The City of SAN DIEGO

City of San Diego
State Lands Sea Level Rise Vulnerability Assessment

July 2019

Prepared for the City of San Diego by ICF

Prepared and submitted in accordance with California Assembly Bill 691

ICF

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This report was developed for submittal to the State Lands Commission on July 1, 2019 and uses financial assumptions that reflect the best information available at that time. Such assumptions and forecasts were reviewed carefully, but actual financial impacts may differ materially from those assumed.

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Executive Summary

This report addresses the impacts of sea level rise on the granted public trust lands; these lands represent a small subset of the City's jurisdiction. The City will be completing additional vulnerability assessments that will consider the entirety of the City's jurisdiction as well as additional climate change related hazards, such as wildfire and extreme heat.

The City of San Diego's granted public trust lands include more than 4,000 acres of land and water, 27 miles of shoreline, and eight official swimming areas. Climate change is expected to increase the risk of flooding and erosion on these lands, with potential impacts to City and non-City assets and resources. This report identifies these risks, presents an inventory of vulnerable resources and facilities, and outlines potential adaptation strategies to address these vulnerabilities.

Key Findings at a Glance

- Sea level rise and storm surge pose increasing risks of flooding and erosion to the City's granted lands
- City assets and public trust resources have increasing exposure to sea level rise between now and the end of the century
- The City has developed vulnerability rankings for City assets and public trust resources
- The City, in collaboration with stakeholders, has developed a suite of potential adaptation strategies to address these vulnerabilities

Climate models project that sea level in the San Diego region is forecasted to rise faster over the course of this century than it did during the previous 100 years, increasing the potential for flooding and erosion along the coastline. Such potential impacts will be greatest during coastal storms, when storm surge occurs alongside higher sea levels.

To analyze climate change risks to granted lands, the City utilized sea level rise projections consistent with the 2018 California Coastal Commission (CCC) Sea-level Rise Policy Guidance and the 2018 California Ocean Protection Council (OPC) State of California Sea-Level Rise Guidance. The potential exposure of the granted lands to flooding were modelled using the U.S. Geological Survey's (USGS) CoSMoS model for sea level rise with and without a 100-year storm (a storm that has one-percent change of occurring any year) for 2030, 2050, and 2100. To evaluate erosion, the City used CoSMoS to evaluate three alternative shoreline and cliff erosion scenarios.

This assessment evaluated impacts of climate change on City-owned assets and public trust resources (including public access, commerce, recreation, coastal habitats, and navigability) within the granted lands. By the end of this century, nearly all of these assets and resources will be exposed to sea level rise to varying extents. In most cases, sea level rise, along with an occurrence of storm surge, increases potential vulnerability. The exposed assets were inventoried and given a vulnerability ranking. The City then identified more than 30 potential mitigation and adaptation measures to reduce projected vulnerabilities on granted lands. These measures were developed in collaboration with members of the Stakeholder Advisory Group for the City's climate change vulnerability assessment. The City will evaluate these and other options as it develops the *Climate Resilient San Diego* Plan to address climate change impacts and ensure that San Diego continues to thrive for years to come.

Introduction

This report presents a sea-level rise vulnerability assessment for the City of San Diego's (hereafter referred to as "the City") granted lands in compliance with California Assembly Bill 691.

When California became a state in 1850, it acquired all rights, titles, and interests in the tidal and submerged lands and the beds of navigable waterways within its borders, holding them in trust for public benefit. The state subsequently granted these public trust lands to more than 80 municipalities along the coast, with a variety of requirements and restrictions attached. Public access and fishing rights are features of all granted lands.

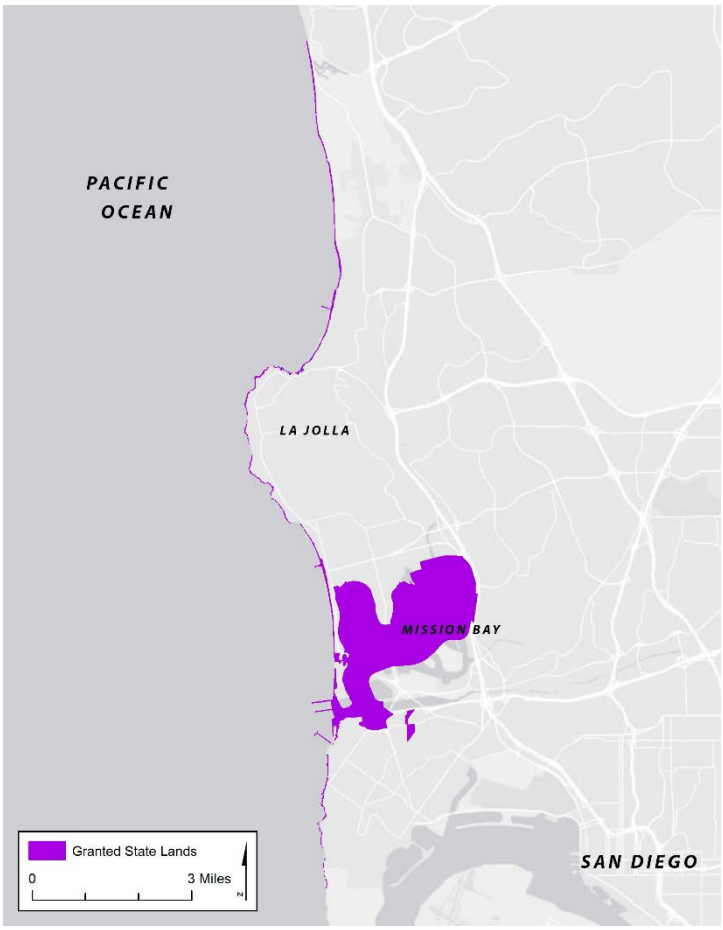

Figure 1. Overview of granted lands in the City

California Assembly Bill 691, enacted in 2013, requires 32 of these grantees (those whose gross public trust revenues averaged more than $250,000 annually between 2009 and 2014) to assess the impacts of sea-level rise on their public trust lands and develop plans to mitigate impacts and address vulnerabilities.

These grantees—including the City—are required to submit reports by July 1, 2019, describing vulnerable assets and the impacts of sea-level rise, and coastal processes and events that are projected to be exacerbated by sea-level rise, over three time horizons: 2030, 2050, and 2100. The reports must also estimate the financial costs of sea-level rise on public trust lands and resources over the same time horizons. Finally, the reports must identify strategies to adapt and reduce vulnerabilities, including a timeline for implementing these strategies.

Granted Lands in the City of San Diego

The City's granted lands run along the coastline, with the largest area concentrated in Mission Bay Park (see Figure 1 for all granted lands in the City and Figure 2 for a closer look at Mission Bay), which includes more than 4,000 acres of land and water, 27 miles of shoreline, and eight official swimming areas (City of San Diego 2019). Annual attendance in Mission Bay Park is estimated at 15 million visitors (City of San Diego 2019).

City revenues from granted lands include lease revenues (more than $12 million in FY 2018), park use revenues (approximately $539,000 in FY 2018), and concessions ($13,000 in FY 2018). Expenditures by the City in granted lands include those for lifeguards, police, parks and recreation, and facility maintenance. Other services provided in granted lands (mainly Mission Bay Park) include street repair maintenance, water/sewer maintenance, and emergency/fire protection services (City of San Diego 2018).

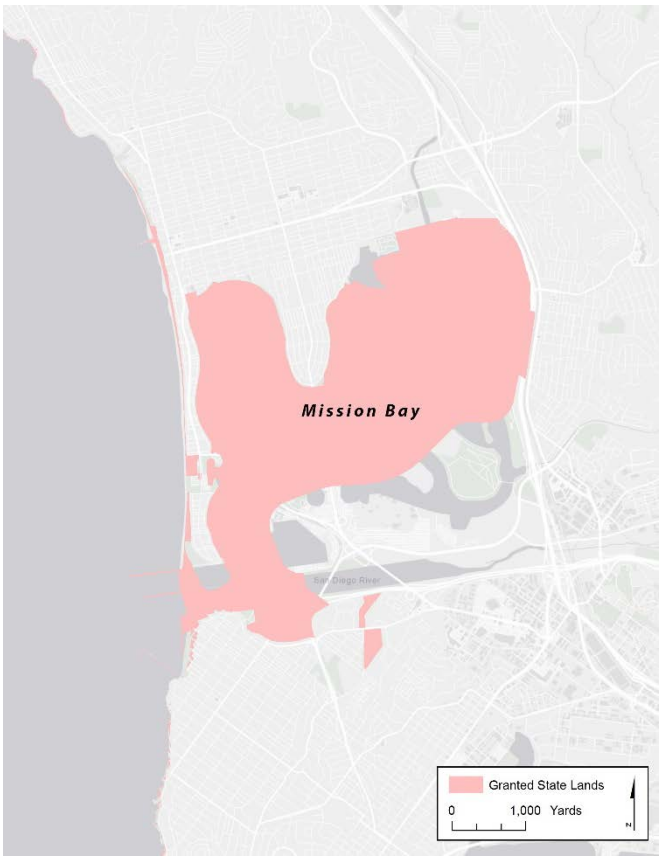

Figure 2. Subset of Granted lands, Mission Bay

Granted Lands' Climate Risks

Since granted lands lie along the coast, the greatest risks posed by climate change to these lands are related to sea-level rise and storm surge. Sea level in the San Diego region is expected to rise 5 to 14 times faster over the course of this century than it did in the previous century, leading to risks of increased flooding (California Coastal Commission 2018).

Coastal erosion is also a concern in the City. Sea-level rise and changes in storms are expected to increase coastal erosion, though the timing and specific affected locations are unclear. Saltwater intrusion also poses potential risks to granted lands and the facilities and infrastructure located on them.

The City of San Diego's Response

To address these hazards and prepare for expected changes, the City is currently developing a climate resilience plan. As part of this effort, the City conducted a climate change vulnerability assessment in 2018 and 2019, focusing on identifying vulnerabilities related to sea-level rise, changes in precipitation, extreme heat, and wildfires. Much of the information in this report is drawn from relevant sections of the vulnerability assessment. The resilience planning process also involves developing a set of potential adaptation strategies to address vulnerabilities and enhance resilience. The mitigation and adaptation measures described in this report are drawn from a preliminary list of measures identified by stakeholders as well as measures proposed or adopted by a number of other coastal municipalities in the United States.

Sea-level Rise Impacts Assessment

The primary climate-related threats to granted lands in the City include sea-level rise, coastal flooding, and coastal erosion.

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 since 1993 (IPCC 2013). From 1906 to 2017, the tide gauge at the City suggests a rise of approximately 2.17 mm per year (about 0.09 inches per year) (see Figure 3) (NOAA 2018).

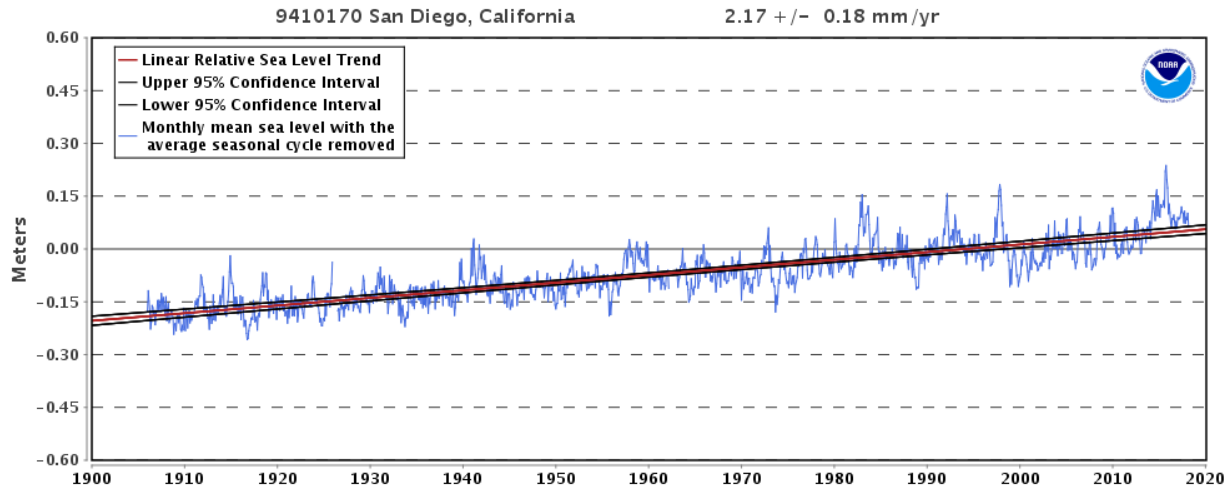

Figure 3: The relative sea level trend is 2.17 millimeters/year with a 95 percent confidence interval of +/- 0.18 mm/yr. based on monthly mean sea level data from 1906 to 2017, which is equivalent to a change of 0.71 feet in 100 years (tide gauge 9410170 San Diego, CA). Source: NOAA 2018.

Sea-level Rise Projections and Related Assumptions

The City selected the following sea-level rise scenarios from the U.S. Geological Survey's (USGS) CoSMoS model for its vulnerability assessment: 0, 0.25, 0.5, 0.75, 1.0, 1.5, and 2.0 meters of sea-level rise with daily average flooding and storm surge (100-year storm) flooding. These scenarios align with sea-level rise projections from the 2018 California Coastal Commission (CCC) Sea-level Rise Policy Guidance and the 2018 California Ocean Protection Council (OPC) State of California Sea-Level Rise Guidance for 2030, 2050, and 2100 (see Table 1, comparison table below) given varying levels of probability. Zero meters of sea-level rise indicates the current base elevation of mean higher high water (the average height of high tide); if projections show that granted lands and assets are exposed to sea-level rise at zero meters, this means that they likely currently experience flooding (USGS undated).

Consistent with the CCC and OPC guidance, the City uses probabilistic sea-level rise projections and considers the H++ scenario (an extreme sea-level rise scenario with unknown probability) in its analysis.

Table 1. Sea-level Rise Scenarios Considered in the San Diego Vulnerability Assessment

Year	**Low Risk Aversion Scenario** 17% probability SLR meets or exceeds		**Medium-High Risk Aversion** 0.5% probability SLR meets or exceeds		**Extreme Risk Aversion Scenario** H++ scenario, no assigned probability	
	CCC/OPC 2018 Projection	Closest CoSMoS Increment	CCC/OPC 2018 Projection	Closest CoSMoS Increment	CCC/OPC 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.)

Through 2100, the City's coast is projected to subside at a rate of 1.4 mm/year, and the glacial geostatic adjustment[1] is projected to cause local relative sea level to increase by 0.4 mm/year (NRC 2012). These values are factored into the City's sea-level rise projections.

Coastal Flooding

The frequency of extreme coastal flooding is expected to increase under all projections of sea-level rise. In addition, rising seas boost the occurrence of severe floods (e.g., the 500-year flood) more than moderate floods (e.g., the 10-year flood) along the Pacific coast of the United States (Buchanan 2017). By elevating storm tides, sea-level rise allows waves to surpass natural barriers, increasing the relative frequency of flooding along the Pacific coast.

Figure 4. King tide flooding on pedestrian path, July 18, 2018. Photo by ICF.

The City included the 100-year storm as a series of flood scenarios (under different sea-level rise scenarios) as a hazard in its vulnerability analysis. The 100-year storm has a one percent annual chance of occurrence, and a 55 percent chance of occurring between 2020 and 2100. Additionally, the effects of a storm are inherently shorter-term than those of sea-level rise. While sea-level rise results in a permanent loss of land, facilities damaged by storm surge results can be repaired or rebuilt in place.

[1] 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 weight of the ice are still rebounding, while areas that were near, but not covered with glaciers were pushed up during the ice age and are still subsiding.

Erosion

The relatively soft sandstone bluffs that are common along the City's coast are prone to erosion from waves and from storm water runoff. Cliff erosion is likely to increase with sea-level rise and heavier rainfall events, but models cannot reliably reveal where and when this will occur. Research by the Scripps Institute 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. Researchers have not yet determined how to predict when cliff erosion may slow or accelerate.

Figure 5. Cliff erosion on San Diego coast. Photo by ICF.

Beach erosion is likely to accelerate with sea-level rise. While the City currently nourishes the beaches, it is likely that historical rates of nourishment will be insufficient to halt future beach erosion. The City included scenarios in its analysis that considered erosion with and without nourishment.

The City completed the last City-wide coastal erosion assessment, consisting of geotechnical reports, site visits, and photographic documentation of erosion, in 2003 (City of San Diego 2003). The City worked with consultants to update this coastal erosion assessment in 2018 and found that while the City has made improvements to pedestrian access and safety along the erosion sites, there are now additional sites with safety concerns to pedestrians. The City's *Climate Resilient San Diego* plan will identify measures to address erosion concerns.

The City selected the best available spatial projections from USGS (the California-wide CoSMoS model) to analyze coastal erosion in the area, covering shoreline and cliff retreat under 2.0 m of sea-level rise and three scenarios (USGS undated). The following scenario terminology and the associated spatial modeling come from the USGS:

- Shoreline erosion:
  - "No hold, no nourish" assumes the shoreline is allowed to retreat unimpeded and with no human increases in sediment (i.e., beach nourishment).
  - "No hold, continued nourish" assumes the shoreline retreat is allowed to retreat unimpeded 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 sea level rises.

Shoreline erosion and cliff retreat are distinct forms of erosion, with shoreline erosion occurring only where there are beaches and cliff retreat only where there are cliffs. These two forms of erosion occur in various parts of the City – sometimes overlapping, sometimes not. As such, there are some resources and facilities exposed to shoreline erosion but not cliff retreat and vice-versa.

Mapping Sea-Level Rise Impacts on Granted Lands in 2030, 2050, and 2100

The maps in this section illustrate granted lands the area around Mission Bay under six sea-level rise scenarios. Maps show daily conditions and flooding with storm surge on top of sea-level rise, as well as coastal erosion. See Table 1 for a description of the scenarios and their correspondence to 2030, 2050, and 2100 time frames.

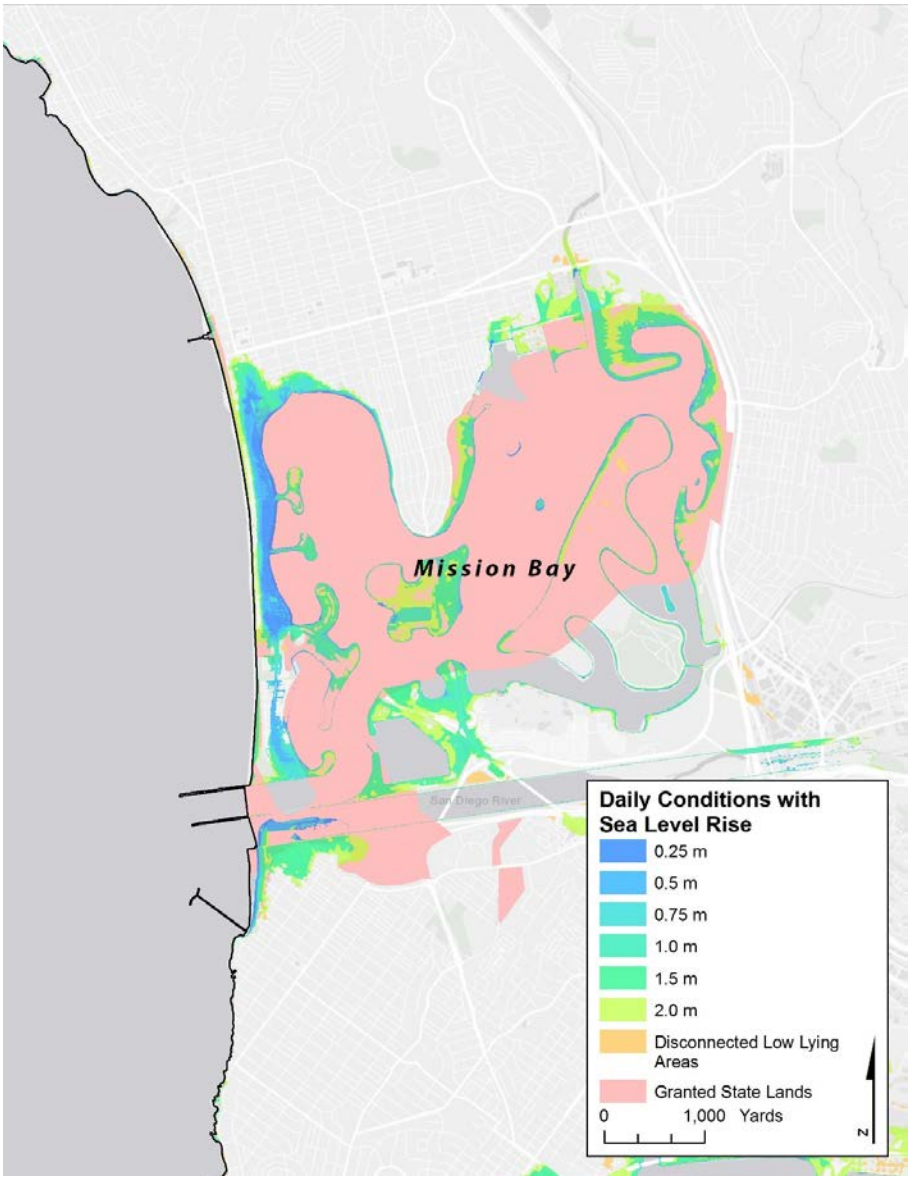

Figure 6. Mission Bay daily conditions under six sea-level rise scenarios.

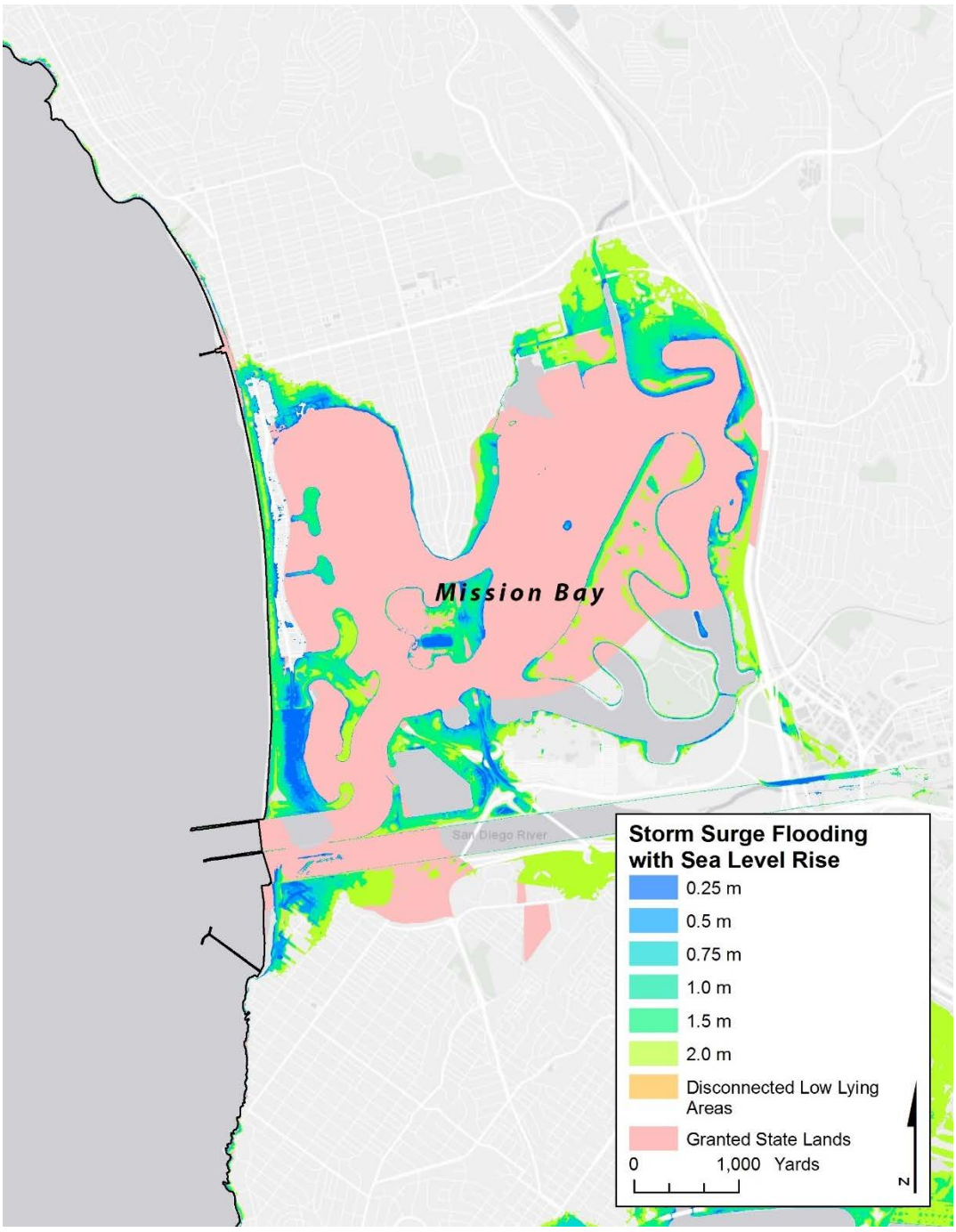

Figure 7. Mission Bay, storm surge flooding under six sea-level rise scenarios.

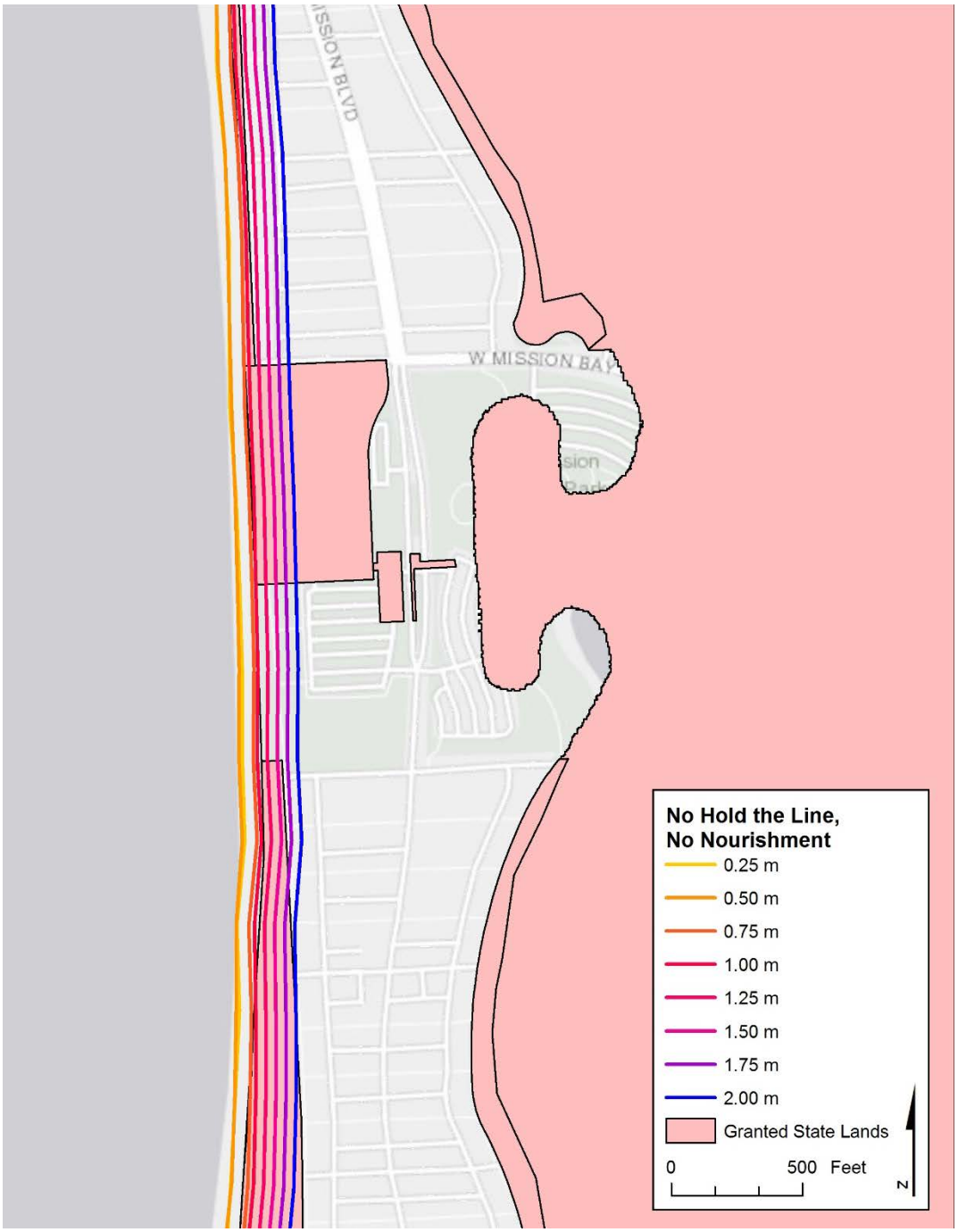

Figure 8. Coastal erosion at Mission Bay under eight sea-level rise scenarios.

Inventory of Vulnerable Natural and Built Resources and Facilities on Granted Lands in the City of San Diego Based on Exposure Analysis

The tables below present an inventory of vulnerable natural and built resources and facilities on granted lands in the City based on exposure. Exposure to coastal flooding is shown in

Sea-Level Rise Projections for the City of San Diego

2030: 0.25 m

2050: 0.5–0.75 m

2100: 1.0–2.0 m

Table 2, which details the number of assets and/or acres projected to experience sea-level rise and storm surge flooding in 2030 (0.25 m of sea-level rise), 2050 (at 0.5 to 0.75 m of sea-level rise), and 2100 (at 1.0 to 2.0 m of sea-level rise). The storm surge scenario assumes a 100-year storm (a 1 percent annual chance of occurrence) on top of the previously stated sea-level rise projections for 2030, 2050, and 2100. While sea-level rise results in a permanent loss of land, storm surge only occurs occasionally and results in temporary flooding.

When determining the exposure of private development (i.e., non-City assets) on granted lands, the total area of a parcel (a land unit determined by the County assessor's office) was used rather than only the area overlapping with a flood zone. That is, if a parcel was found to be at all exposed to coastal hazards, then the whole acreage of the parcel was counted as flooded. While this method overestimates the area that will flood, it appropriately captures vulnerability, as flooding on any part of the parcel could render the rest of it inaccessible.

Granted lands in the City are home to a variety of resources and facilities. City-owned assets on/within these lands include lifeguard stations, water pipes, wastewater pipes, wastewater pumps, roads, bridges, storm water infrastructure, recreation centers, parks, natural habitat, and historic and cultural resources. Privately owned resources and facilities on granted lands include hotels and motels, industrial land, institutional land, marina docks, office space (which includes office condos, commercial offices, retail, radio stations, banks, and miscellaneous business), agricultural preserves, entertainment (which includes bowling alleys and golf courses), restaurants and bars, undefined land uses (e.g., slivers/small parcels, "miscellaneous/special", "information parcel," and others), and vacant land. There are also twenty-four coastal access points along granted lands.

Table 2. Inventory of Assets Vulnerable to Coastal Flooding on Granted Lands in the City Based on Assessment of Exposure

Timeframe		2030		2050		2100	
Resources and Facilities	**Asset (total number or acreage on granted lands)**	**Sea-level rise**	**SLR + Storm surge**	**Sea-level rise**	**SLR + Storm surge**	**Sea- level rise**	**SLR + Storm surge**
City assets on granted lands (number of assets unless stated otherwise)[2]	Lifeguard stations (32)[3]	3–4	10	5–9	13–18	14–28	22–31
	Water pipes (226 segments)	14	27	19–24	34–65	40–152	89–205
	Wastewater pipes (436 segments)	27	47	36-62	80-163	82-305	222-361
	Wastewater pumps (23)	2	5	5	11-16	9-15	16-17
	Bridges (6)	1	1	1	1	1–2	2
	Major arterials (24 segments)	10	10	10	10	11–12	11–14
	Storm water drain pump stations (2)	0	1	1	1–2	1–2	2
	Storm water outfalls (96)	49	63	56–61	71–77	67–79	79–90
	Recreation centers (2)	0	0	0	0	0–1	0–1
	Parks (1,089 acres)	30 acres	34 acres	56–95 acres	81–158 acres	159–505 acres	244– 569 acres
	Conservation areas (2)	0	0	0	0	0	1
	Bog and marsh habitat (12 acres)	7 acres	7 acres	7 acres	7 acres	7 acres	7–11 acres
	Scrub and chaparral habitat (2 acres)	1 acre	2 acres	1 acre	2 acres	1 acre	2 acres
	Historic and cultural resources (6 locations)	0	3	1–2	3	2–3	3–5
Non-City assets on granted lands (acres)[4]	Hotels/motels (331)	32	309–311	39	311	39-59	313– 331
	Industrial (111)	111	111	111	111	111	111
	Institutional (118)	5	118	5	118	118	118
	Marina docks (22)	22	22	22	22	22	22
	Office space (102)	102	102	102	102	102	102
	Agricultural preserves (2)	1	1-2	1-2	2	2	2
	Entertainment (272)	0.1	272	0.1	272	0.1	272

[2] Source for data on the inventory of City-owned assets: City of San Diego Asset Management Program and the City of San Diego Department of Information Technology.

[3] Lifeguard stations can be broken down into permanent and seasonal (i.e., movable) stations. In total, there are 4 permanent stations and 28 seasonal stations. For sea-level rise, there is 1 permanent station and 2-3 seasonal stations exposed in 2030, 1 permanent station and 4-8 seasonal stations exposed in 2050, and 1-2 permanent stations and 13-26 seasonal stations exposed in 2100. For sea-level rise with storm surge, there is 1 permanent station and 9 seasonal stations exposed in 2030, 1-2 permanent stations and 12-16 seasonal stations exposed in 2050, and 3-4 permanent stations and 19-27 seasonal stations exposed in 2100.

[4] Source for data on the inventory of Non-City assets: SanGIS parcel database with information on the tax-assessed value.

	Restaurants/bars (149)	149	149	149	149	149	149
	Not defined (190)	129	129	129	129–142	129– 143	143– 174
	Vacant (25)	3–18	18	18–25	25	25	25
Public Access (#)[5]	Coastal Access Points (24 points)	4	6	4–5	8–9	7–16	14–18

Exposure to erosion is shown in Table 3. In this table, the erosion scenarios assumed 2 meters of sea-level rise in order to estimate the maximum projected level of exposure between now and 2100. The 2100 scenario was selected for analysis because the timing of erosion is particularly uncertain. Rather than provide false confidence in near term scenarios, it was deemed more appropriate to summarize the impacts that could occur between now and 2100 without assigning an exact timeframe to the impacts.

Table 3. Inventory of Assets Vulnerable to Erosion on Granted Lands in the City Based on Assessment of Exposure

Resources and Facilities	Asset (total on granted lands)	Cliff Let it Go	Shoreline No Hold, No Nourish	Shoreline No Hold, Continued Nourish
City assets on granted lands (number of assets unless stated otherwise)[6]	Lifeguard stations (32)[7]	2	24	24
	Water pipes (226 segments)	0	24	23
	Wastewater pipes (436 segments)	0	16	16
	Wastewater pumps (23)	0	0	0
	Bridges (6)	0	0	0
	Major Arterials (24 segments)	0	0	0
	Storm water outfalls (96)	5	19	19
	Parks (1,089 acres)	15 acres	107 acres	115 acres
	Scrub and chaparral habitat (2 acres)	0 acres	0.1 acres	0.4 acres
	Historic and cultural resources (6)	0	6	5
	Hotels/motels (331)	1	291	291

[5] Source for data on public access points: the City of San Diego Department of Information Technology.
[6] Source for data on the inventory of City-owned assets: City of San Diego Asset Management Program and the City of San Diego Department of Information Technology.
[7] Lifeguard stations can be broken down into permanent and seasonal (i.e., movable) stations. In total, there are 4 permanent stations and 28 seasonal stations. For cliff let it go, there is 1 permanent station and 1 seasonal station exposed. For shoreline no hold, no nourish, there are 3 permanent stations and 21 seasonal stations exposed. For shoreline no hold, continued nourish, there are 3 permanent stations and 21 seasonal stations exposed.

Non-City assets on granted lands (acres)[8]	Industrial (111)	0	0	0
	Institutional (118)	0	112	118
	Marina docks (22)	0	0	0
	Office space (102)	0.4	90	90
	Agricultural preserves (2)	0.6	0.6	0.6
	Entertainment (272)	0	272	272
	Restaurants/bars (149)	149	149	149
	Not defined (190)	0.7	20	20
	Vacant (25)	0.6	25	25
Public Access (#)[9]	Coastal Access Points (24 points)	1	5	5

Impacts to Public Trust Resources and Values

AB 691 requires special consideration of the impacts of sea-level rise and storm surge to public trust resources and values. Those resources are specifically reviewed in this section, while other resources and facilities on granted lands are covered in more detail in Appendix 1: Non-public Trust Resources and Facilities. The following resources and facilities are discussed in this section:

- Public Access, including coastal access points;
- Commerce, including hotels and motels, office space (which includes office condos, commercial offices, retail, radio stations, banks, and miscellaneous business), restaurants and bars, and industrial and institutional land;
- Recreation, including parks and recreation property, parks, and entertainment land use types (bowling alleys and golf courses);
- Coastal Habitats, including conservation areas, bog and marsh habitat, and scrub and chaparral habitat; and
- Navigability, including marina docks.

Public Access

There are 24 coastal access points on granted lands in the City. Of these, four are projected to be exposed to daily flooding and six are projected to be exposed to sea-level rise with storm surge by 2030. These numbers increase to four to five and eight to nine, respectively, by 2050. By 2100, up to 16 coastal access points are projected to be exposed to daily flooding and up to 18 exposed to sea-level rise with storm surge (Figure 10).

These projections indicate that roughly a quarter of public access points on granted lands in the City will be exposed to flooding in the short term, and up to three-quarters may be exposed by 2100.

[8] Source for data on the inventory of Non-City assets: SanGIS parcel database with information on the tax-assessed value.

[9] Source for data on public access points: the City of San Diego Department of Information Technology.

A smaller portion of public access points show potential exposure to cliff erosion and shoreline erosion by 2100 (Figure 11).

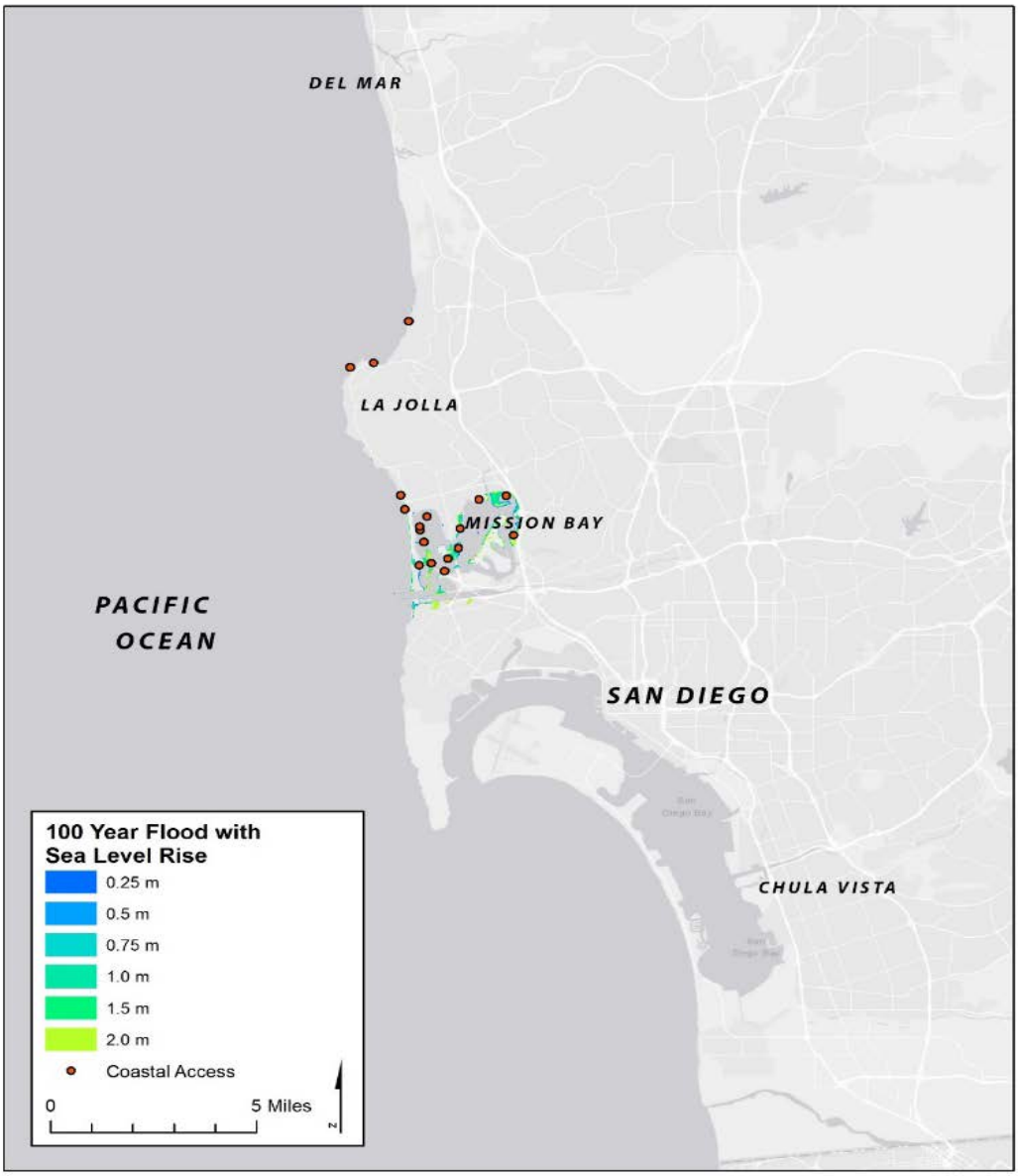

Figure 9. Coastal access points exposed to sea-level rise with storm surge on granted lands

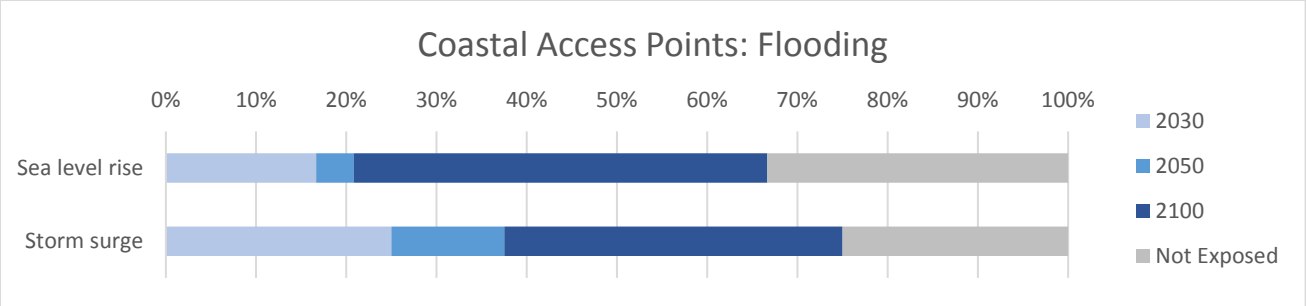

Figure 10. Percentage of public access points on granted lands exposed to coastal flooding over time

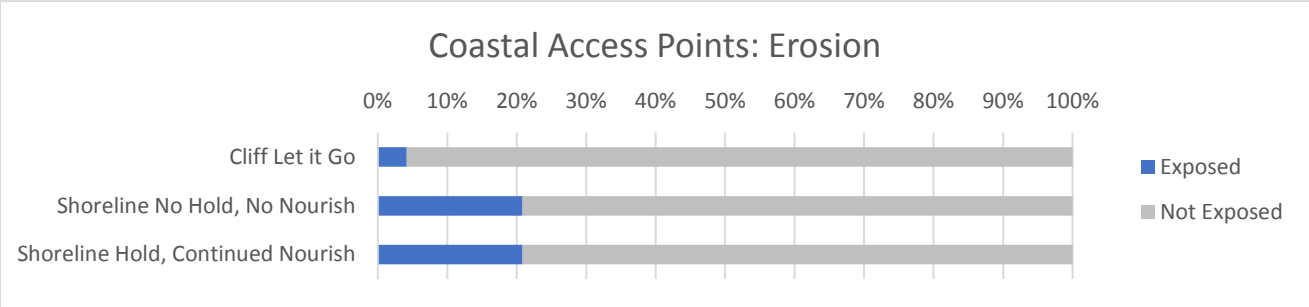

Figure 11. Percentage of public access points on granted lands exposed to erosion between present day and 2100

Commerce

Commerce resources and facilities include hotels and motels, office space (which includes office condos, commercial offices, retail, radio stations, banks, and miscellaneous business), restaurants and bars, and industrial and institutional land. When determining the exposure of commerce resources on granted lands, the total area of a parcel (a land unit determined by the County assessor's office) was used rather than only the area overlapping with a flood zone. That is, if a parcel was found to be at all exposed to coastal hazards, then the whole acreage of the parcel was counted as exposed. While this method overestimates the area that will flood, it appropriately captures vulnerability, as flooding on any part of the parcel could render the rest of it inaccessible.

Hotel and motel parcels on granted lands amount to 331 acres in total. The exposed acreage of these parcels increases over time for both sea-level rise and storm surge. For sea-level rise, the number of potentially exposed acres increases from 32 by 2030 to 59 by 2100. For sea-level rise with storm surge, the number of potentially exposed acres increases from 311 by 2030 to all parcels (331 acres) by 2100. (See ***Figure 12***.) Only one acre out of the 331 total acres faces exposure to cliff erosion by 2100, whereas 291 acres face exposure to shoreline erosion by 2100 (***Figure 13***).

Office space shows consistent projected exposure to sea-level rise, storm surge, and shoreline erosion. There are 102 acres of office space parcels on granted lands; all parcels face exposure to flooding (Figure 14). These areas currently face exposure to flooding even without sea-level rise, and no new areas become exposed to flooding as sea levels rise. Ninety acres face exposure to shoreline erosion, although less than half an acre faces exposure to cliff erosion (Figure 15).

Restaurants and bars also have consistent projections: under each timeframe, all restaurant and bar parcels on granted lands face exposure to flooding from sea-level rise and storm surge (Figure 16). Restaurants and bars represent the commercial land use type with the highest proportional projected exposure to coastal erosion, with all parcels facing exposure to each erosion scenario (Figure 17).

There are 118 acres of institutional land parcels on granted lands in the City. Of these, parcels that cover five acres face exposure to sea-level rise starting in 2030, increasing to all parcels by 2100. All parcels face exposure to sea-level rise with storm surge starting in 2030 (Figure 18). None face exposure to cliff erosion and 112 to 118 acres face exposure to shoreline erosion, depending on whether the City nourishes the shoreline with additional sand (Figure 19).

There are 111 acres of industrial land parcels on granted lands in the City. All of these parcels face exposure to sea-level rise and storm surge by 2030 and throughout the rest of the century (Figure 20). None of this area faces exposure to cliff or shoreline erosion.

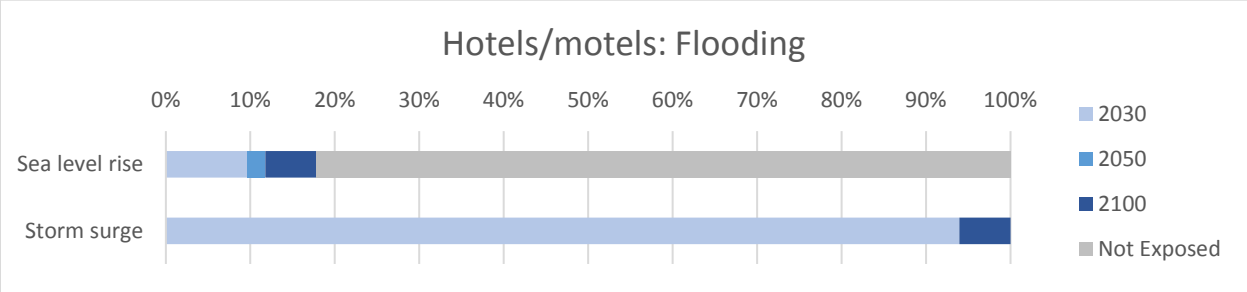

Figure 12. Percentage of hotels and motels on granted lands exposed to coastal flooding over time

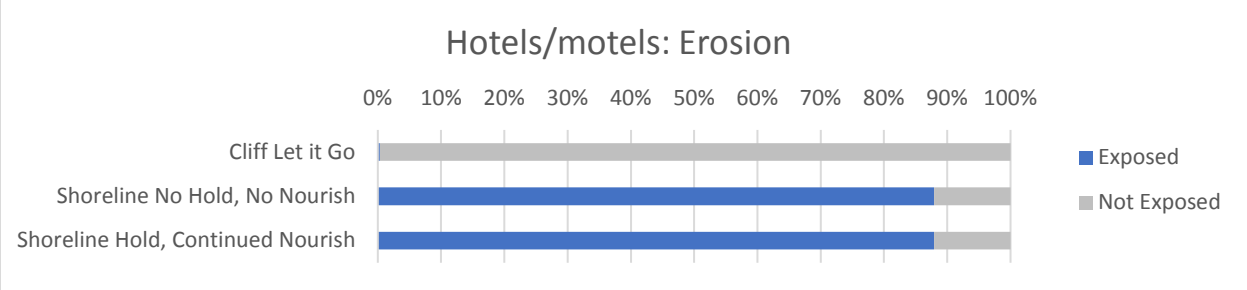

Figure 13. Percentage of hotels and motels on granted lands exposed to erosion between present day and 2100

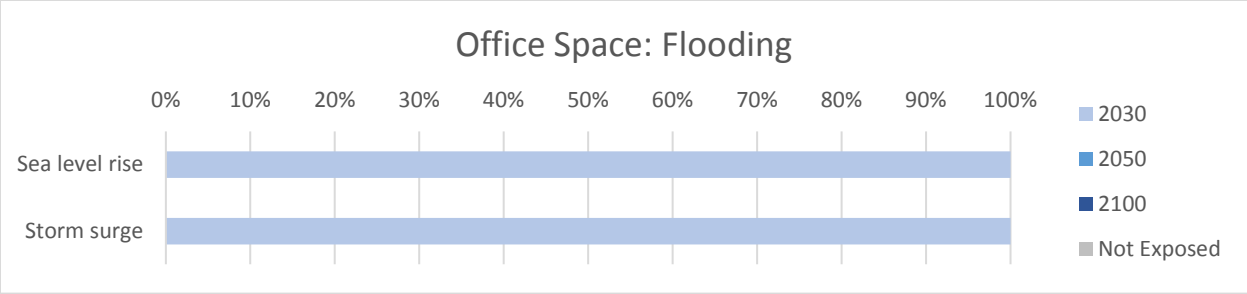

Figure 14. Percentage of office space on granted lands exposed to coastal flooding over time

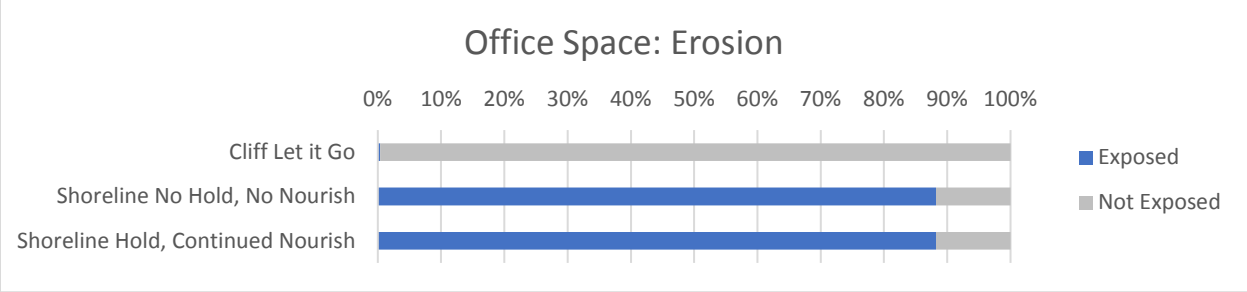

Figure 15. Percentage of office space on granted lands exposed to erosion between present day and 2100

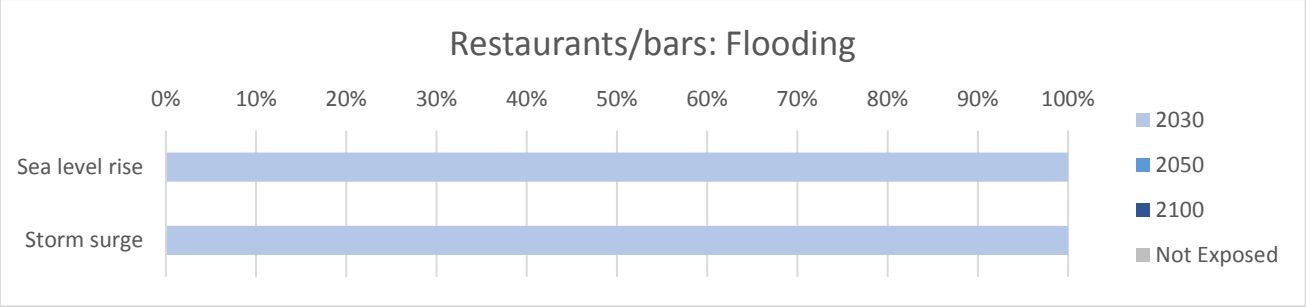

Figure 16. Percentage of restaurants and bars on granted lands exposed to coastal flooding over time

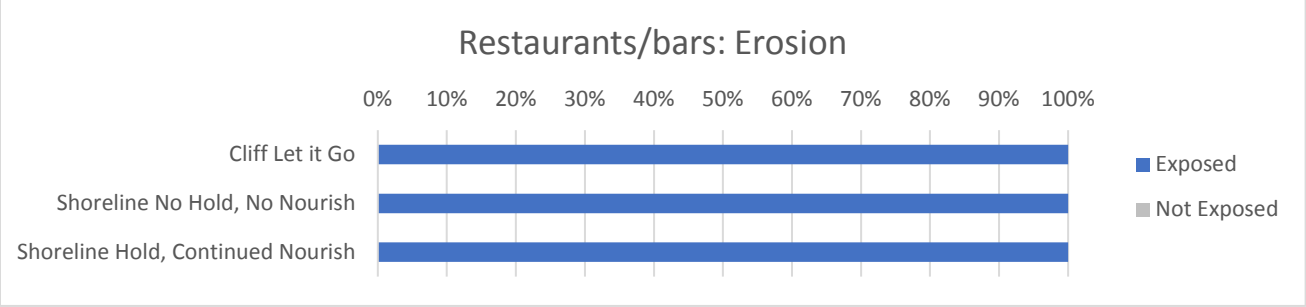

Figure 17. Percentage of restaurants and bars on granted lands exposed to erosion between present day and 2100

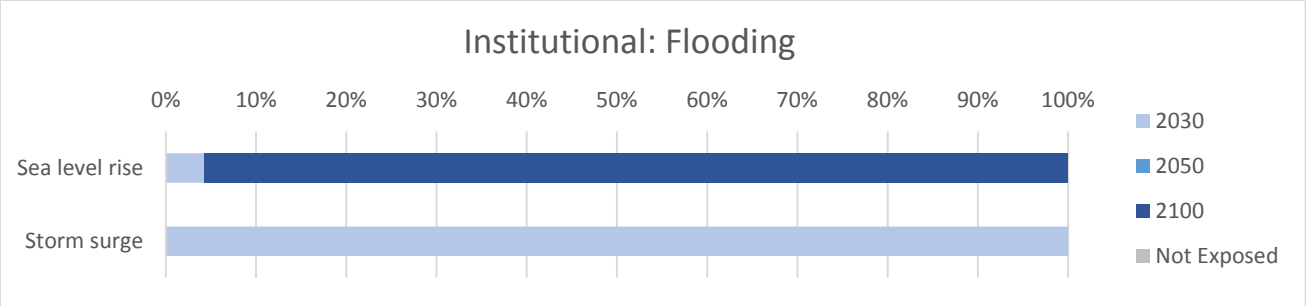

Figure 18. Percentage of institutional land on granted lands exposed to coastal flooding over time

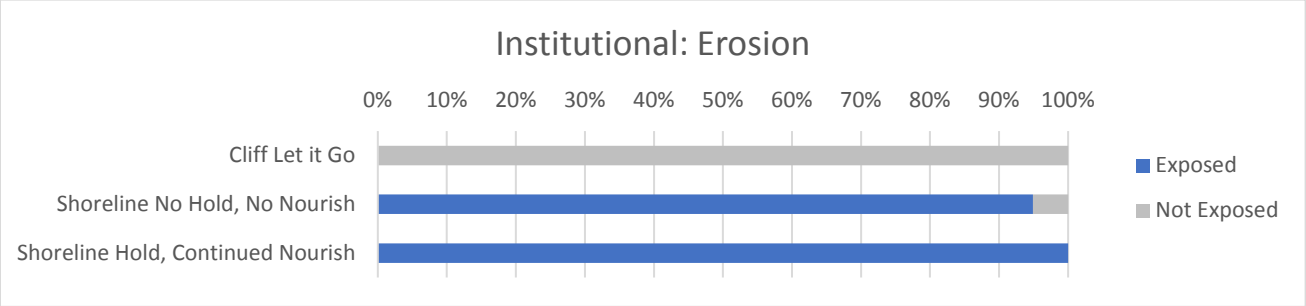

Figure 19. Percentage of institutional land on granted lands exposed to erosion between present day and 2100

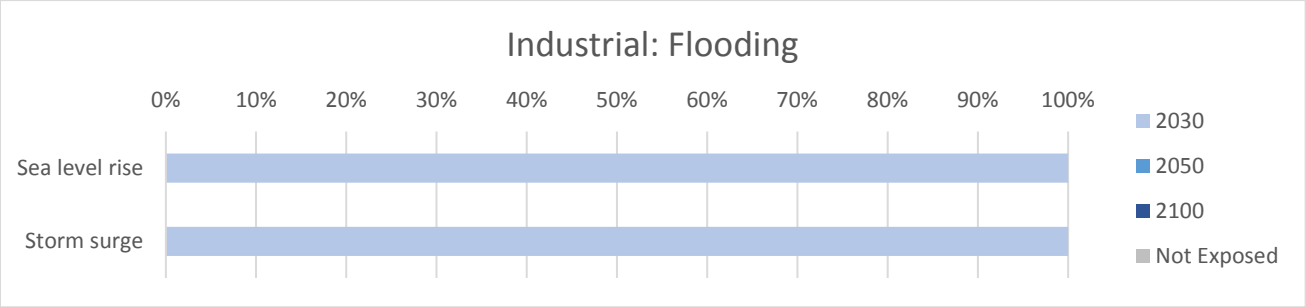

Figure 20. Percentage of industrial land on granted lands exposed to coastal flooding over time

Recreation

There are two City recreation centers and 1,089 acres of park lands on granted lands in the City. Most of this park area is in Mission Bay Park, which encompasses 933 acres of land within granted lands and is the largest park on granted lands in the City.

One recreation center is projected to face exposure to coastal flooding by 2100 under 2.0 meters of sea-level rise (Figure 21). No recreation centers on granted lands are projected to be exposed to coastal erosion.

The analysis to determine exposure of parks was slightly different than that used for the other resources measured in acres (e.g., non-City assets and habitat types). The analysis for other resources assumed that if any portion of the resource faced exposure to flooding and erosion, then the acreage of the entire resource was counted as exposed. This approach made sense for those resources, as they represented assets that could not be easily used if a part became compromised by flooding or erosion (e.g., critical habitat is degraded when area is lost; buildings cannot be entered even if only part is flooded). However, parks *can* remain useful even if a portion of the park is exposed to flooding and erosion. Therefore, the analysis for parks only included acres within parks that explicitly overlapped with the hazard zones.

The parks analysis found that of the 1,089 total acres of parks on granted lands in the City, 30 to 34 acres face exposure to flooding by 2030 and 159 to 569 acres face exposure to flooding by 2100. This translates to roughly half of park acreage on granted lands (Figure 22). Fewer acres face exposure to erosion: 15 acres face exposure to cliff erosion, or about 1 percent of total park acreage on granted lands, while 107 to 115 acres face exposure to shoreline erosion, or about 10 percent of total park acreage on granted lands (Figure 23).

The private development types categorized as “entertainment” include bowling alleys and golf courses. Bowling alleys (0.1 acres) face exposure to sea-level rise; golf courses do not. Both bowling alleys and golf courses (covering 272.1 acres) face exposure to sea-level rise with storm surge. The exposure of this land to flooding remains consistent over time (Figure 24). None of this land is projected to be exposed to cliff erosion, while golf courses are projected to be exposed to shoreline erosion with or without protective measures (Figure 25).

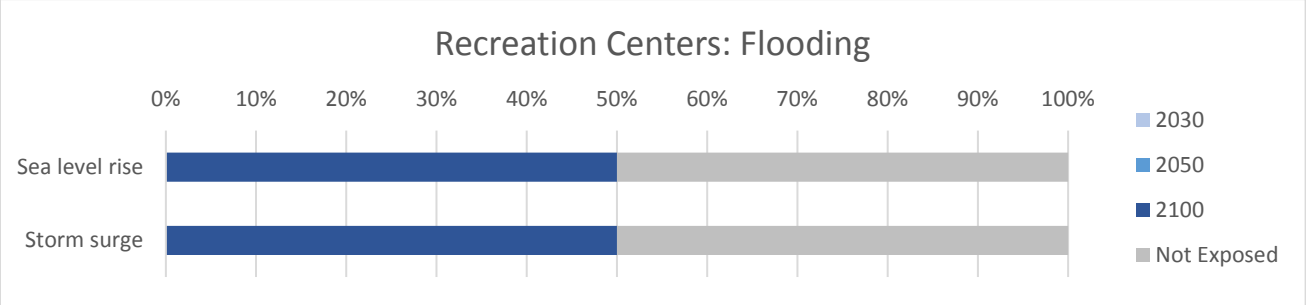

Figure 21. Percentage of recreation centers on granted lands exposed to coastal flooding over time

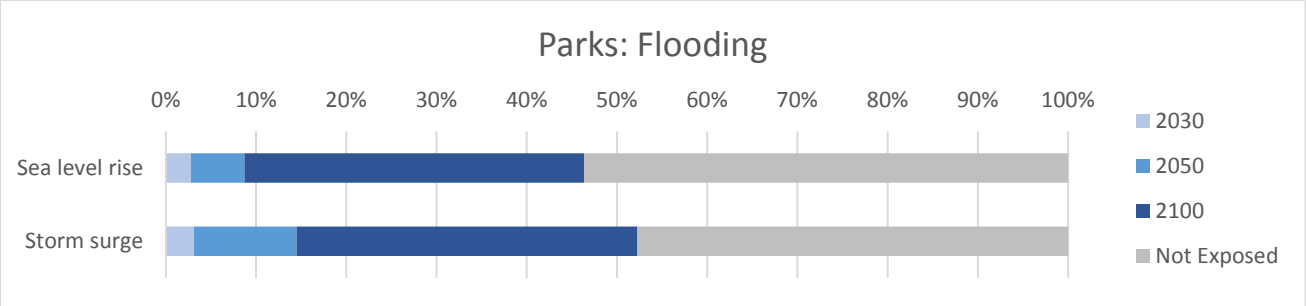

Figure 22. Percentage of parks acreage on granted lands exposed to coastal flooding over time

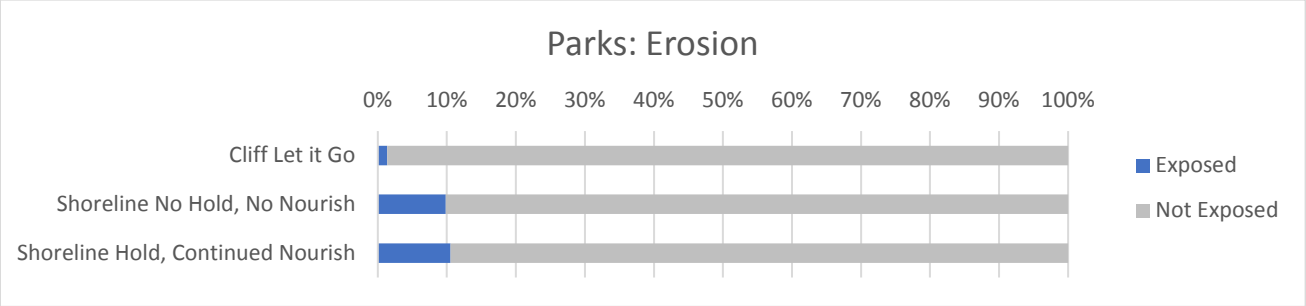

Figure 23. Percentage of parks acreage on granted lands exposed to erosion between present day and 2100

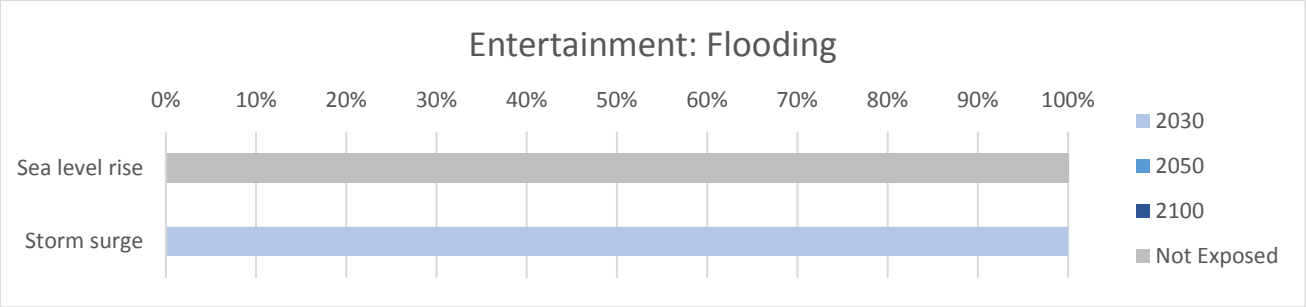

Figure 24. Percentage of entertainment acreage on granted lands exposed to coastal flooding over time

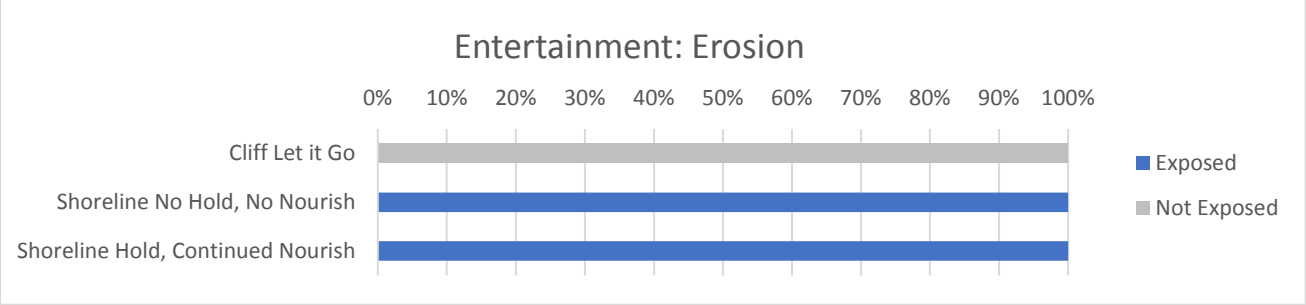

Figure 25. Percentage of entertainment acreage on granted lands exposed to erosion between present day and 2100

Coastal Habitats

Conservation areas and two habitat types (bog/marsh and scrub/chaparral) on granted lands within the City are projected to be exposed to coastal flooding; one of these habitat types (scrub/chaparral) also is projected to be exposed to erosion. One conservation area on granted lands is projected to be exposed to sea-level rise with storm surge by 2100 (***Figure 26***). Seven acres of bog and marsh habitat are projected to be exposed to sea-level rise through 2100, and up to 11 acres are projected to be exposed to sea-level rise with storm surge by 2100 (***Figure 27***).

Scrub and chaparral habitat is projected to be exposed to both flooding and erosion. Of the two acres of scrub and chaparral habitat on granted lands in the City, one acre faces exposure to sea-level rise and 2 acres face exposure to sea-level rise with storm surge across all time horizons (***Figure 28***). None face exposure to cliff erosion, and 0.1 to 0.4 acres face exposure to shoreline erosion (Figure 29).

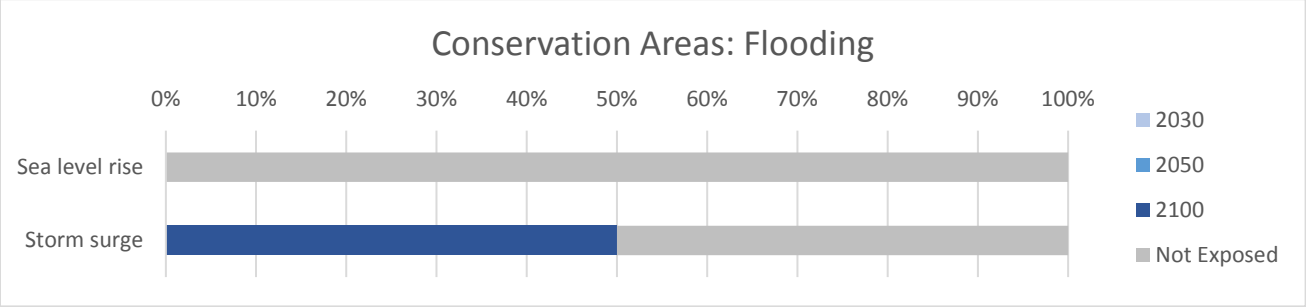

Figure 26. Percentage of conservation areas on granted lands exposed to coastal flooding over time

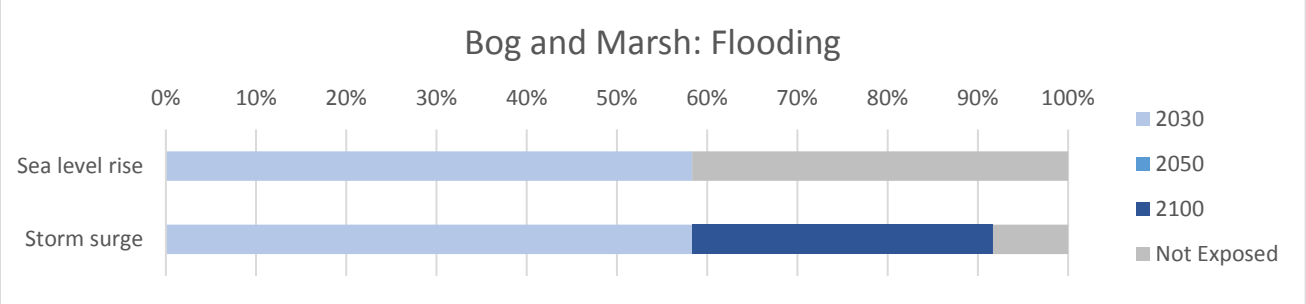

Figure 27. Percentage of bog and marsh habitat on granted lands exposed to coastal flooding over time

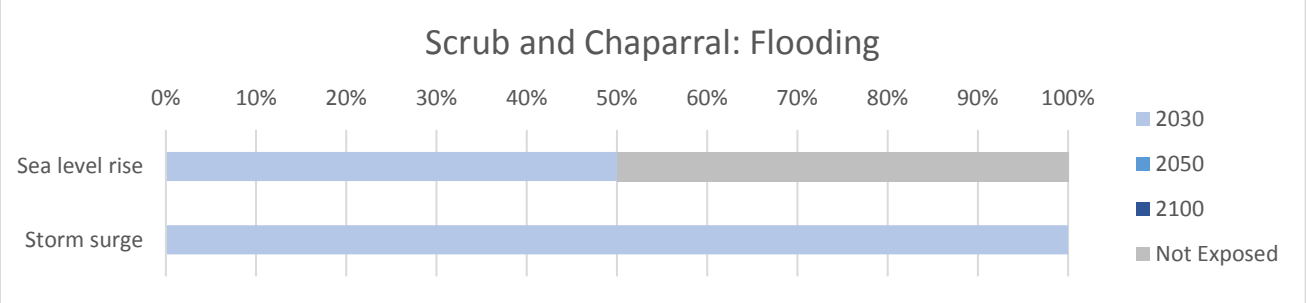

Figure 28. Percentage of scrub and chaparral habitat on granted lands exposed to coastal flooding over time

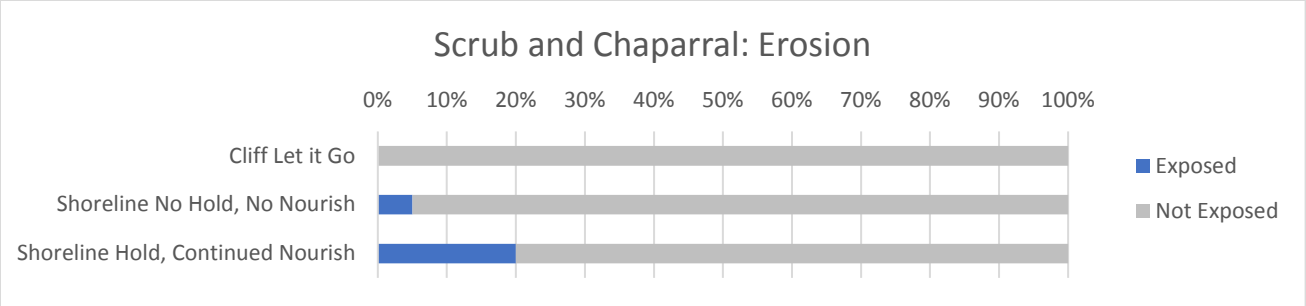

Figure 29. Percentage of scrub and chaparral habitat on granted lands exposed to erosion between present day and 2100

Navigability

Navigability itself is unlikely to be affected by sea-level rise, as navigable waterways are likely to expand as sea levels rise. Vulnerabilities would most likely involve impacts to docks if they are not designed for large fluctuations in stillwater levels. There are 22 acres of marina docks on granted lands in the City; all are projected to be exposed to both sea-level rise and storm surge throughout all timeframes (Figure 30). No marina docks face exposure to erosion.

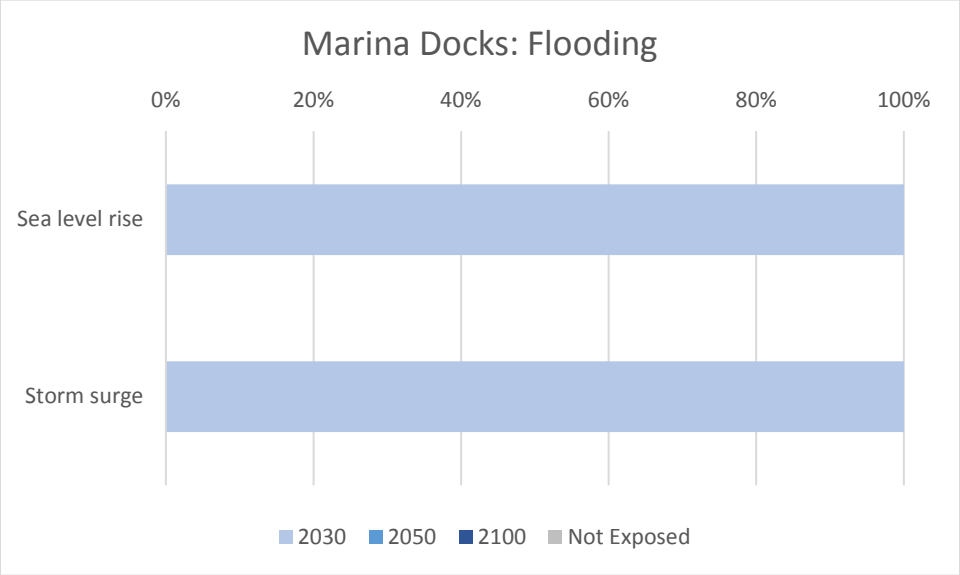

Figure 30. Percentage of marina docks on granted lands exposed to coastal flooding over time

Sea-Level Rise Financial Cost Estimates

This section provides replacement/repair cost estimates and non-market value estimates for resources and facilities on granted lands affected by sea-level rise and future 100-year storms for 2030, 2050, and 2100. These estimates represent the value of exposed assets, not the cost to the City of San Diego to protect or repair damaged assets. It is essentially the value of assets that would be exposed to sea-level rise and sea-level rise with storm surge if no actions are taken to protect or move them. It is also important to note that the following cost estimates are approximate and for the extreme risk aversion scenario.

Over the normal course of the City's capital program, all of the equipment and much of the infrastructure detailed in this section will be replaced or reinforced with resiliency and adaptation measures. The implementation of mitigation and adaptation measures over time will help to reduce many of these costs, both public and private. Some costs associated with implementing mitigation and adaptation measures are already accounted for in the City's work plan.

Replacement Costs of Affected Resources and Facilities

To assess the replacement costs of affected resources and facilities, the following approaches were used. All cost estimates are approximate and may underestimate or overestimate actual costs. Actual costs will vary due to multiple factors, such as location, size, and site conditions. In addition, variability in many of the cost estimates is due to a range of sea-level scenarios and in some cases, a range in the replacement cost of a single asset.

- Quantitative estimates of replacement/repair costs were calculated for bridges,[10] major arterials,[11] water pipes,[12] and wastewater pipes[13] based on average asset replacement cost data from the City of San Diego Enterprise Asset Management System.[14] The estimated cost of affected City assets was determined by taking the 95th percentile cost per asset and multiplying that value by the number of exposed assets within the granted lands area. These are conservative estimates due to the selection of the 95th percentile costs and given that not all affected assets will require full replacement.
- For the remaining city assets, quantitative estimates of replacement/repair costs were based on best available information from various City departments and resources:
    - *Lifeguard stations* – Under the assumption that movable lifeguard stations could be relocated in the event of sea-level rise or storm surge, the cost estimate is based only on the number of exposed permanent lifeguard stations. A cost estimate for a single

[10] Estimate based on the 95th percentile cost of bridges in the City's Enterprise Asset Management System.
[11] Estimate based on the 95th percentile cost of major roadway pavement in the City's Enterprise Asset Management System.
[12] Estimate based on the 95th percentile cost of water distribution pipes and the 95th percentile cost of water transmission pipes in the City's Enterprise Asset Management System.
[13] Estimate based on the 95th percentile cost of wastewater mains in the City's Enterprise Asset Management System.
[14] These cost data include the cost of all assets in the City and cannot be disaggregated to calculate average costs for granted lands alone. It is unknown whether the costs to replace assets on granted lands is higher or lower than the City-wide averages.

permanent lifeguard station was multiplied by the total number of exposed permanent structures (Source: City of San Diego Fire-Rescue Department).

- *Wastewater pumps,[15] storm water drain pump stations,[16] and storm water outfalls[17]* – Estimated replacement values for each asset type were multiplied by the total number of exposed assets (Source: City of San Diego Public Utilities Department and City of San Diego Transportation and Storm Water Department).
- *Recreation centers* – A replacement value was estimated from the City of San Diego Facilities Condition Assessment report for fiscal years 2014-2016 (City of San Diego 2016).
- *Parks* – The total project development costs for playgrounds, comfort stations, and park acreage were provided by the City of San Diego Parks and Recreation Department's Park Planning Cost Estimate Template and used as a proxy for park value.[18] The number of playgrounds and comfort stations exposed to each sea-level and storm surge scenario was determined and multiplied by the respective replacement value. The cost estimate for exposed acreage under each scenario was also included in the total cost estimate. The cost estimate does not include sports fields, parking lots, boardwalks, or picnic shelters (Source: City of San Diego Parks and Recreation Department).

- For non-City assets, tax assessed land value was used as a proxy for the cost of structures and facilities on the land. Tax assessed land values were used due to these data being the most complete third-party estimates of value across different types of non-City assets, and because this cost information is tied directly to the spatial information used to estimate exposure. Assessed values, however, may not be equal to market value and may differ between properties of the same market value.[19] Estimates were made using the total acreage of exposed granted parcels. This approach assumes a complete loss of structure, which is a conservative assumption since flooding may not cause severe, long-lasting damage.
    - The inventory of vulnerable non-City assets indicates the total footprint of all exposed parcels. If a parcel (a land unit determined by the County assessor's office) was found to be at all exposed to coastal hazards, then the whole acreage of the parcel was counted

[15] Wastewater pump costs are highly dependent on multiple factors including horsepower, pump size, location, and other variables. As a result, the Public Utilities Department provided a wide and conservative cost estimate range for wastewater pumps. Specific costs would be determined on a case-by-case basis.

[16] Storm water drain pump station costs will vary depending on site conditions, California Environmental Quality Act requirements, mitigation needs, resource agency permitting, easement and property acquisition and the components of scope of work. As a result, the Transportation and Storm Water Department provided a high-level approximate cost estimate range that encompasses design and construction.

[17] Storm water outfall costs will vary depending on site conditions, California Environmental Quality Act requirements, mitigation needs, resource agency permitting, easement and property acquisition and the components of scope of work. As a result, the Transportation and Storm Water Department provided a high-level approximate cost estimate range that encompasses design and construction.

[18] The City of San Diego Parks and Recreation Department is currently conducting a Facilities Assessment report, which will help the city further refine the cost of park assets on granted lands.

[19] Note that California Proposition 13 may cause the tax-assessed value of some properties to be artificially low. All tax assessed values are based on a 1975 base year value unless ownership has changed since 1975, in which case the year of transfer is the base year. Therefore, two properties with the same market value can have different taxable assessed values. In addition, new construction does not change the base year value of the land, only the base year value of the newly constructed property.

as exposed. While this method overestimates the area that will actually be flooded, it appropriately captures vulnerability as flooding on any part of the parcel may render the rest of it inaccessible.

- For public access, the 2019 *Audit of Mission Bay and San Diego Regional Parks Improvement Funds for Fiscal Year 2018* provides costs for a number of new and continuing coastal access projects (City of San Diego 2019). The range of costs from this report is applied to the number of affected locations to estimate the financial cost of sea-level rise to coastal access points. This is a conservative estimate as some exposed coastal access points may not experience significant damage.

Table 4 provides approximate cost estimates of resources and facilities impacted by sea-level rise for 2030, 2050, and 2100. Where applicable, cost estimates include a lower and upper bound due to a range of sea-level scenarios and in some cases, a range in average replacement cost. As a result, the upper end of the cost estimate may be an overestimate. The City would have no obligation to repair or replace non-City assets on granted lands. Other city assets with primarily non-market values are discussed in the next section.

Table 4. Sea-Level Rise: Replacement Cost Estimates for Resources and Facilities on Granted Lands if No Mitigation or Adaptation Measures are Implemented[20]

Resources and Facilities	Asset	Obligated Party	Quantitative Cost Estimates		
			2030	2050	2100
City assets on granted lands	Lifeguard stations	City/Non-Enterprise	$3 million–$4.5 million	$3 million–$4.5 million	$3 million–$9 million
	Water pipes[12]	City/Enterprise	$7.5 million	$8.8 million–$6.4 million	$10.3 million–$46.4 million
	Wastewater pipes[13]	City/Enterprise	$2.7 million	$3.6 million–$6.3 million	$8.3 million–$30.8 million
	Wastewater pumps[15]	City/Enterprise	$983,000–$4.8 million	$2.5 million–$12 million	$4.4 million–$36.1 million
	Bridges[10]	City/Non-Enterprise	$925,000	$925,000	$925,000–$1.9 million
	Major arterials[11]	City/Non-Enterprise	$19.8 million	$19.8 million	$21.7 million–$23.7 million
	Storm water drain pump stations[16]	City/Non-Enterprise	$0	$4.5 million–$6 million	$4.5 million–$12 million

[20] Cost estimates represent the value of exposed assets, not the cost to the City of San Diego. Cost estimates are approximate and may vary. Proactive planning for climate change will help to reduce many of these costs, both public and private. Over the time-period assessed, asset replacement may already be accounted for due to asset lifespan.

[21] Cost estimates represent the value of exposed assets, not the cost to the City of San Diego. Cost estimates are approximate and may vary. Proactive planning for climate change will help to reduce many of these costs, both public and private. Over the time-period assessed, asset replacement may already be accounted for due to asset lifespan.

	Storm water outfalls[17]	City/Non-Enterprise	$66.2 million–$98 million	$75.6 million–$122 million	$90.5 million–$158 million
	Recreation centers	City/Non-Enterprise	$0	$0	$5.6 million
	Parks*[18]	City/Non-Enterprise	$16 million	$32.4 million–$52.9 million	$109.5 million–$291.2 million
Non-City assets on granted lands[19]	Hotels/motels	Non-City	$116 million	$169 million	$172 million–$283 million
	Industrial	Non-City	$1.4 million	$1.4 million	$1.4 million
	Institutional	Non-City	$51 million	$51 million	$51 million
	Marina docks	Non-City	$14.6 million	$14.6 million	$14.6 million
	Office space	Non-City	$6.4 million	$6.4 million	$6.4 million
	Agricultural preserves	Non-City	$3 million	$3 million–$4 million	$4 million
	Entertainment	Non-City	$756,000	$756,000	$756,000
	Restaurants/bars	Non-City	$3.2 million	$3.2 million	$3.2 million
	Not defined	Non-City	$722,000	$5.9 million	$5.9 million–$10.9 million
	Vacant	Non-City	$2.6 million	$2.6 million	$2.6 million
Public access	Coastal Access Points	Non-City	$108,000–$1.5 million	$108,000–$1.9 million	$189,000–$6 million

*The non-market value of this asset is estimated in the next subsection of the report. Given Parks are non-essential assets, the City maintains the discretion to determine repair, replacement or alternative design of park space, including a zero-cost option.

Table 5. Sea-Level Rise + Storm Surge: provides the same information as Table 4, but for a 100-year storm surge on top of future sea-level rise scenarios. The 100-year storm has a one percent annual chance of occurrence, and a 55 percent chance of occurring between 2020 and 2100. Overall, this table represents a lower likelihood event than the prior table, which only covered sea-level rise. Additionally, the effects of a storm are inherently shorter-term than those of sea-level rise. While sea-level rise results in a permanent loss of land, a storm surge results in damage, but facilities can be repaired or rebuilt in place.

Where applicable, cost estimates include a lower and upper bound due to a range of sea-level scenarios and in some cases, a range in average replacement cost. As a result, the upper end of the cost estimate may be an overestimate. The City would have no obligation to repair or replace non-City assets on granted lands. Since this table uses combined sea-level rise and 100-year storm scenarios, the values should not be summed with the prior table.

Table 5. Sea-Level Rise + Storm Surge: Replacement Cost Estimates for Resources and Facilities on Granted Lands if No Mitigation or Adaptation Measures are Implemented[21]

Resources and Facilities	Asset	Obligated Party	Quantitative Cost Estimates		
			2030	2050	2100
City assets on granted lands	Lifeguard stations	City/Non-Enterprise	$3 million–$4.5 million	$6 million–$9 million	$9 million–$18 million
	Water pipes[12]	City/Enterprise	$10.7 million	$12.5 million–$23.1 million	$28.9 million–$62.8 million
	Wastewater pipes[13]	City/Enterprise	$4.7 million	$8.1 million–$16.5 million	$22.4 million–$36.5 million
	Wastewater pumps[15]	City/Enterprise	$2.5 million–$12 million	$5.4 million–$38.5 million	$7.9 million–$40.9 million
	Bridges[10]	City/Non-Enterprise	$925,000	$925,000	$1.9 million
	Major arterials[11]	City/Non-Enterprise	$19.8 million	$19.8 million	$21.7 million–$27.8 million
	Storm water drain pump stations[16]	City/Non-Enterprise	$4.5 million–$6 million	$4.5 million–$12 million	$9 million–$12 million
	Storm water outfalls[17]	City/Non-Enterprise	$71.6 million–$126 million	$95.9 million–$154 million	$106.7 million–$180 million
	Recreation centers	City/Non-Enterprise	$0	$0	$5.6 million
	Parks*[18]	City/Non-Enterprise	$21.2 million	$54.5 million–$95 million	$160.1 million–$330.8 million
Non-City assets on granted lands[19]	Hotels/motels	Non-City	$172 million–$225 million	$225 million	$229 million–$337 million
	Industrial	Non-City	$1.4 million	$1.4 million	$1.4 million
	Institutional	Non-City	$51 million	$51 million	$51 million
	Marina docks	Non-City	$14.6 million	$14.6 million	$14.6 million
	Office space	Non-City	$6.4 million	$6.4 million	$6.4 million
	Agricultural preserves	Non-City	$3 million–$4 million	$4 million	$4 million
	Entertainment	Non-City	$6 million	$6 million	$6 million
	Restaurants/bars	Non-City	$3.2 million	$3.2 million	$3.2 million
	Not defined	Non-City	$5.9 million	$5.9–$7.4 million	$10.9 million–$75.9 million
	Vacant	Non-City	$2.6 million	$2.6 million	$2.6 million
Public access	Coastal Access Points	Non-City	$162,000–$2.3 million	$216,000–$3.4 million	$378,000–$6.8 million

[21] Cost estimates represent the value of exposed assets, not the cost to the City of San Diego. Cost estimates are approximate and may vary. Proactive planning for climate change will help to reduce many of these costs, both public and private. Over the time-period assessed, asset replacement may already be accounted for due to asset lifespan.

* The non-market value of this asset is estimated in the next subsection of the report. Given Parks are non-essential assets, the City maintains the discretion to determine repair, replacement or alternative design of park space, including a zero-cost option.

Non-Market Values of Affected Public Trust Resources

The City's granted lands include more than 4,000 acres of land and water, 27 miles of shoreline, and eight official swimming areas (City of San Diego 2019). These lands provide countless economic, social, environmental, and cultural benefits to the City and its users, some of which can be easily estimated and some of which cannot.

From an economic perspective, City revenues from granted lands include lease revenues (more than $12 million in FY 2018), park use revenues (approximately $539,000 in FY 2018), and concessions ($13,000 in FY 2018). Expenditures by the City in granted lands include those for lifeguards, police, parks and recreation, and facility maintenance. Other services provided in granted lands (mainly Mission Bay Park) include street repair maintenance, wastewater/sewer maintenance, and emergency/fire protection services (City of San Diego 2018). Annual attendance in Mission Bay Park is estimated at 15 million visitors (City of San Diego 2019).

Key non-market values include access to and recreational use of granted lands and ecosystem services such as biodiversity and protection or abatement of hazards such as flooding or erosion. Table 6 provides a summary of key non-market values exposed to sea-level rise and sea-level rise with a 100-year storm surge in 2100, including the methodology used to evaluate each asset or land type. Non-market values are challenging to assess and therefore these values are only estimates based on a simplified approach. In addition, they likely represent only a small sample of potential non-market values.

Table 6. Example Non-market Values on Granted Lands for 2100 (in 2018 dollars)[22]

Asset or Land Type	Methodology	2100 Non-Market Value (2018 $) of Areas Exposed To:	
		Sea-level Rise	SLR + Storm Surge
All Granted Lands	As a proxy for the non-market value of granted lands, annual City revenues (lease revenues, park use revenues, and concession revenues) were multiplied by the percentage of granted lands inundated by sea-level rise and sea-level rise with 100-year storm impacts for the 2100 scenario.	$7.5 million–$7.8 million	$11.9 million–$12.3 million

[22] Non-market value estimates are approximate and may vary.

Asset or Land Type	Methodology	2100 Non-Market Value (2018 $) of Areas Exposed To:	
		Sea-level Rise	SLR + Storm Surge
Parks and Beach Loss (Recreational Value)	As a proxy for the lost non-market value of recreational and ecotourism activities, a value of $22,414 per acre[23] was applied to affected park acreage and beach loss acreage.[24]	$7.3 million–$20.3 million	$9.2million–$21.7 million
Bog and Marsh Habitat and Scrub and Chaparral Habitat	As a proxy for the non-market value of coastal habitat loss, a value of $849 per acre[25] was applied to affected bog and marsh habitat acreage and scrub and chaparral habitat acreage.	$6,800	$11,000
Beach Loss (Ecosystem Value)	As a proxy for the non-market value of beach loss, a value of $2,300 per acre[26] was applied to the no hold, no nourish; no hold, continued nourish; and hold, continued nourish shoreline loss scenarios to provide a range of costs. This estimate represents the minimum cost due to shoreline erosion; it does not take into account additional beach loss from flooding or storm surge events.	$390,000–$920,000	$390,000–$920,000
Coastal Access Points	To assess loss of access to coastal areas, the following qualitative scale was applied based on the percentage of exposed assets: - Low: No loss of access - Medium: Temporary loss of access - High: Permanent loss of access	High	Medium

[23] EPA estimates the economic value of coastal ecosystems in California for activities associated with recreation and ecotourism as $16,946 per acre in 2008 dollars (Raheem, et al. 2009).

[24] Beach loss encompasses the no hold, no nourish; no hold, continued nourish; and hold, continued nourish shoreline loss scenarios. These shoreline erosion scenarios do not take into account additional beach loss from flooding or storm surge events.

[25] *An Economic Valuation of Southern California Coastal Wetlands* estimates a low-end conservative wetland value of $1,814 per hectare or $734 per acre in 2015 dollars (Ballard, Pezda and Spencer 2017). This estimate encompasses the following ecosystem services: carbon sequestration, shoreline stability and erosion control, water flow regulation, flood and storm protection, science and education, recreation, aesthetics, cultural activities, refugia habitat, nutrient cycling, and pollution buffering and wastewater.

[26] A joint report by the California Department of Boating and Waterways and San Francisco State University estimates the value of beaches at $1,619 per acre in 2006 dollars, which encompasses biodiversity, habitat, and additional ecosystem service values (King, McGregor and Whittet 2012).

Asset or Land Type	Methodology	2100 Non-Market Value (2018 $) of Areas Exposed To:	
		Sea-level Rise	SLR + Storm Surge
Cultural and Historical Resources	To assess loss of cultural and historical resources, the following qualitative scale was applied based on the percentage of exposed assets: - Low: No loss of resources - Medium: Loss of some resources - High: Loss of significant number of resources	High	High

Prioritization of Vulnerabilities

Prioritizing vulnerabilities helps the City identify focus areas for resilience efforts and prioritize mitigation and adaptation measures. Table 7 summarizes the qualitative scores (high, medium, low) for the vulnerability of resources and facilities on granted lands to sea-level rise and storm surge. The resources and facilities are organized into three groups—City assets on granted lands, non-City assets on granted lands, and public access—and individual assets within each group are ordered from highest to lowest vulnerability scores. For example, bridges, storm water drain pump stations, and historic and cultural resources would be the highest priorities for adaptation measures among City assets on granted lands, since they received high vulnerability scores to both sea-level rise and storm surge.

To score vulnerabilities across different resources and facilities, the following methodology was used:

- For City assets, vulnerability scores are based on exposure, sensitivity, and adaptive capacity rankings from the draft *City of San Diego Climate Change Vulnerability Assessment*[27]. It is assumed that the vulnerability score for all City assets is also representative of the subset of City assets within granted lands.
    - **Low**: The asset type would suffer minor damage but can maintain functionality, or the asset type would not be damaged at all.
    - **Medium**: The asset type would be damaged such that repairs would be necessary before it can resume full functionality.
    - **High**: The asset type would become damaged beyond repair or destroyed and could not resume normal function until replaced.
- For non-City assets, vulnerability scores are based on the estimated replacement and repair costs for the year 2100. Costs are categorized as:
    - **High**: Cost is greater than $100 million
    - **Medium**: Cost is between $4 million and $100 million
    - **Low**: Cost is less than $4 million

[27] This document is still under development internally. A final version is anticipated to be released by the end of 2019.

- For public access, all exposed coastal access points are considered high vulnerability since the City is required to maintain coastal access.

Table 7. Prioritized Vulnerabilities of Resources and Facilities on Granted Lands Affected by Sea-Level Rise and Sea-Level Rise with Storm Surge

Resources and Facilities	Asset	Vulnerability to Sea-Level Rise	Vulnerability to SLR + Storm Surge
City assets on granted lands	Bridges	High	High
	Storm water drain pump stations	High	High
	Historic and cultural resources	High	High
	Lifeguard stations	High	Medium
	Storm water outfalls	High	Medium
	Parks and recreation property	High	Medium
	Conservation areas	High	Medium
	Bog and marsh habitat	High	Medium
	Scrub and chaparral habitat	High	Medium
	Parks	High	Low
	Wastewater pipes	Medium	Medium
	Wastewater pumps	Medium	Medium
	Major arterials	Medium	Medium
Non-City assets on granted lands	Hotels/motels	High	High
	Institutional	Medium	Medium
	Marina docks	Medium	Medium
	Office space	Medium	Medium
	Not defined	Medium	Medium
	Entertainment	Low	Medium
	Industrial	Low	Low
	Agricultural preserves	Low	Low
	Restaurants/bars	Low	Low
	Vacant	Low	Low
Public access	Coastal access points	High	High

Mitigation and Adaptation Measures to Address Vulnerabilities

The options available for adaptation to sea-level rise fall into four broad categories: 1) do not intervene, 2) protect (e.g., through hard and soft defensive measures such as seawalls or natural infrastructure), 3) accommodate (e.g., through elevating structures, modifying zoning ordinances, or flood-proofing existing buildings and infrastructure), or 4) retreat (e.g., relocating vulnerable existing development and restricting future development). Related measures include public outreach, data collection, and monitoring.

Table 8 lists a variety of potential mitigation and adaptation measures to address risks to granted lands, organized by hazard. For each measure, the table includes a qualitative (low, medium, high) estimate of its capital and ongoing costs, along with the general timeframe for implementation (near term equates to 2020–2030, medium term equates to 2030–2050, and long term equates to 2050–2100).

The benefits of each adaptation measure include its avoided damages (see the damage cost estimates in Table 4 and Table 5. Sea-Level Rise + Storm Surge:) plus any co-benefits. While co-benefits will be evaluated on a case-by-case basis as specific measures are selected for implementation, initial indication of potential environmental, equity, and economic benefits are provided in the last columns of Table 8. Examples of environmental co-benefits include the wildlife and plant habitat benefits of living shorelines, natural infrastructure, and relocation. Examples of equity benefits include increasing quality of life, increasing access to green space, increasing access to services, and other benefits to vulnerable populations. Examples of economic co-benefits include potential tourism income benefits from beach nourishment, and reduced maintenance and repair costs associated with retreat/relocation or abandon-in-place measures.

A number of the measures in Table 8 (indicated by asterisks) were proposed by members of the Stakeholder Advisory Group for the City's climate change vulnerability assessment, during a workshop held on April 9, 2019. Other measures are drawn from a variety of municipal adaptation planning efforts across the United States.

Table 8. Potential Mitigation and Adaptation Measures

Hazard	Measure	Category	Capital Costs	Ongoing Costs	Timeframe	Environmental Co-Benefits	Equity Co-Benefits	Economic Co-Benefits
Flooding	Build marshes to serve as buffers against sea-level rise* (also applies to erosion)	Accommodate	High	Low	Medium term	✓		
	Make public places resilient to SLR (waterproof, moveable, elevated facilities)*	Accommodate	High	Medium	Medium term		✓	✓
	Plan land uses for habitat mitigation*	Accommodate	Low	Low	Near term	✓		
	Restore coastal dunes and habitat*	Accommodate	Medium	Low	Medium term	✓		
	Identify buildings requiring redundant power sources and purchase backup sources	Accommodate	Low	Low	Near term			
	Identify flood debris storage sites that are outside of the future floodplain to facilitate a faster clearing of debris after a storm	Accommodate	Low	Low	Near term			✓
	Consider longer planning horizons to better align plans with sea-level rise impacts	Accommodate	Low	Low	Near term			
	Consider sea-level rise projections when determining the length of long-term leases	Accommodate	Low	Low	Near term			
	Install sensors at key intersections prone to flooding to alert staff; consider investing in automatic barriers that rise during flood events to prevent vehicles from passing	Accommodate	Medium	Medium	Medium term			

Hazard	Measure	Category	Capital Costs	Ongoing Costs	Timeframe	Environmental Co-Benefits	Equity Co-Benefits	Economic Co-Benefits
	Develop a long-term plan for installing stormwater outfall pumps/lift stations to ensure that water can be drained from the system even when the outfalls are submerged	Accommodate	High	Medium	Long term	✓		
	Develop a storm protocol that identifies thresholds for shifting vehicles from potentially flooded garages and facilities to locations outside storm surge areas	Accommodate	Low	Low	Near term			
	Develop or improve coastal flood warning systems	Accommodate	Medium	Medium	Near term		✓	
	Support sea-level rise monitoring and research*	Monitor	Medium	Medium	Near term			
	Develop a system to map flooding complaints to validate flood modeling results and identify vulnerabilities	Monitor	Low	Low	Near term			
	Monitor the cost of flood events by tracking in work order system, employee time sheets, and capital costs	Monitor	Low	Low	Near term			✓
	Educate public about predicted and experienced SLR impacts*	Outreach	Low	Low	Near term		✓	
	Educate lessees on availability and necessity of flood insurance; target outreach to those within high probability flood zones	Outreach	Low	Low	Near term		✓	✓

Hazard	Measure	Category	Capital Costs	Ongoing Costs	Timeframe	Environmental Co-Benefits	Equity Co-Benefits	Economic Co-Benefits
	Screen planned infrastructure for climate risks; require new facilities in flood hazard zones to be raised above the existing base elevation plus projected sea-level rise over the life of the infrastructure	Protect	Medium	Low	Near term			✓
	Require changes in infrastructure design and materials to increase waterproofing	Protect	Medium	Low	Near term			✓
	Protect critical infrastructure in vulnerable areas, with hard or soft measures	Protect	High	Medium	Near term	✓	✓	✓
	Design protective measures so they can be raised over time	Protect	Medium	Medium	Near term			✓
	Implement flood-proofing measures on building and infrastructure when conducting routine maintenance	Protect	Medium	Low	Near term			✓
	Create habitat/open space*	Retreat	Medium	Low	Long term	✓	✓	
	Convert parking lots to restore open space*	Retreat	Medium	Low	Medium to long term	✓	✓	
	Convert leaseholds to mitigation areas*	Retreat	Low	Low	Long term	✓		
	Develop a long-term managed retreat plan, including triggers for relocation or removal of structures	Retreat	Low	Low	Near term	✓		
Cliff and Beach Erosion	Monitor erosion and land loss impacts from sea-level rise and storm events	Monitor	Low	Low	Near term			
	Develop a beach management plan to add sediment to places that need to aggrade, nourish beaches*	Protect	Low	Low	Near term	✓		✓

Hazard	Measure	Category	Capital Costs	Ongoing Costs	Timeframe	Environmental Co-Benefits	Equity Co-Benefits	Economic Co-Benefits
	Build marshes to serve as buffers against sea-level rise* (also applies to flooding)	Protect	Medium	Medium	Medium term	✓		✓
	Regulate development in erosion zones	Retreat	Low	Low	Near term	✓		
	Relocate buildings and infrastructure threatened by erosion	Retreat	High	Medium	Medium to long term			
	Abandon structures in place	Do Not Intervene	Low	Low	Medium term	✓		✓

*Measure identified through stakeholder outreach at the April 9, 2019 Stakeholder Advisory Group workshop.

Monitoring Climate Hazards and Measure Effectiveness

The City is developing a plan to track climate hazards, including sea-level rise. Tracking and regularly reviewing data on extreme weather and climate impacts will allow the City to monitor changes in climate trends and be prepared to respond to climate risks as they become increasingly relevant. Tracking extreme weather and climate impacts will help the City:

- Determine when to implement additional adaptation actions;
- Build the business case for adaptation given repeated costs from disruptions;
- Better understand the magnitude of impacts and their consequences; and
- Target and prioritize specific locations in need.

The City already collects some of the information required for some climate impact metrics, but for other metrics the City may need to establish new systems for tracking information. The largest departure from current practices would involve saving the information in a structured database rather than individual storm reports and forms. Table 9 lists metrics that the City is considering, along with existing logging activities that could be used to feed a database.

Table 9. Potential Monitoring Metrics

Metric	Description	Frequency	Existing Logging Activities
Frequency of extreme weather events	Record the number of weather events of each type that result in damage and/or closures: • Inland flooding • Coastal flooding • Mudslide • Wildfire • Extreme heat events	Annually	Initial Damage Estimates; After Action Reports; Range Logs
Extent of weather-related damages or infrastructure closures	Record the location and type/magnitude of damages or disruptions, including identification numbers for affected infrastructure. Include photos as possible	For each event	Initial Damage Estimates; After Action Reports; Ranger Logs; Federal Emergency Management Agency (FEMA) funding request documentation; asset management system
Duration of weather-related damage or infrastructure closures	Record how long the infrastructure was out of service (e.g., hours, days)	For each event	Asset management system
Cause of weather-related damage or infrastructure closures	Record what appears to have caused damage or disruption to infrastructure (e.g., insufficient maintenance, overwhelmed system design)	For each event	Initial Damage Estimates; After Action Reports; Ranger Logs; FEMA funding request documentation; asset management system

Resultant community impact	Record any delays, detours, injuries, ecosystem impacts, health impacts, public safety threats, or other disruptions to the community	For each event	
Maintenance and repair costs	Quantify costs associated with damages from extreme weather events	For each event	Initial Damage Estimates; After Action Reports; FEMA funding request documentation
Costs of materials/ staff time	Quantify costs associated with materials and staff time required to prepare for and recover from each event	For each event	Initial Damage Estimates; After Action Reports; Ranger Logs
Frequency of emergency fund requisition	Record the number of times and amounts the City spends emergency funds due to extreme weather events	Annually	Emergency Proclamation Documents; FEMA funding request documentation

Potential uses of this information include activities such as:

- Mapping the costs of weather events over time to understand hot spots (location and sensitivity thresholds) and further develop and justify adaptation strategies. Once adaptation strategies are implemented, this will also help to track effectiveness over time, as represented by decreased response costs.
- Monitoring and inform more resilient long-term decision making through better tracking of ongoing costs and impacts of extreme weather events on exposed assets.
- Mapping the frequency of maintenance or repairs linked to weather events to understand the frequency of impacts. This information can indicate areas that require attention or the effectiveness of adaptation strategies.
- Annually reviewing impacts to asset classes or sub-groups to determine if extreme events are impacting condition of assets.
- Identifying tipping points in the frequency or severity of events when the City may begin planning for long-term changes.

It is risky to select and implement a set of adaptation actions in the face of an uncertain future. An approach known as flexible adaptation pathways can help the City address this challenge, allowing them to develop strategies designed to shift in response to changes that occur over a long period and in unpredictable ways. Flexible adaptation pathways can take different forms, but generally share the following key elements:

- A clear statement of the need for adaptation, tied to a specific climate risk;
- A variety of adaptation measures that can be used to meet the objective in different ways;
- Thresholds or triggers to initiate a shift from one pathway to another (e.g., a damage cost threshold or a flooding frequency threshold);
- A monitoring system to identify when thresholds or trigger points are reached (e.g., monitor extent, duration, and depth of coastal flooding at specific locations; monitor beach elevations

and widths; conduct structural monitoring; monitor relative sea-level rise based on tide gauge data);
- Metrics for comparing cost, feasibility, and other attributes of measures within each pathway, allowing planners to determine a current optimal pathway.

Adaptation pathways are an approach endorsed by the Climate-Safe Infrastructure Working Group to the California State Legislature and the Strategic Growth Council, in its 2018 report *Paying it Forward: The Path Toward Climate-Safe Infrastructure in California* and have been adopted by a growing number of municipalities worldwide, including New York City and London, UK.

Measuring the effectiveness of adaptation actions in reducing climate-related risks involves establishing and monitoring metrics and thresholds for climate-related service disruptions, repair, and maintenance. Some of the metrics listed in Table 9 could be used for this purpose.

Regional Partnerships

The City has developed an inclusive process for conducting its vulnerability assessment and developing adaptation responses to the risks posed by sea-level rise. In 2018, the City convened the first of a series of stakeholder workshops to provide input and feedback on the vulnerability assessment and draft adaptation strategies. The participating organizations include:

- California Governor's Office of Emergency Services (Cal OES)
- US Department of Defense
- US Federal Emergency Management Agency (FEMA), Region IX
- Caltrans Headquarters
- Caltrans District 11
- Port of San Diego
- San Diego Metropolitan Transit System
- Scripps Institute of Oceanography
- California Health and Human Services Agency
- Community Action Partnership
- County of San Diego
- US Fish and Wildlife Service
- California Department of Fish and Wildlife
- Coastal Conservancy
- Circulate San Diego
- Clean Tech San Diego
- San Diego Bike Coalition
- Environmental Health Coalition
- San Diego Association of Governments (SANDAG)
- University of California San Diego
- San Diego Chamber of Commerce
- San Diego Gas & Electric
- San Diego Audubon
- El Dorado Properties
- San Diego Airport

Additionally, the City is an active member of the San Diego Regional Climate Collaborative (SDRCC). Founded in 2012, the SDRCC supports regional efforts to advance comprehensive solutions to reduce greenhouse gas emissions and prepare for local climate change impacts. The SDRCC helps to build capacity across the San Diego region to respond to climate change impacts and create a more sustainable region. The City is a member of the Collaborative, holds a seat on the steering committee, and participates in the Collaborative's Adaptation Planning Working Group.

The City is developing recommended adaptation options, which will be discussed, reviewed, and coordinated within the context of these partnerships.

Next Steps

The City's 2015 Climate Action Plan identified the need for a standalone climate adaptation plan to help the City prepare for the impacts of climate change. Accordingly, the City is developing the *Climate Resilient San Diego (Climate Resilient SD)* Plan to address climate change hazards and ensure San Diego is ready for changes anticipated in the decades ahead. This City-wide effort is focused on four primary climate change hazards that pose special risks to the City: sea-level rise (including coastal flooding and erosion), extreme heat, changes in precipitation (including droughts and heavy rainfall), and wildfire.

Climate Resilient SD will contain a broader list of priority vulnerabilities and adaptation measures than those identified in this report since it covers a larger area and a greater number of climate change hazards. Similarly, the adaptation measures listed in this report represent a sample of possible measures the City can take to address coastal hazards across its entire jurisdiction. The City will examine a broader list of potential adaptation measures, based in part on discussion with key stakeholders, to address all four primary hazards and all priority vulnerabilities across the entire City jurisdiction. The *Climate Resilient SD* plan will be publicly available when completed and, as appropriate, will incorporate the findings of this AB 691 assessment.

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Appendix 1: Non-public Trust Resources and Facilities

A number of City-owned resources and facilities that were included in the exposure assessment do not fit under the public trust resources' categories of public access, commerce, recreation, coastal habitats, or navigability. These additional resources and facilities, which are considered in the current City effort to develop a comprehensive vulnerability assessment and *Climate Resilient San Diego* plan, include resources and facilities across key sectors such as public safety, wastewater, transportation, storm water, and historic and cultural resources.

Additionally, the parcels used to determine privately owned resources and facilities on granted lands also included certain land use types that are not considered to be "public trust" resources and facilities, including agricultural preserves, undefined, and vacant lands. The exposure of these non-public trust resources and facilities is discussed below and shown in Table 10 and Table 11.

Public safety assets on granted lands potentially exposed to coastal flooding and erosion consist entirely of lifeguard stations, of which there are 32 on granted lands. By 2100, as many as 28 lifeguard stations could be exposed to sea-level rise and 31 to sea-level rise with storm surge. Two face exposure to cliff erosion and up to 24 face exposure to shoreline erosion.

Water infrastructure on granted lands potentially exposed to coastal flooding and erosion includes water pipes (encompassing 226 segments on granted lands), wastewater pipes (encompassing 436 segments), and wastewater pumps (23 on granted lands). By 2030, 14 to 27 water pipe segments, 27 to 47 wastewater pipe segments, and 2 to 5 wastewater pumps face exposure to coastal flooding. These numbers increase to 19 to 65, 36 to 163, and 5 to 16, respectively, by 2050 and as high as 205 water pipe segments, 361 wastewater pipe segments, and 17 wastewater pumps by 2100. No water pipe or wastewater pipe segments face exposure to cliff erosion and 23 to 24 water pipe segments and 16 wastewater pipe segments face exposure to shoreline erosion, depending on whether adaptive actions are taken. No wastewater pumps on granted lands face exposure to erosion.

Transportation infrastructure on granted lands potentially exposed to coastal flooding and erosion includes bridges (of which there are six on granted lands) and major arterials (encompassing 24 segments on granted lands). One to two bridges are projected to be exposed to coastal flooding by 2100, and none face exposure to erosion. Ten segments of major arterials face exposure to flooding by 2030 and up to 14 by 2100. No segments face exposure to either cliff or shoreline erosion.

Storm water infrastructure on granted lands potentially exposed to coastal flooding includes storm water drain pump stations (of which there are two) and storm water outfalls (of which there are 96). One to two storm water drain pump stations face exposure to coastal flooding by 2100, and none face exposure to erosion. Storm water outfalls face more varied exposure: 49 to 63 face exposure to coastal flooding by 2030, 56 to 77 by 2050, and 67 to 90 by 2100. Five storm water outfalls face exposure to cliff erosion, and 19 face exposure to shoreline erosion, regardless of whether adaptive action is taken.

Historic and cultural resources (of which there are six on granted lands) face exposure to both coastal flooding and erosion. By 2030, none of these assets face exposure from sea-level rise alone, but three face exposure to sea-level rise with storm surge. By 2050, one to two face exposure to sea-level rise alone and three still face exposure to sea-level rise with storm surge. By 2100, two to three face exposure to sea-level rise and three to five face exposure to sea-level rise with storm surge. None face exposure to cliff erosion and five to six face exposure to shoreline erosion.

There are two acres of agricultural preserves on granted lands in the City. One to two acres of this land face exposure to sea-level rise throughout the century, and 0.6 acres face exposure to both cliff and coastal erosion.

There are 190 acres of undefined land use types on granted lands in the City. One hundred twenty-nine acres of undefined land use types face exposure to sea-level rise by 2030 and 2050, and up to 143 acres face exposure to sea-level rise by 2100. Similarly, 129 acres face exposure to sea-level rise with storm surge by 2030, then 129 to 142 acres face exposure by 2050 and 143 to 174 acres face exposure by 2100. Only 0.7 acre of land with an undefined land use faces exposure to cliff erosion, while 20 acres face exposure to shoreline erosion.

There are 25 acres of vacant land within granted lands in the City. Of these, 3 to 18 acres face exposure to sea-level rise by 2030, 18 to 25 acres face exposure by 2050, and all 25 acres face exposure by 2100. Eighteen acres face exposure to sea-level rise with storm surge by 2030 and all 25 acres face exposure by 2050 and 2100. Only 0.6 acre of vacant land faces exposure to cliff erosion, while all 25 acres face exposure to shoreline erosion.

Table 10. Exposure of Other Public Trust Resources on Granted Lands to Sea-Level Rise and Sea-Level Rise with Storm Surge over Time

Timeframe		2030		2050		2100	
Resources and Facilities	**Asset (total number or acreage on granted lands)**	**Sea-level rise**	**SLR + Storm surge**	**Sea-level rise**	**SLR + Storm surge**	**Sea- level rise**	**SLR + Storm surge**
City assets on granted lands (number of assets unless stated otherwise)[28]	Lifeguard stations (32)[29]	3–4	10	5–9	13–18	14–28	22–31
	Water pipes (226 segments)	14	27	19–24	34–65	40–152	89–205
	Wastewater pipes (436 segments)	27	47	36-62	80-163	82-305	222-361
	Wastewater pumps (23)	2	5	5	11-16	9-15	16-17
	Bridges (6)	1	1	1	1	1–2	2
	Major arterials (24 segments)	10	10	10	10	11–12	11–14
	Storm water drain pump stations (2)	0	1	1	1–2	1–2	2

[28] Source for data on the inventory of City-owned assets: City of San Diego Asset Management Program, supervised by City of San Diego Department of Information Technology.

[29] Lifeguard stations can be broken down into permanent and seasonal (i.e., movable) stations. In total, there are 4 permanent stations and 28 seasonal stations. For sea-level rise, there is 1 permanent station and 2-3 seasonal stations exposed in 2030, 1 permanent station and 4-8 seasonal stations exposed in 2050, and 1-2 permanent stations and 13-26 seasonal stations exposed in 2100. For sea-level rise with storm surge, there is 1 permanent station and 9 seasonal stations exposed in 2030, 1-2 permanent stations and 12-16 seasonal stations exposed in 2050, and 3-4 permanent stations and 19-27 seasonal stations exposed in 2100.

	Storm water outfalls (96)	49	63	56–61	71–77	67–79	79–90
	Recreation centers (2)	0	0	0	0	0–1	0–1
	Historic and cultural resources (6 locations)	0	3	1–2	3	2–3	3–5
Non-City assets on granted lands (acres)	Agricultural preserves (2)	1	1-2	1-2	2	2	2
	Not defined (190)	129	129	129	129–142	129– 143	143– 174
	Vacant (25)	3–18	18	18–25	25	25	25

Table 11. Exposure of Other Public Trust Resources on Granted Lands to Erosion by 2100

Resources and Facilities	Asset (total on granted lands)	Cliff Let it Go	Shoreline No Hold, No Nourish	Shoreline No Hold, Continued Nourish
City assets on granted lands (number of assets unless stated otherwise)[30]	Lifeguard stations (32)[31]	2	24	24
	Water pipes (226 segments)	0	24	23
	Wastewater pipes (436 segments)	0	16	16
	Wastewater pumps (23)	0	0	0
	Bridges (6)	0	0	0
	Major Arterials (24 segments)	0	0	0
	Storm water outfalls (96)	5	19	19
	Historic and cultural resources (6)	0	6	5
Non-City assets on granted lands (acres)	Agricultural preserves (2)	0.6	0.6	0.6
	Not defined (190)	0.7	20	20
	Vacant (25)	0.6	25	25

[30] Source for data on the inventory of City-owned assets: City of San Diego Asset Management Program and the City of San Diego Department of Information Technology.

[31] Lifeguard stations can be broken down into permanent and seasonal (i.e., movable) stations. In total, there are 4 permanent stations and 28 seasonal stations. For cliff let it go, there is 1 permanent station and 1 seasonal station exposed. For shoreline no hold, no nourish, there are 3 permanent stations and 21 seasonal stations exposed. For shoreline no hold, continued nourish, there are 3 permanent stations and 21 seasonal stations exposed.