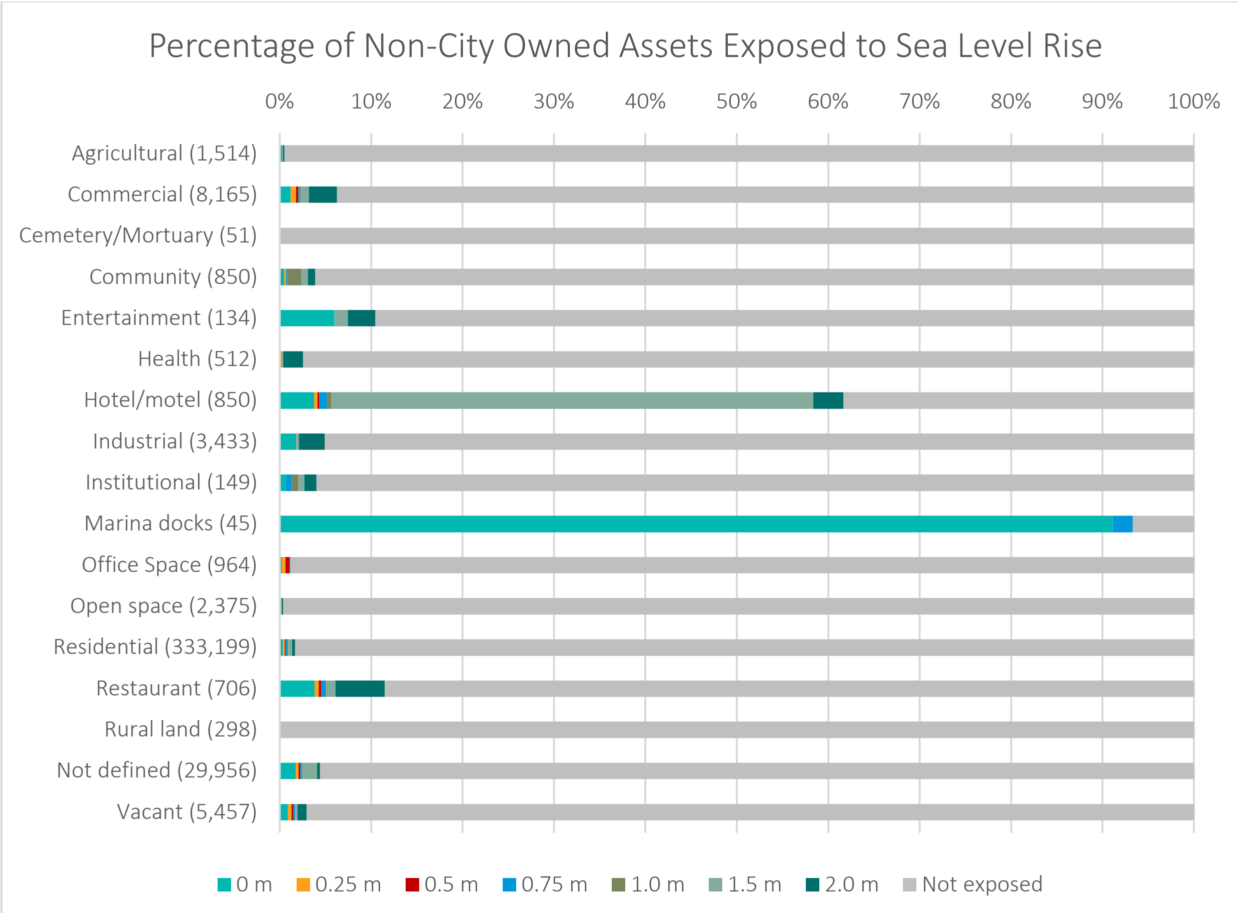


Figure 28. Non-City Owned Assets exposed to sea level rise. The value after each land use category indicates the total number of parcels of that land use category. The colored bars for each increment of sea level rise show how many additional parcels become inundated in each sea level rise scenario.

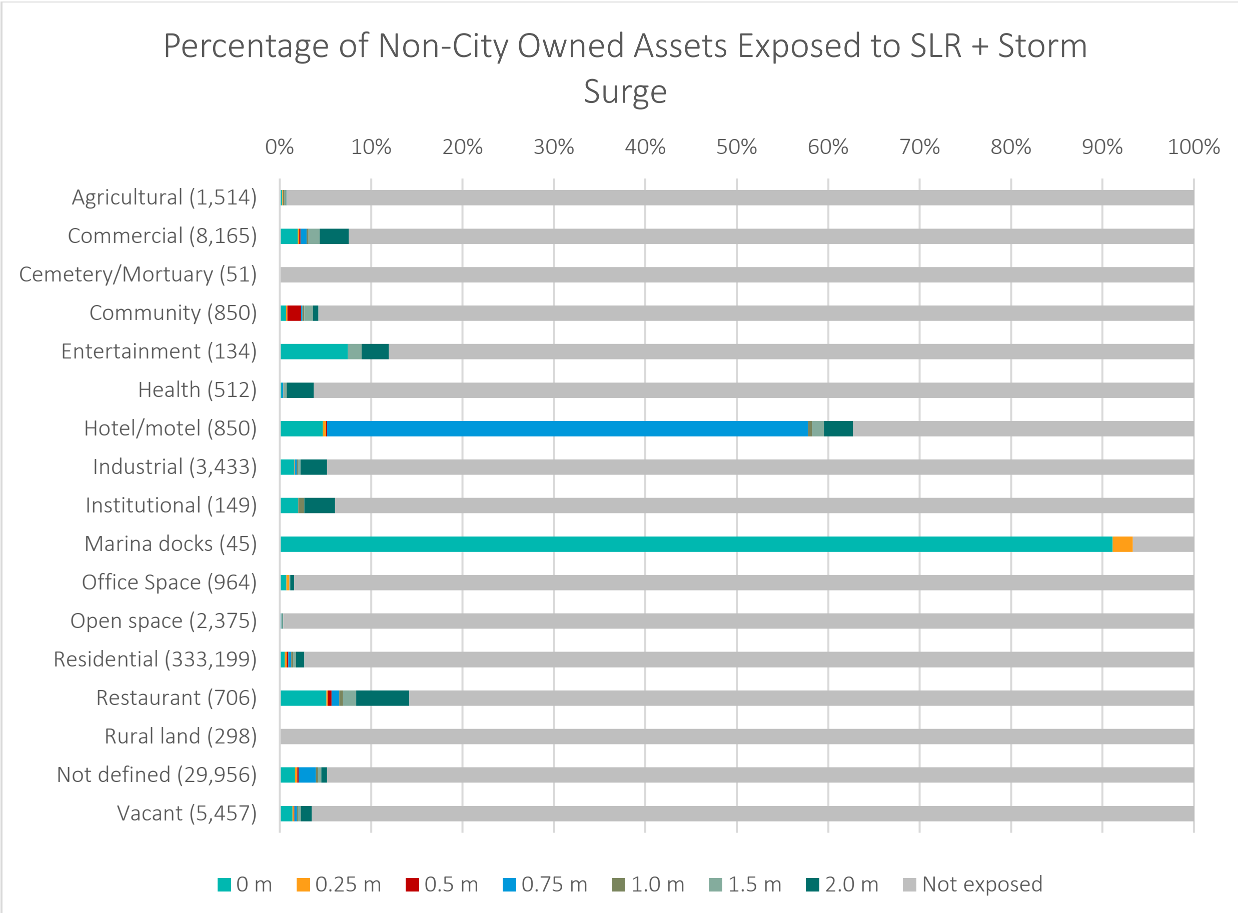


Figure 29. Non-City Owned Assets exposed to sea level rise with storm surge; this includes the 100-year storm on top of sea level rise. The value after each land use category indicates the total number of parcels of that land use category. The colored bars for each increment of sea level rise show how many additional parcels become inundated in each sea level rise scenario.

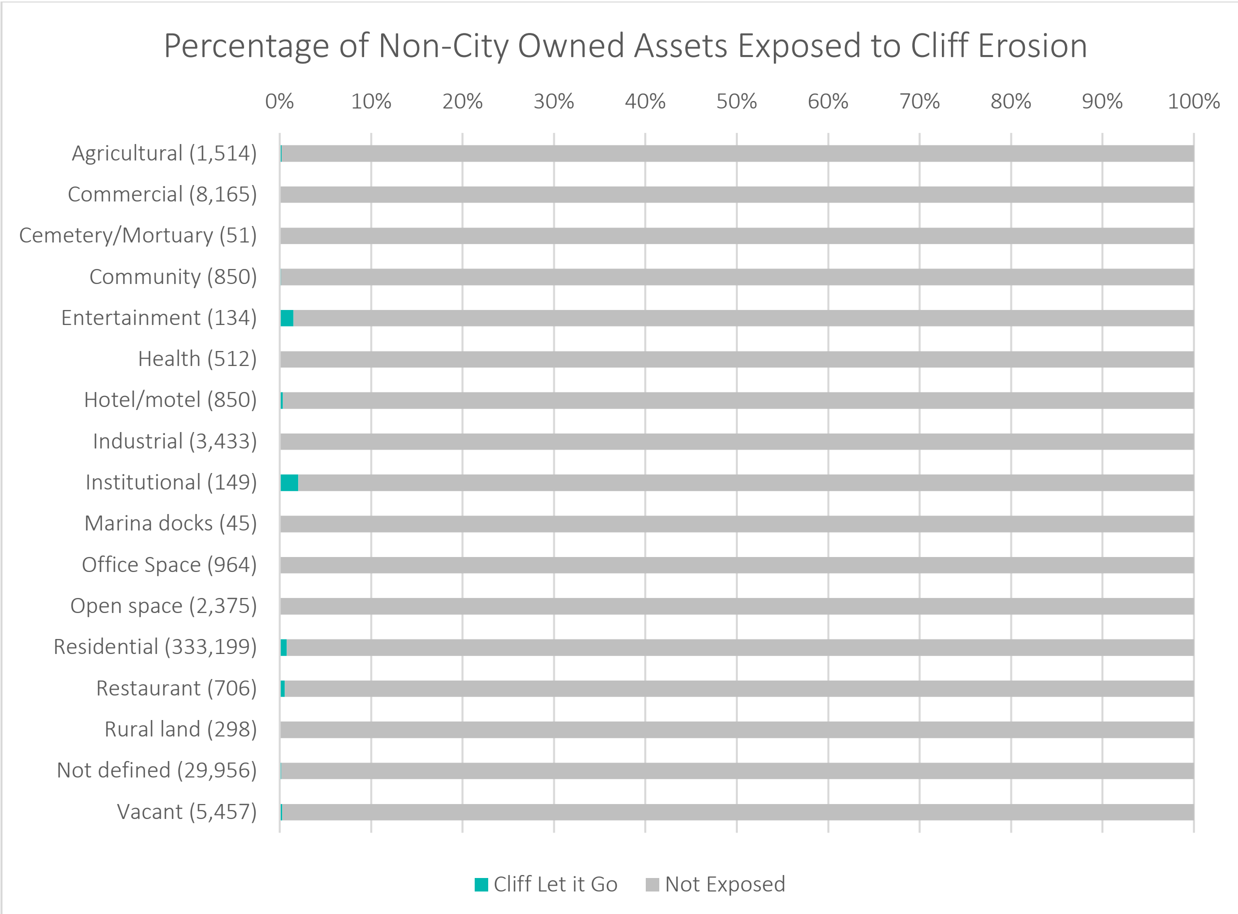


Figure 30. Non-City Owned Assets exposed to cliff erosion. The value after each land use category indicates the parcel count. "Cliff let it go" represents the percentage of parcels exposed to flooding if the City does not implement coastal armoring and allows cliff retreat and erosion.

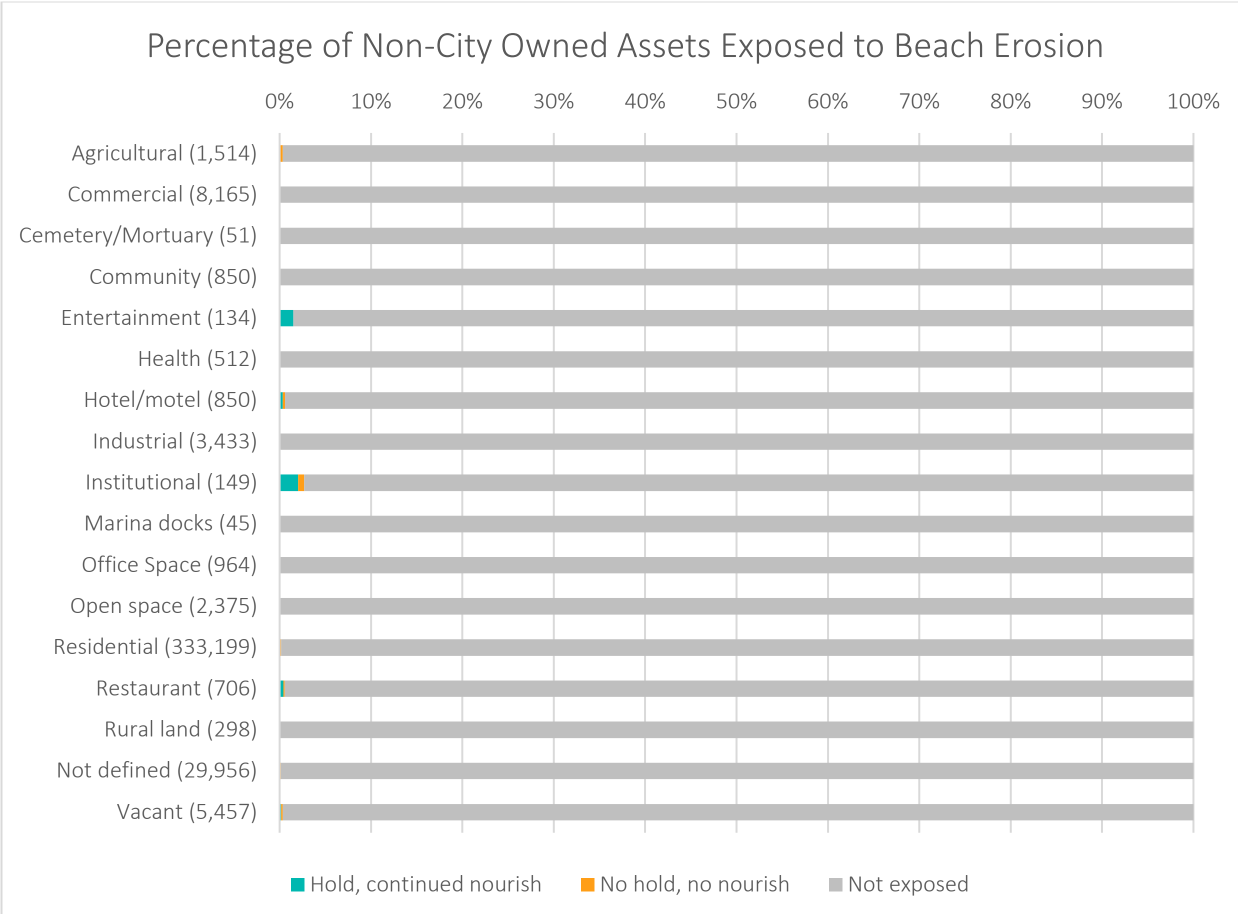


Figure 31. Non-City Owned Assets exposed to beach erosion. The value after each land use category indicates the parcel count. "Shoreline hold, continued nourish" represents the percentage of parcels exposed to flooding if the City continues beach nourishment and sea wall repair, while "Shoreline No Hold, No Nourish" represents the percentage of parcels exposed if the City were to stop beach nourishment and seawall repair.

Building Toward a City-Wide Climate Resilient San Diego Plan

The findings of this assessment will be a component of the City's broader effort to develop a comprehensive city-wide climate change vulnerability assessment covering multiple climate change hazards. The city-wide climate change vulnerability assessment will consider coastal hazards as well as hazards associated with changes in precipitation, heat, and wildfire potential. The methodology described in this assessment will be expanded to include a more detailed analysis of the sensitivity and adaptive capacity of critical assets to various climate hazards.

Based on the findings of the city-wide vulnerability assessment, key vulnerable asset types will be identified for a detailed risk assessment. The risk assessments will investigate climate risk and impacts at the individual asset scale. Individual assets will be assessed and focused adaptation strategies for the asset will be developed. These vulnerability assessments will inform the development of *Climate Resilient SD,* the City of San Diego climate adaptation plan.

References

Bedsworth, Louise, Dan Cayan, Guido Franco, Leah Fisher, and Sonya Ziaja. 2018. "California's Fourth Climate Change Assessment: Statewide Summary Report." SUM-CCCA4-2018-013.

Brennan, Deborah Sullivan. 2018. "Studying the journey of beach sand can combat sea level rise, improve surf conditions." *The San Diego Union-Tribune*, April 29. https://www.sandiegouniontribune.com/communities/north-county/sd-me-beach-sand-20180423-story.html.

Buchanan, M. K., Oppenheimer, M., & Kopp, R. E. 2017. "Amplification of flood frequencies with local sea level rise and emerging flood regimes." *Environmental Research Letters* 12 (6): 064009.

California Coastal Commission. 2018. "Sea Level Rise Policy Guidance." https://www.coastal.ca.gov/climate/slrguidance.html.

CEMA and CNRA. 2012. "California Adaptation Planning Guide: Planning for Adaptive Communities."

City of San Diego. 2003. "2003 Coastal Erosion Assessment Update from Sunset Cliffs Park to Torrey Pines State Beach." Document No.: C-11542.

—. 2019. "Asset Management Program Data." March.

City of San Diego. 2017. "Multi-jurisdictional Hazard Mitigation Plan Section 5: City of San Diego." https://www.sandiegocounty.gov/content/dam/sdc/oes/emergency_management/HazMit/2017/City-of-San-Diego-HazMit-Section-5.pdf.

Esri. 2018. "Demographic and Income Profile: San Diego." Accessed May 16, 2019. https://www.sandiego.gov/sites/default/files/demographic_and_income_profile_87fde97c-6e52-4caa-824a-29bc6042cf0e.pdf.

FEMA. 2005. "Wave Runup and Overtopping." https://www.fema.gov/media-library-data/20130726-1541-20490-9494/frm_p1wave2.pdf.

Hummel, M. A., Berry, M. S., & Stacey, M.T. 2018. "Sea level rise impacts on wastewater treatment systems along the U.S. coasts." *Earth's Future* 6: 622-633. doi:10.1002/2017EF000805.

ICF. 2018. "City of San Diego Coastal Erosion Assessment Photo Analysis Update: 1993/2003 - 2018." ICF 00687.17, San Diego CA.

ICLEI. 2017. *San Diego Regional Coastal Resilience Assessment.* ICLEI-Local Governments for Sustainability USA.

IPCC. 2013. *Climate Change 2013: The Physical Science Basis.* Cambridge, MA: Cambridge University Press. http://www.ipcc.ch/report/ar5/wg1/.

IPCC. 2012. "Glossary of Terms." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, by IPCC, 555-564. New York, NY: Cambridge University Press.

Kalansky, J., Cayan, D., Barba, K., Walsh, L., Brouwer, K., Boudreau, D. 2018. *San Diego Summary Report.* Publication number: SUM-CCCA4-2018-009, California’s Fourth Climate Change Assessment.

NOAA. 2018. *Relative Sea Level Trend 9140170 San Diego, California.* https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9410170.

NRC. 2012. "Chapter 5: Projections of Sea-Level Change." In *Sea-Level Rise for the Coastal of California, Oregon, and Washington: Past, Present, and Future*, by National Academy of Sciences. https://www.nap.edu/read/13389/chapter/7#97.

Spiegel, Jan Ellen. 2016. *As Sea Levels Rise, How Best to Protect Coasts?* July 12. https://www.yaleclimateconnections.org/2016/07/as-sea-levels-rise-how-best-to-protect-our-coasts/.

U.S. DOT. 2018. *Transportation Climate Change Sensitivity Matrix.* U.S. Department of Transportation. https://toolkit.climate.gov/tool/transportation-climate-change-sensitivity-matrix.

US Census Bureau. 2017. *American Fact Finder: San Diego City.* Accessed March 28, 2019. https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk.

—. 2019. *QuickFacts, San Diego City, California.* May 16. Accessed 2019. https://www.census.gov/quickfacts/fact/table/sandiegocitycalifornia,sandiegocountycalifornia/PST045218.

USAID. 2014. *Addressing Climate Change Impacts on Infrastructure: Preparing for Change.* U.S. Agency for International Development.

USGS. n.d. *Coastal Storm Modeling System (CoSMoS).* Accessed March 4, 2019. https://www.usgs.gov/centers/pcmsc/science/coastal-storm-modeling-system-cosmos?qt-science_center_objects=0#qt-science_center_objects.

Vitousek, S., Barnard, P. L., Limber, P., Erikson, L., and Cole, B. 2017. "A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change." *Journal of Geophysical Research Earth Surface* 122 (4): 782-806. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2016JF004065.

Willows, R.I., and Connell, R.K. 2003. *Climate Adaptation: Risk, Uncertainty and Decision-making.* UKCIP Technical Report, Oxford: UKCIP, 154. http://www.ukcip.org.uk/wordpress/wp-content/PDFs/UKCIP-Risk-framework.pdf.

Young, A.P. 2018. "Decadal-scale coastal cliff retreat in southern and central California." *Geomorphology* 300: 164-175. https://www.sciencedirect.com/science/article/pii/S0169555X17304476.

Department Consultations

The Planning Department consulted with staff members across various City departments to better understand critical asset consequences and vulnerability. The findings associated with these citations represent the judgments based on the best information available to these individuals, within the time constraints of this grant. Departments were consulted between January and September 2019, and do not reflect official departmental policies.

Glossary

Adaptation: “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which minimizes harm or takes advantage of beneficial opportunities.” (California Coastal Commission 2018)

Adaptive Capacity: “The ability of a system to respond to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences” (California Coastal Commission 2018) citing (Willows 2003).

Consequence: The effect of climate change exposure on community structures, functions, and populations and on the asset owner or service providers’ ability to maintain a standard condition or level of service (sometimes referred to as impacts) (CEMA and CNRA 2012).

Exposure: “The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm” (Bedsworth 2018) citing (IPCC 2012).

Sensitivity: “The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (*e.g.*, a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (*e.g.*, climatic or non-climatic stressors may cause people to be more sensitive to additional extreme conditions from climate change than they would be in the absence of these stressors).” (California Coastal Commission 2018)

Vulnerability: “The extent to which a species, habitat, ecosystem, or human system is susceptible to harm from climate change impacts. More specifically, the degree to which a system is exposed to, susceptible to, and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.” (California Coastal Commission 2018)

Wave runup: The height above stillwater elevation reached by a wave along a beach or structure. (FEMA 2005)

Appendix

As described in the Methods section above, the City collected detailed spatial data on coastal hazards in the City of San Diego. These data are shown in the maps below.

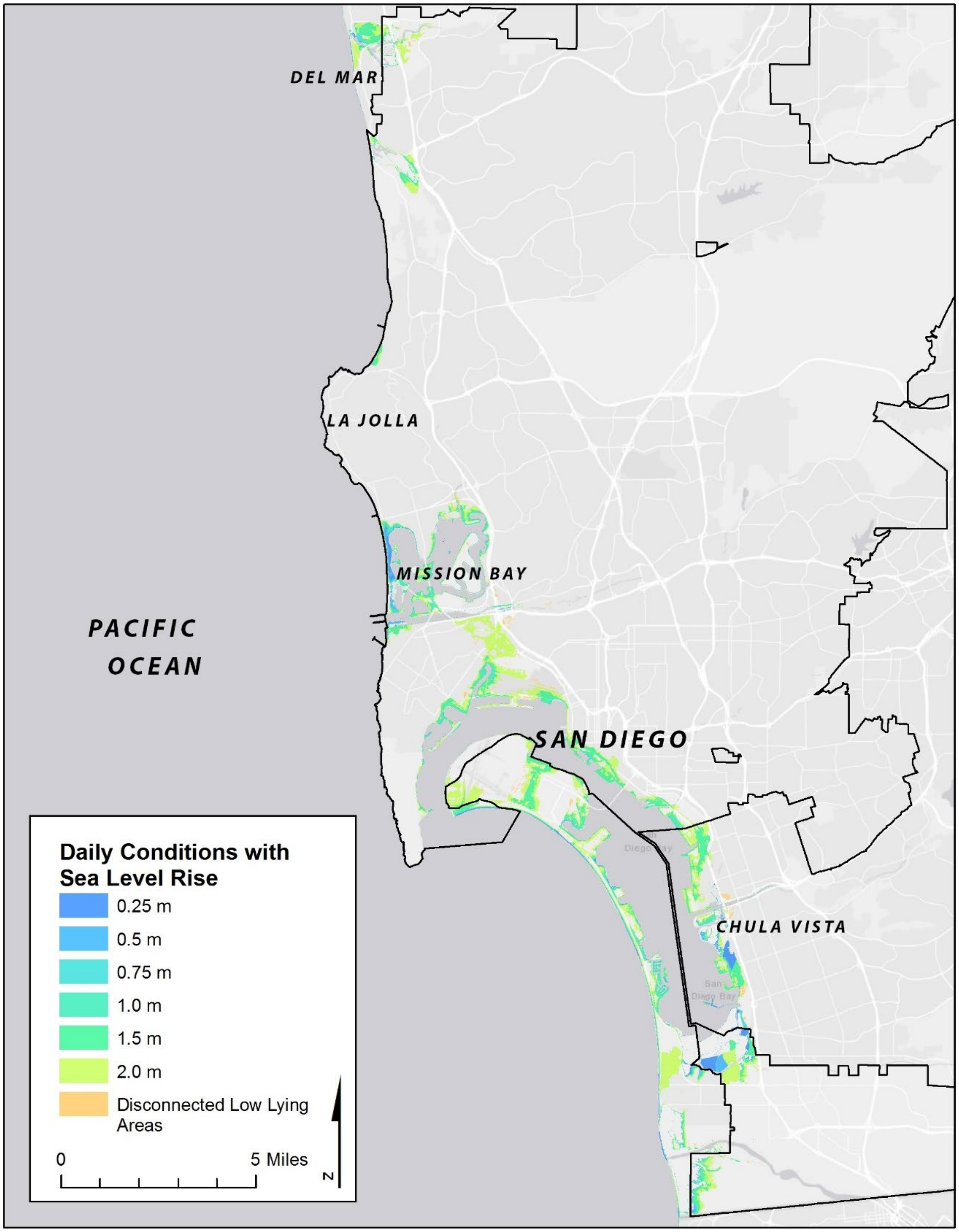


Figure 32. City-wide exposure to daily flooding at various levels of sea level rise. Source: ICF, based on SanGIS and CoSMoS data

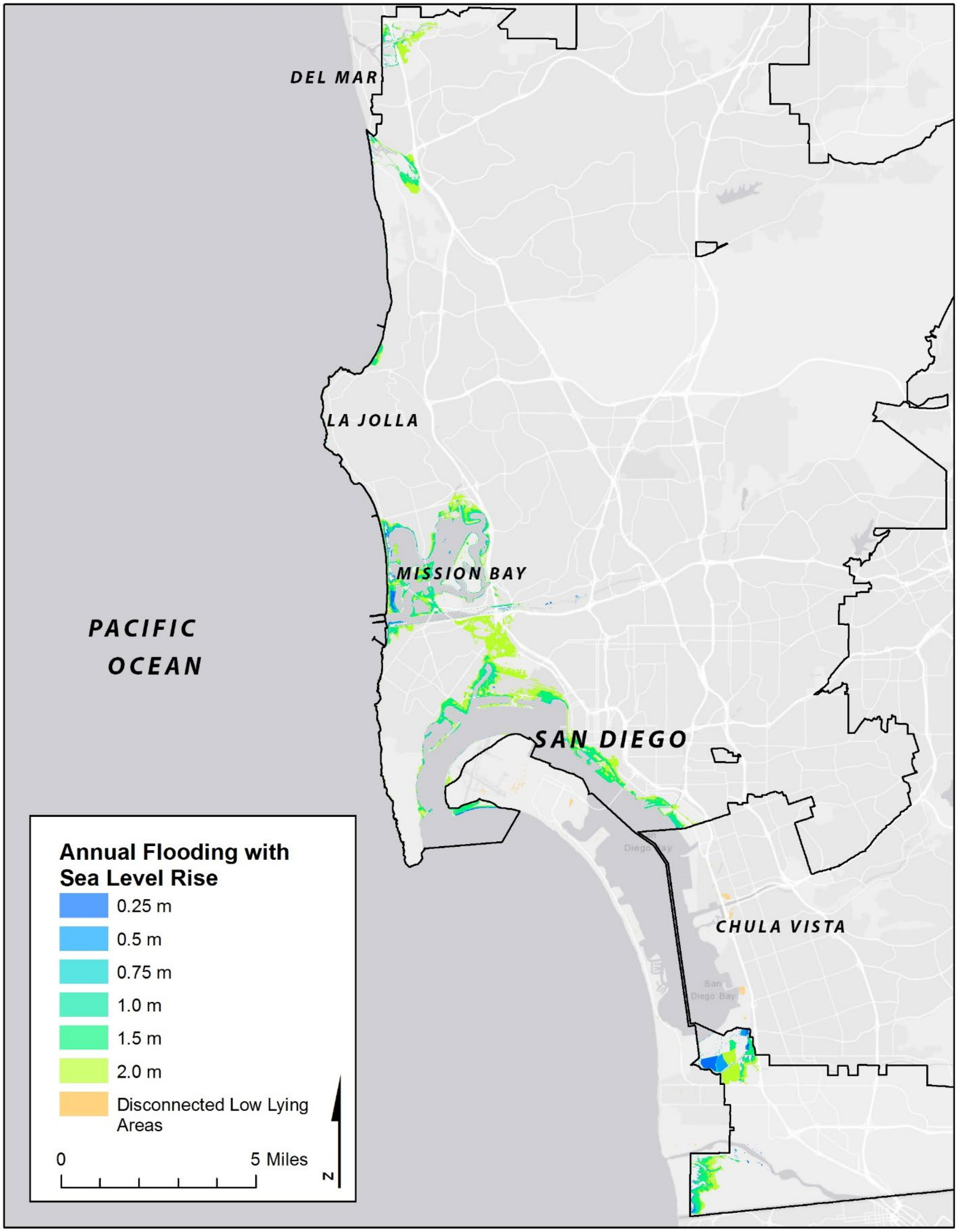


Figure 33. City-wide exposure to annual flooding at various levels of SLR. Source: ICF, based on SanGIS and CoSMoS data

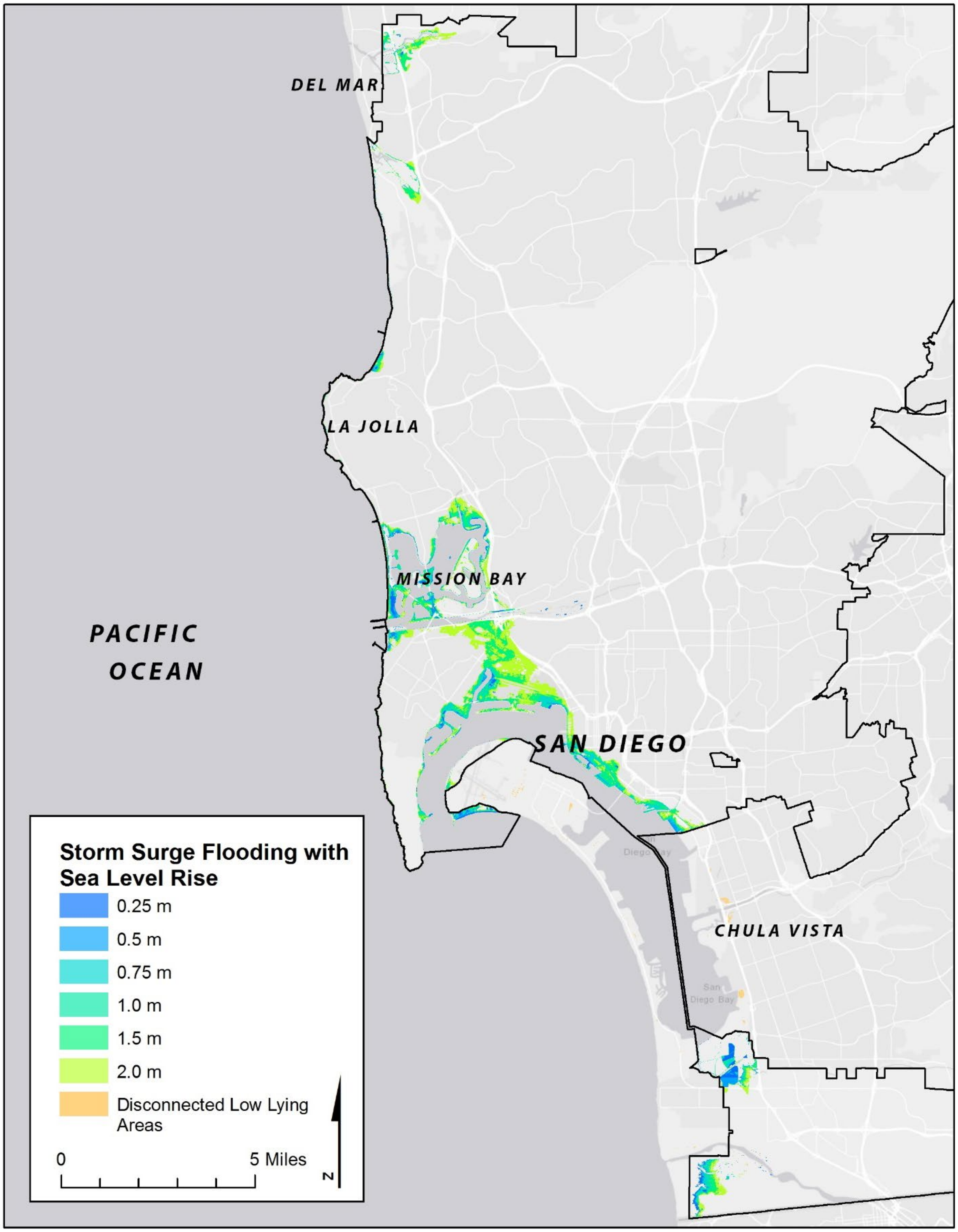


Figure 34. City-wide exposure to storm surge flooding at various levels of SLR. Source: ICF, based on SanGIS and CoSMoS data

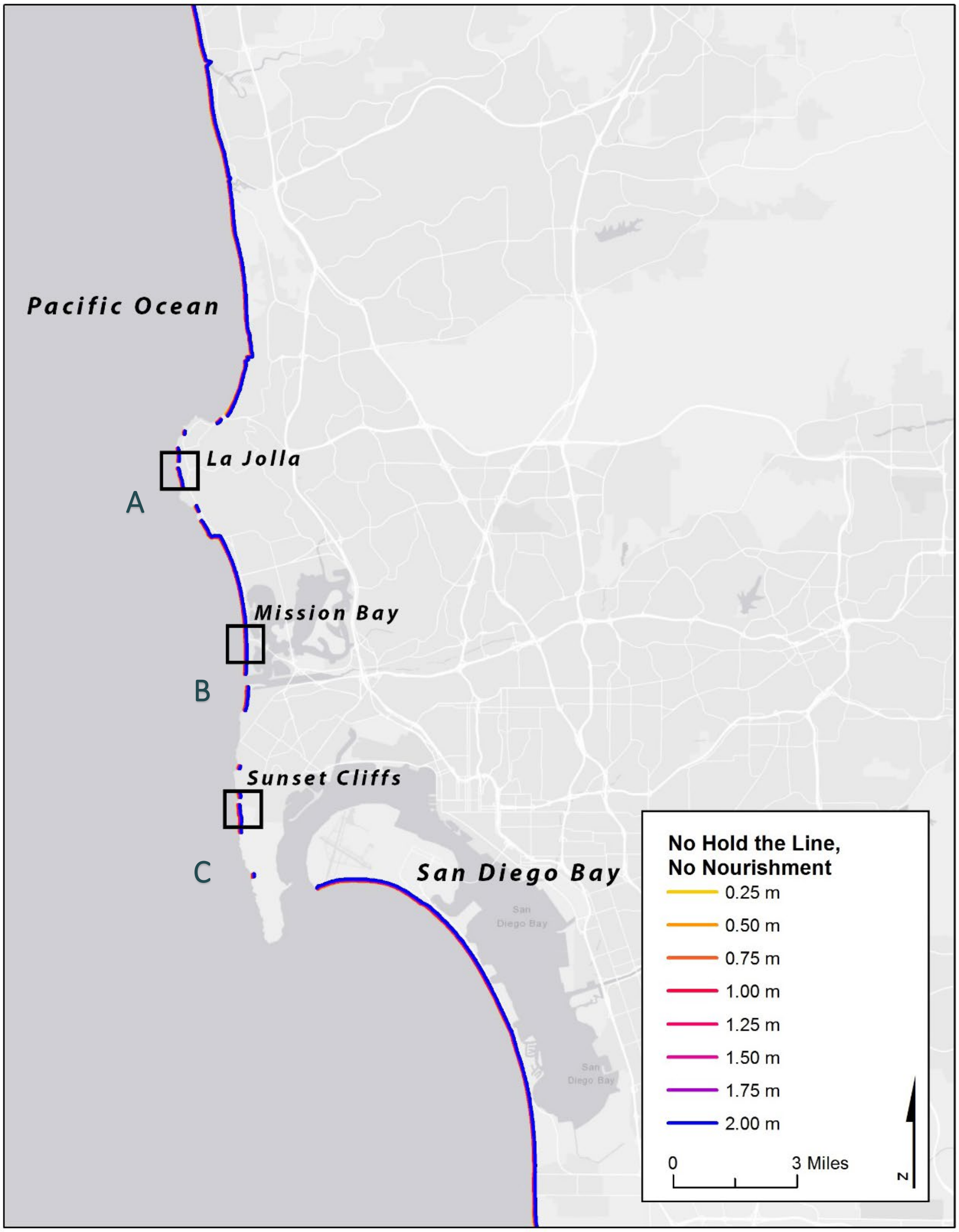


Figure 35. Coastal erosion in the City of San Diego. Source: ICF, based on CoSMos data.

The various levels of exposure to coastal erosion are relatively similar and are difficult to distinguish at this City-wide scale. Three maps at a more detailed extent have been created for La Jolla, Mission Bay, and Sunset Cliffs (as shown by boxes in Figure 35). In these maps, “No Hold the Line” and “No Nourishment” assumes that current coastal armoring will not be maintained, and the shoreline is allowed to retreat unimpeded and with no increases in sediment.

These maps are presented below.

Figure 36. Detail of Figure 35. Coastal erosion given no protection at various levels of SLR at La Jolla.

Figure 37. Detail of Figure 35. Coastal erosion given no protection at various levels of SLR at Mission Bay.

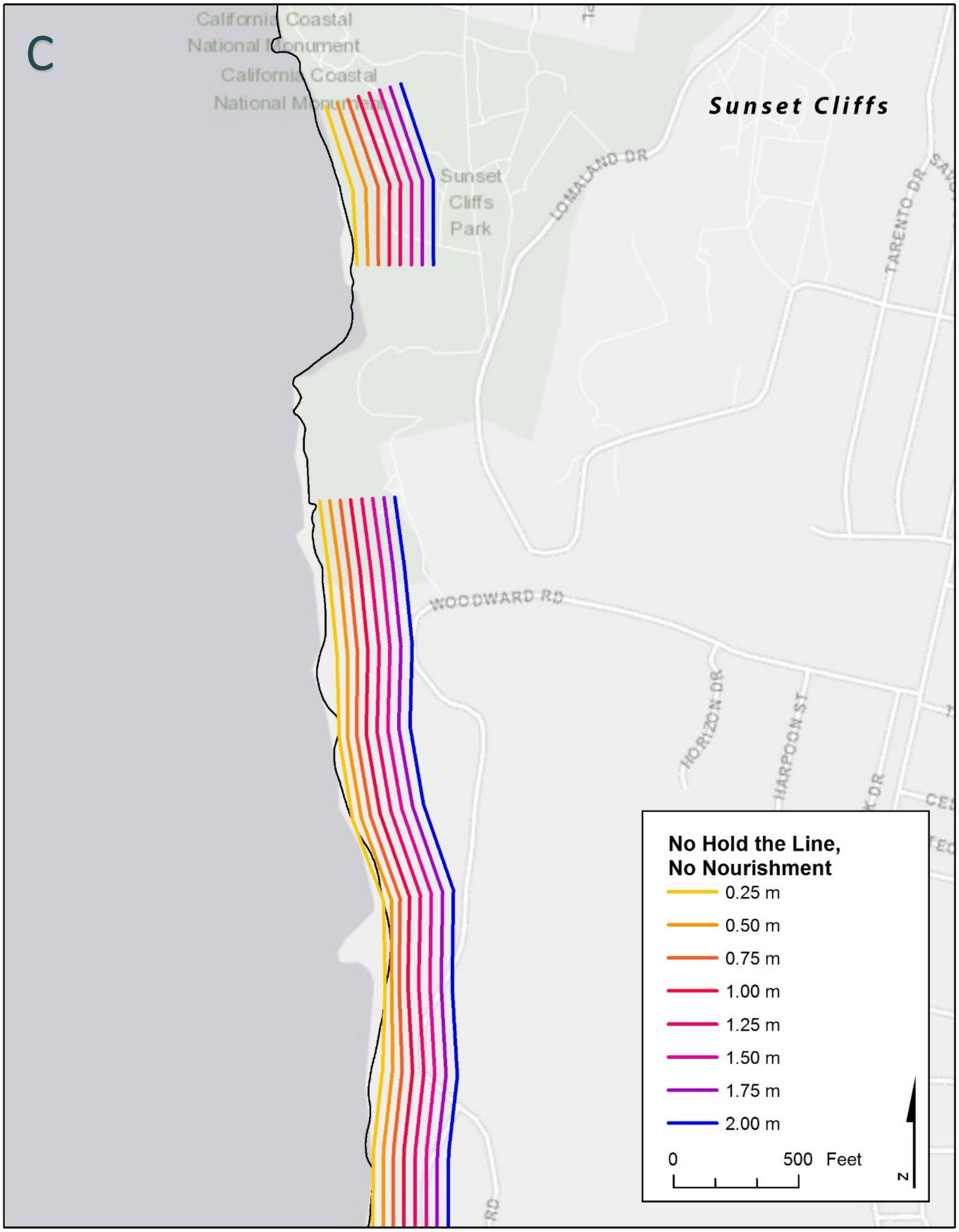


Figure 38. Detail of Figure 35. Coastal erosion given no protection at various levels of SLR at Sunset Cliffs.