AECOM

Assembly Bill 691 Compliance

City of Long Beach

Submitted June 27, 2019

Table of Contents

Section 1. **Executive Summary**

The City of Long Beach was granted trust over sovereign tide and submerged lands by the State of California in the early 1900s. The City is responsible for reporting to the State Lands Commission on the way in which these lands are managed and stewarded to the benefit of the people of California. In 2013/2014, Assembly Bill No. 691 (AB 691) was enacted, requiring trustees of granted public lands to prepare an assessment of how the local trustee proposes to address sea level rise (SLR) to help proactively plan for future impacts. This report was prepared by the City of Long Beach in response to the criteria outlined by AB 691, which includes, but is not limited to:

- Development of SLR and storm flooding maps;
- Identification of exposed assets,
- Estimates of the financial costs of taking no action to mitigate coastal hazards as well as the costs and benefits conveyed by investments in adaptation; and
- Discussion of strategies that can position the City to protect and preserve assets at-risk to existing and future coastal hazards.

The City of Long Beach is located within San Pedro Bay on the Pacific coast of California. The City's shoreline is a combination of a 5.5 mile stretch of sandy beach along with a fortified shoreline within portions of the sheltered embayments and port. Portions of the City lie at a low elevation and have major industry along the water's edge, notably the Port of Long Beach – the second busiest seaport in the United States – as well as transportation, water, and power infrastructure, beaches, marinas, homes, and businesses. Increases in sea level will elevate the mean sea level baseline, thereby elevating tides, waves, and storm surge. Even a small increase in sea levels will increase the frequency of coastal storm flooding events. The effects of tides, storm waves, and SLR are additive and together combine to cause increased coastal flooding, inundation, and erosion.

The City of Long Beach is in the process of developing a Climate Action and Adaptation Plan (CAAP), a draft of which was released for public review in June 2019. The CAAP is intended to be a comprehensive planning document outlining the City's proposed approach both to address climate impacts to the City and to reduce the City's impact on the climate through reducing greenhouse gas emissions. The vision of the Long Beach CAAP is to create a more sustainable, resilient and equitable city by addressing climate change in a way that addresses existing environmental health disparities while improving health, quality of life, and enhancing economic vitality throughout Long Beach.

Several assessments have been undertaken as part of the CAAP process to better understand community vulnerability to a range of climate stressors, including sea-level rise (SLR) and coastal storms, and to develop and prioritize strategies to address these climate-related risks. These assessments have been conducted in a manner to ensure their relevance and application to AB 691. In addition to the technical assessments that form the basis of the CAAP, adaptation actions were prioritized by soliciting feedback from a Scientific Working Group, a Business Working Group, consultation with other city departments, the Long Beach City Council, and over 9,000 Long Beach residents reached at over 50 CAAP community engagement opportunities between June 2018-June 2019.

A summary of key elements of the analysis undertaken to ensure compliance with AB 691 is provided below.

Developing and Assessing Exposure to SLR and Coastal Storms: Figures 3-7 in this report map out projected SLR and coastal storm impacts for four SLR scenarios (11, 24, 37 and 66 inches) and for smaller sub-areas of the city's coast. The areas of exposure to SLR and coastal flooding in Long Beach were divided into three different geographic areas to support the development of neighborhood or district scale strategies that may help provide protection from SLR and/or coastal storm flooding or build the resilience of multiple assets: (1) Southeastern Subarea, (2) Downtown Subarea, and (3) Western Subarea. Within the Southeastern Subarea, with higher levels of SLR, substantial public infrastructure and public and private property in Belmont Shore, Naples, the Peninsula, and the Marina Pacifica area are projected to experience flooding from high tides, including the beaches and parks that provide active recreation and boating access. In the Downtown Subarea, parts of the Shoreline Marina, Rainbow Harbor, and Golden Shore Marine Reserve are projected to be exposed to future annual king tides. The Western Subarea, which is largely an industrial area, is not anticipated to experience flooding from high tides until end-of-century and the flood pathways would likely come through the Harbor District area.

Estimating the Cost of Inaction: If the City of Long Beach does not take action to mitigate the potential impacts of SLR and coastal storms, the financial costs could be significant. In 2030 and 2050, coastal storms pose greater financial risk to the Long Beach waterfront property compared to gradual tidal inundation from SLR. By 2100, SLR poses greater financial risk to waterfront property compared to the coastal storm impacts that were evaluated. Significant impacts to public trust lands in the City of Long Beach result from impacts to the beaches along the open coast and bays. These impacts result from the gradual rise in sea level, which over time, without any intervention, will result in a reduction in beach width and loss in recreational area available to users. This can result in a loss of beach visitation and associated spending (e.g. sundries, parking, meals) and related fiscal revenues (e.g., sales taxes) as well as a loss in ecosystem services (e.g., recreational value) provided by sandy beach environments. There is also the potential for significant impacts to city property, which can include structures, land, and infrastructure. These impacts are expected to increase significantly after the middle of the century.

Identifying the Costs and Benefits of Adaptation: A number of adaptation actions were identified to improve the ability of the City and its residents and businesses to adapt to climate change and related impacts of flooding due to SLR and intensifying storm events, now and in the future. Strategies were developed for three distinct buckets: (1) Governance; (2) Informational; and (3) Physical / Structural for both the short-term (i.e., present year to 2050) and the long-term (i.e., 2050 to 2100). An analysis of long-term adaptation actions that would collectively help to mitigate the impacts from the modeled coastal hazards, indicates that the benefits of investing in adaptation outweigh the costs of taking no action. Further, the distributed nature of benefits conveyed by adaptation to both public and private assets demonstrate the importance of developing a funding strategy that shares the cost burden for making these critical investments.

Note: To assist in the interpretation of the information presented in this report, supplemental documentation is included in appendices. Some of the information in the appendices has been extracted from other assessments prepared for the CAAP, including a Climate Stressors Review[1], a Climate Change Vulnerability Assessment[2], and an Adaptation Planning and

[1] http://www.longbeach.gov/globalassets/lbds/media-library/documents/caap/long-beach-final-climate-stressor-review-20180827
[2] http://www.longbeach.gov/globalassets/lbds/media-library/documents/caap/long-beach-vulnerability-assessment

Prioritization Strategy[3]. It should be noted that the geographic coverage for the analyses prepared in support of the CAAP are not confined to public trust lands, but account for the larger geographic boundaries of the City.

[3] http://longbeach.gov/globalassets/lbds/media-library/documents/caap/caap-adaptation-actions--draft-released-053119-logos

Section 2. **Sea Level Rise and Coastal Storm Modeling**

This section describes the SLR scenarios and coastal hazard modeling framework that informs the assessment of exposed assets and the financial cost analysis described in Section 3 and Section 4 of this report, respectively.

2.1 **Sea Level Rise Projection Scenarios**

Until recently, the state of California utilized the National Research Council (NRC) 2012 SLR projections as best available science in state policy and guidance. In 2017, a new study was released by Griggs et al. (2017) with updated SLR projections for the California coast. The Griggs study informed the development of the Ocean Protection Council's (OPC) new SLR guidance document that was adopted in March 2018.

OPC developed future SLR projections at each tide station along the California coast. Table 1 presents SLR projections for Los Angeles. The OPC study incorporated a range of global emissions scenarios ranging from aggressive emissions reductions to no emissions reductions through end of century.

Table 1. Sea Level Rise Projections at Los Angeles, CA from OPC (2018)

Year (Emissions Scenario)	Inches Above 1991-2009 Mean Sea Level (in)			
	Median (50% probability of exceedance)	Likely Range (67% percent likely range)	1-In-20 Chance (5% probability of exceedance)	1-In-200 Chance (0.5% probability of exceedance)
2030	4	2 to 6	7	8
2050	8	6 to 12	14	22
2100 (low emissions)	16	8 to 25	36	65
2100 (very high emissions)	26	16 to 38	49	80

Source: OPC (2018)

Not only were the OPC (2018) SLR projections not yet available at the time that the Vulnerability Assessment was undertaken as part of the CAAP, but the SLR projections from NRC (2012) show higher potential SLR for near-term planning horizons (2030 and 2050). Given the differences in projections, it was determined that for the sake of being conservative in developing a plan to preserve life and property, that the more aggressive forecast should be utilized. To understand the implications of a worst-case scenario, and to include a factor of safety, particularly for critical assets, the high-end of the NRC (2012) SLR range was selected for each planning timeframe. This rationale aligns with the State Guidance from the Ocean Protection Council (2011) and California Coastal

Commission (2015). Because there is increased uncertainty (wider ranges of SLR) after 2050, both the projection (mid-range) and high-range magnitudes were selected to guide planning for 2100. In addition, including the mid-range 2100 allows for a range of SLR scenarios to better understand thresholds for exposure of assets or subareas of the City. The City also recognizes the OPC (2018) H++ scenario which estimates a potential for 10 feet of SLR by 2100. Although the likelihood of this scenario is unknown, it is important to consider, particularly for high stakes, long-term decisions, given that the probabilistic projections listed above may underestimate the likelihood of extreme sea-level rise (resulting from loss of the West Antarctic ice sheet), particularly under high emissions scenarios. This potential scenario suggests that the 66 inch SLR projection could happen sooner.

Table 2: Sea Level Rise Projections for Los Angeles, CA from NRC (2012)

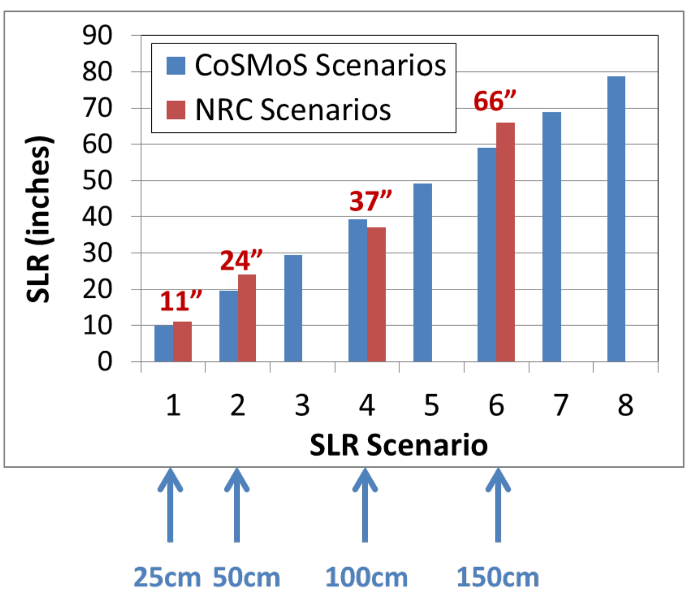
Year	Southern California	
	Projection	Range
2030	5.8 ± 2.0 in	4.6 – 11.8 in
2050	11.2 ± 3.5 in	5.0 – 23.9 in
2100	36.7 ± 9.8 in	17.4 – 65.6 in

Source: NRC (2012)

The following SLR scenarios were adopted for use in the Vulnerability Assessment that was prepared for the City of Long Beach's CAAP. Figure 1 shows how these scenarios (measured in inches) align with the available SLR mapping layers from the U.S. Geological Survey Coastal Storm Modeling System (CoSMoS), which are measured in centimeters.

- 11 inches for year 2030 (high-range) or year 2050 (mid-range) = 25 cm SLR CoSMoS scenario
- 24 inches for year 2050 (high-range) = 50 cm SLR CoSMoS scenario
- 37 inches for year 2100 (mid-range) = 100 cm SLR CoSMoS scenario
- 66 inches for 2100 (high-range) = 150 cm SLR CoSMoS scenario

Figure 1: CoSMoS and NRC Sea Level Rise Scenarios



2.2 Coastal Hazards Mapping

This section describes the coastal hazard mapping and analysis that was used to evaluate the exposure of assets to permanent inundation (daily high tide), frequent temporary flooding (annual king tide), and rare temporary flooding (100-year storm surge).

Daily, Annual, and Extreme Coastal Water Levels

A description of the daily high tide, annual king tide, and 100-year storm surge water levels is provided below:

- **Daily high tide inundation.** There are two high tides each day of unequal height in Long Beach. A commonly used measure of the average high tide is referred to as mean higher high water (MHHW), which is the average elevation of the higher of the two high tides each day. MHHW represents the typical high tide elevation on a daily basis. Areas that are exposed to daily high tide inundation are considered to be "permanently inundated" because of the frequency at which they are flooded (daily).

- **Annual king tide flooding**. King tides are the largest annual tide events and occur several days each year when a spring tide coincides with the moon being in its closest position to the Earth. In Long Beach, king tide events are approximately 1.5 feet above the average daily high tide. They can cause flooding of low-lying coastal areas, particularly if coinciding with a storm event that elevates tides above normal levels. Assets that are exposed to king tide flooding are considered to be "frequently flooded" because they would be temporarily flooded two to three times each year.

- **100-year storm surge flooding.** The 100-year storm surge has a 1-percent chance of occurring in any given year. The 100-year storm surge event includes the effects of the astronomical tide, storm conditions (due to atmospheric pressure and meteorological effects), and precipitation. The influence of temporary flooding caused by wave runup is not included. Assets that are exposed to 100-year storm surge flooding are considered to be "rarely flooded" because they would be temporarily flooded only during very infrequently occurring extreme coastal storm events. The 100-year storm surge elevation is commonly used as an indicator to inform assessments of flood risk and includes the following components in Long Beach:
  - **Sheltered embayments** (such as within Port of Long Beach and Alamitos Bay): inundation extents include high tide and storm surge inundation of the shoreline; runoff from larger watersheds is also included.
  - **Open coast** (such as Long Beach): inundation extents include high tide and storm surge inundation of the shoreline and inundation caused by storm wave conditions (i.e., wave setup); temporary flooding caused by wave runup is not included.

Mapping Layers

Coastal flooding layers from the CoSMoS 3.0 model results in southern California were used to evaluate asset exposure to temporary flooding events by annual king tides and 100-year storm surge events for each SLR scenario (see chapter 2 for more detail). Data layers can be viewed online through the Our Coast our Future[4] data viewer or downloaded through the USGS website.[5]

Inundation due to typical daily high tides (such as mean higher high water, MHHW) was not available from the CoSMoS model output. This data gap was addressed in two ways:

1. Equivalent flood layers available from CoSMoS were used to represent daily tide inundation. For example, the king tide + 100 cm CoSMoS scenario has a water surface elevation very close to the

[4] ourcoastourfuture.org
[5] https://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/

MHHW + 66 inch scenario. Similarly, the king tide + 25 cm CoSMoS scenario is very close to the MHHW + 24 inch scenario. As a result, impact analysis results for these overlapping scenarios can be used interchangeably.

2. Inundation data for the MHHW + 11” scenario was obtained from the National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Viewer because the CoSMoS scenarios did not have a flood layer output that was a close enough match to the MHHW + 11” water surface elevation. NOAA data were used only for the MHHW + 11” scenario.

Table 3 below shows the financial cost analysis scenarios that were evaluated for daily tidal inundation, the water surface elevation that corresponds to each scenario, and the data source used to represent each scenario (either NOAA or CoSMoS). The water surface elevation for each data layer used in the analysis is shown in the table to allow for comparison of the target water surface elevation for the impact analysis and the actual water surface elevation of the model data layer used in the analysis. In general, the selected data layers are within 0.5 feet of the target water surface elevation for each scenario evaluated and are therefore considered a reasonable approximation for estimating exposure impacts attributable to each scenario.

Table 3. Tidal Inundation Scenarios Evaluated

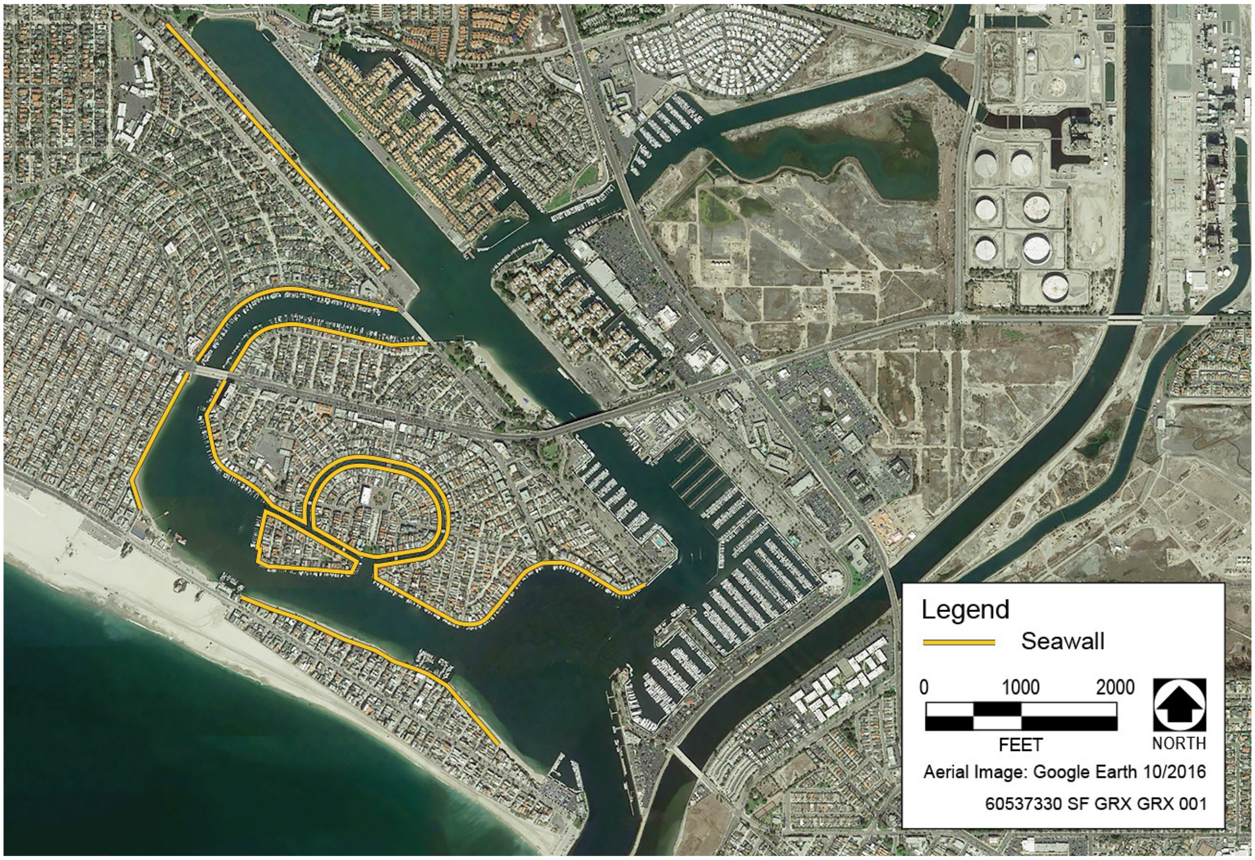
Economic Impact Analysis Scenario	Target Water Surface Elevation (ft NAVD88)	Data Source	Data Source Water Surface Elevation (ft NAVD88)	Difference (ft)
MHHW + 11”	6.2	NOAA: MHHW + 12”	6.3	0.1
MHHW + 24”	7.3	CoSMoS: KT + 25 cm	7.7	0.4
MHHW + 66”	10.8	CoSMoS: KT + 100 cm	10.2	0.6

Note: KT = king tide and MHHW = mean higher high water

Limitations and Inundation Layer Revisions

The annual king tide and 100-year storm surge inundation layers developed by the USGS using the CoSMoS model provide a solid starting point to evaluate existing and future flood risk in Long Beach. It should be noted, however, that small-scale topographic features such as seawalls may not be accurately captured in the flood modeling and mapping. As a result, projected flooding in areas protected by seawalls may be overstated by the CoSMoS model. Areas protected by seawalls include the sheltered shorelines within Alamitos Bay, including Belmont Shore, Naples, and the Peninsula. To help address this issue, the SLR inundation mapping in these areas was modified as part of the Vulnerability Assessment by obtaining topography information on the crest elevation of the seawalls. Crest elevations were estimated by examining Lidar-based elevation data and field measurements of existing seawall heights relative to adjacent ground elevations. Approximate locations for seawalls within Alamitos Bay are shown in Figure 2. This information was used to update the SLR inundation maps to better reflect future flood risk in these areas by comparing the projected future water level scenarios for annual king tide and 100-year storm surge to the seawall elevations and removing low-lying areas of inundation located behind seawalls in cases where the typical elevation of the seawall exceeded the projected water level. Estimated seawall elevations were approximately 8 to 11 ft NAVD88.

Figure 2: Approximate locations of Seawalls within Alamitos Bay



Note: Figure shows location of seawalls that protect low-lying inland areas from flooding and excludes other retaining wall-type features such as bulkheads.

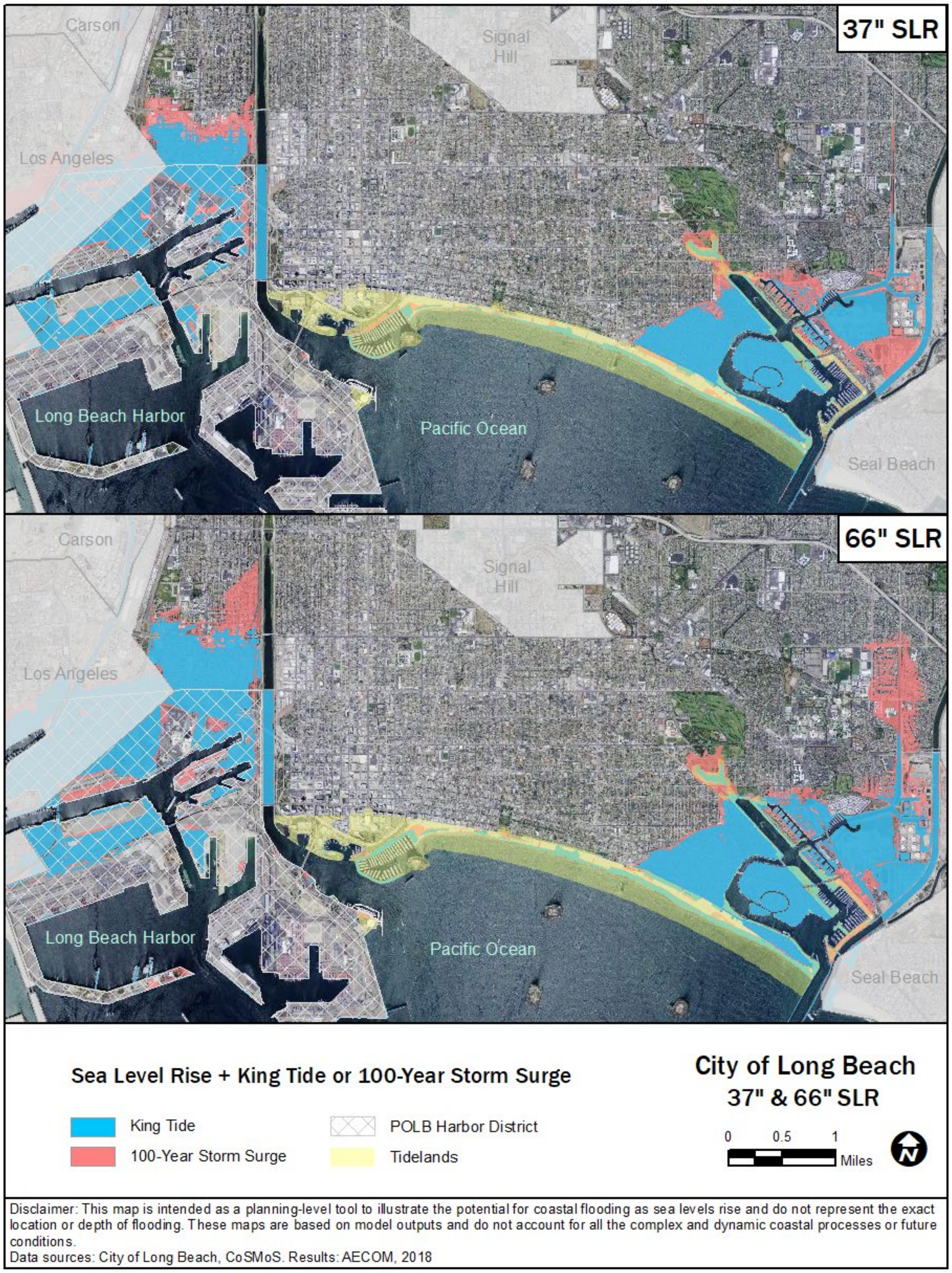
Sea Level Rise Mapping Results

Figure 3 and Figure 4 show the results of the SLR mapping for Long Beach that was used in the exposure assessments described below. The maps show the projected extent of flooding for the King Tide and 100-year storm surge scenarios – both temporary flooding events that could impact Long Beach assets and communities in the near-term. Permanent inundation is not projected to occur within Long Beach until higher amounts of SLR (approximately the 37” SLR scenario) and was therefore not separately mapped in detail since the impacts of temporary flooding will be felt first and addressing these impacts would also address permanent inundation impacts as well. Instead, the analysis showed that King Tide flood extents for the 24” SLR scenario are similar to the permanent inundation extents that would occur for the daily high tide (MHHW) + 37” SLR scenario. Similarly, the King Tide flood extents for the 37” SLR scenario are similar to the permanent inundation extents that would occur for the daily high tide (MHHW) + 66” SLR scenario.

Figure 3: SLR Mapping Results for 11 and 24 Inches of SLR with King Tide and 100-Year Storm

Note: The flooding extents for the King Tide + 24” SLR scenario are similar to the daily high tide (MHHW) + 37” SLR scenario.

Figure 4: SLR Mapping Results for 37 and 66 Inches of SLR with King Tide and 100-Year Storm



Note: The flooding extents for the King Tide + 37” SLR scenario are similar to the daily high tide (MHHW) + 66” SLR scenario.

Section 3. **Exposure Analysis**

This section describes the SLR and coastal storm exposure analysis that was conducted as part of the Vulnerability Assessment prepared for the City's CAAP. The analysis included an assessment of public and private asset exposure for the scenarios listed below:

- 11 inches for year 2030 (high-range) or year 2050 (mid-range) = 25 cm SLR CoSMoS scenario
- 24 inches for year 2050 (high-range) = 50 cm SLR CoSMoS scenario
- 37 inches for year 2100 (mid-range) = 100 cm SLR CoSMoS scenario
- 66 inches for 2100 (high-range) = 150 cm SLR CoSMoS scenario

3.1 Data Collection Process

The first step in the asset inventory was a review of departmental surveys that were conducted as part of the CAAP to understand what assets Long Beach City departments consider critical to providing core services/functions. AECOM reviewed that list and developed an asset data request list for the City departments and collected publicly available data for privately-owned assets, such as electricity assets and buildings. AECOM also reviewed publicly available demographic data for vulnerable populations in Long Beach.

3.2 Sectors and Asset / Population Types

As summarized in Table 4, assets were evaluated for a number of unique sectors as part of the City's CAAP Vulnerability Assessment. Each sector focused on asset types of particular importance in the City.

Table 4: Sectors and Asset Types

Sector	Asset
Buildings and Facilities	City-Owned Buildings, Privately-Owned Buildings
Parks and Open Space	City Parks, Beaches, Wetlands, Marinas
Transportation	Roads, Bike Paths, Bridges
Energy	Substations, Transmission, Generation Facilities, Natural Gas Mains
Wastewater	Pump Stations, Sewer Main, Sewer Forced Main
Stormwater	Storm drain Outfalls, Storm drain Carriers, Stormwater Pump Stations
Potable Water	Potable Facilities, Potable Mains
Public Health*	Vulnerable Populations

Note*: Public health was not evaluated as part of the AB 691 Financial Cost Analysis (see Section 4).

3.3 **Summary Maps**

The areas of exposure to SLR and coastal flooding in Long Beach were divided into three different geographic areas as part of the CAAP Vulnerability Assessment: (1) Southeastern Subarea, (2) Downtown Subarea, and (3) Western Subarea. These subareas were created to support the development of neighborhood or district scale strategies that may help provide flood protection or build the resilience of multiple assets. Figure 5, Figure 6 and Figure 7 show various assets at risk in the defined subareas to temporary flooding due to King Tides with 11, 24, 37, and 66 inches of SLR. The summaries below provide a high-level overview of the areas of flooding and impacts to assets are discussed in greater detail in Appendix B.

Note: The Port of Long Beach has its own climate adaptation plan and has its own governance body and revenue sources. As such, the City's Vulnerability Assessment focused on the parts of the City of Long Beach that are not within the Port of Long Beach Harbor District.

Southeastern Subarea

As can be seen in Figure 5, the areas of darkest blue would be exposed to annual king tides earliest, with 11 inches of SLR. These areas include parts of Marina Pacifica, the Los Cerritos Wetlands Complex, and the Alamitos Bay shoreline of the Peninsula. There are no major roads exposed during the 11 inch scenario, but the Bayshore Walk along the Peninsula is exposed. With higher levels of SLR, substantial public infrastructure and public and private property in Belmont Shore, Naples, the Peninsula, and the Marina Pacifica area are projected to experience king tide flooding, including the beaches and parks that provide active recreation and boating access. Beginning under the 37 inch scenario, widespread daily high tide flooding is projected. Assets in this area that could be subject to risk include sewer and force mains, multiple pump stations, a solid waste facility, a fire station, the Belmont Shore Library, the Naples Bayside Academy, portions of Belmont Plaza, and other parks and recreation open spaces and marine facilities such as Marine Stadium, Leeway Sailing Center, Bayshore Playground, and Jack Nichol, and Rosie's Dog Beach.

Downtown Subarea

As can be seen in Figure 6, in the Downtown Subarea, parts of the Shoreline Marina, Rainbow Harbor, and Golden Shore Marine Reserve are projected to be exposed to future annual king tides. The Golden Shore Marine Reserve is projected to be flooded by king tides combined with 11 inches of SLR. The edges of the Marina and Harbor start to experience king tide flooding at 11 inches and with higher levels of SLR, the pedestrian paths and parks also flood. Alamitos Beach also experiences king tide flooding, resulting in a narrowing of the beach, particularly with higher levels of SLR. Assets in this area that may be impacted include the Aquarium of the Pacific, the bike path around Shoreline Marina, and the sewer lift stations associated with the comfort stations around the Marina.

Western Subarea

As can be seen in Figure 7, the Western Subarea, which is largely an industrial area, is not anticipated to experience flooding due to king tides until end-of-century (37 and 66 inches of SLR) and the flood pathways would likely come through the Harbor District area. Adaptation efforts by the Harbor District may provide flood protection benefits for West Long Beach, and on-going coordination between the Harbor District and City of Long Beach is recommended. Assets in West Long Beach that are at-risk include a potable water facility, two police facilities, and a Health Resource Center serving individuals experiencing homelessness. Within the Harbor District, there are also two potable facilities, a solid waste facility, and multiple fire stations.

Note: In Figure 5 through Figure 7, only a subset of the assets evaluated in the City's CAAP Vulnerability Assessment as well as the AB 691 analysis are shown.

Citywide Social Vulnerability

The Climate-Smart Cities Los Angeles Project, with a Technical Advisory Team that included public health experts, local academic and research institutions, and community leaders developed a GIS decision support tool that includes a social vulnerability index comprised of ten indicators. This index is based primarily on the

Environmental Protection Agency's EJSCREEN definition of demographic factors that indicate a community's potential susceptibility to environmental stressors, which include: people of color, low income, educational attainment less than a high school degree, linguistic isolation, population under 5, and population over 64. The index includes three additional characteristics, which were added based on recommendations from the Technical Advisory Team: unemployment, asthma, and low birth weight. Figure 8 shows the result of this index for Long Beach, demonstrating higher levels of indicators of social vulnerability in Central, West, and North Long Beach. As shown in Figure 8, portions within the western and southeastern sea level rise sub-areas include sensitive populations with social vulnerabilities to the impacts of climate change. For example, the Western subarea includes low income communities of color with limited means for protecting themselves and their property from flooding impacts. The Southeastern portion of Long Beach, which is susceptible to coastal and riverine flooding, has a higher share of residents over the age of 65 than other parts of the City. Elderly people may be less able to evacuate and at higher risk of exacerbation of exiting health conditions as a result of a flooding.

Figure 5: Exposure to SLR in the Southeastern Subarea

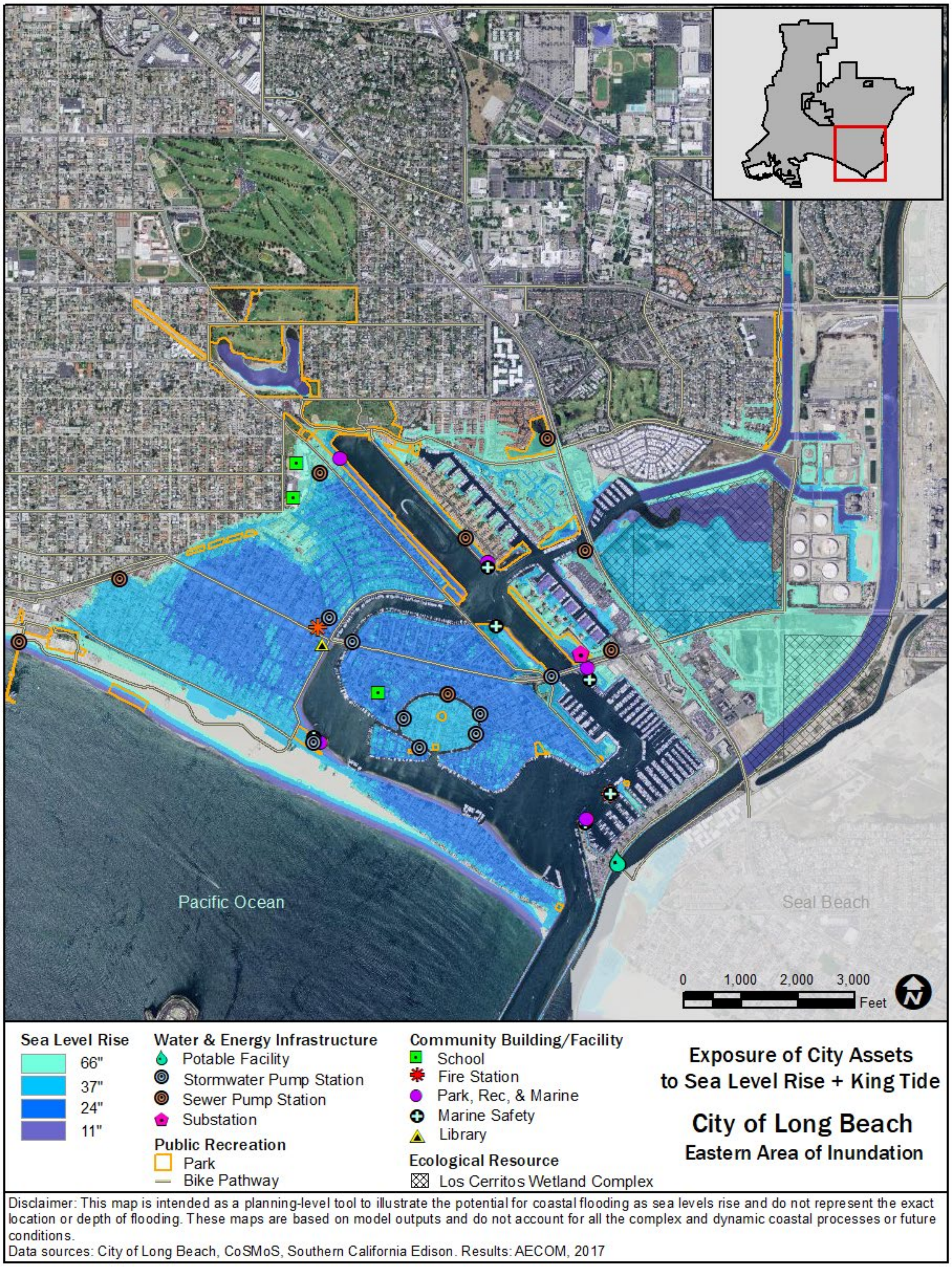


Figure 6: Exposure to SLR in the Downtown Subarea

Figure 7: Exposure to SLR in the Western Subarea

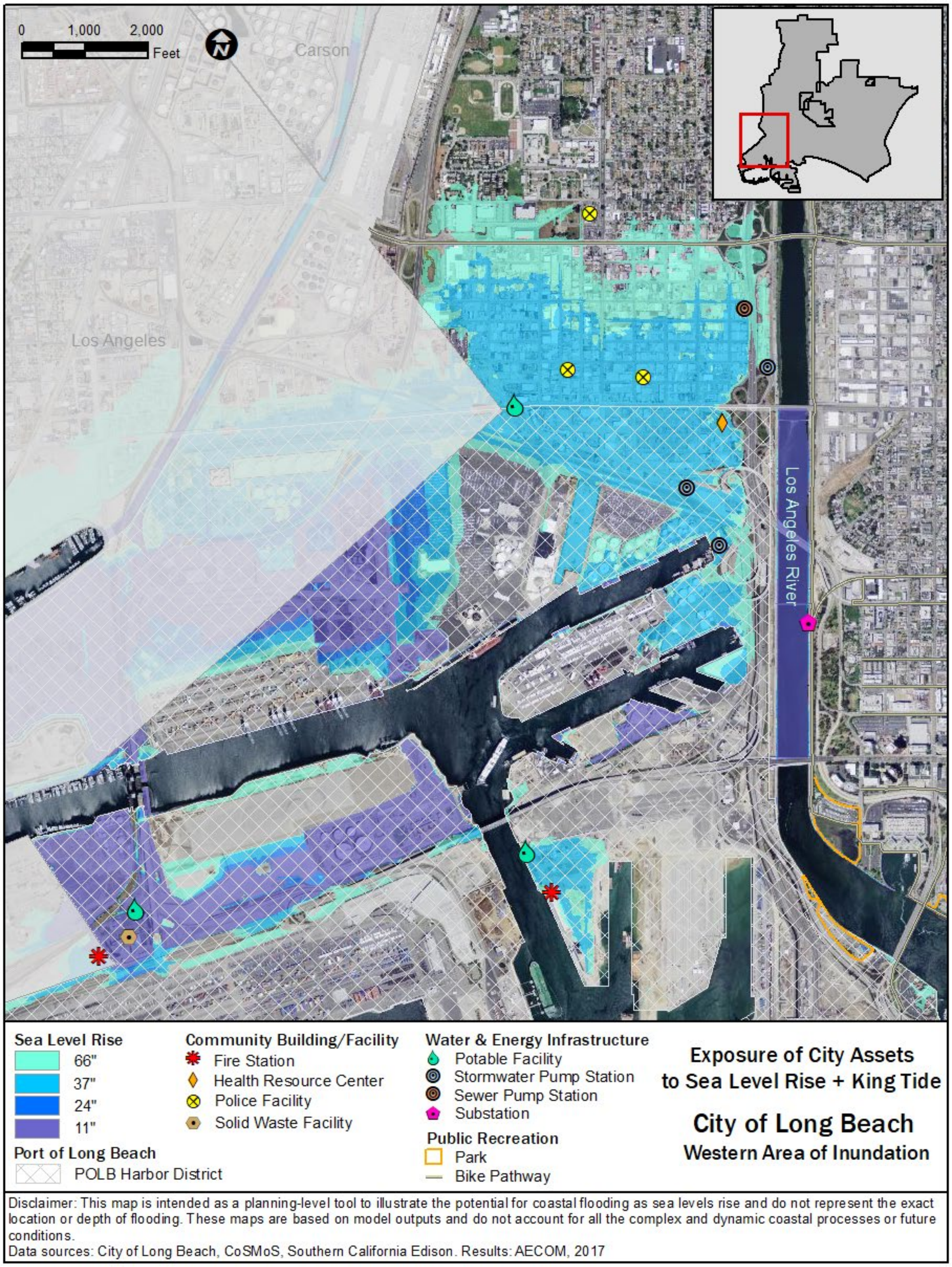
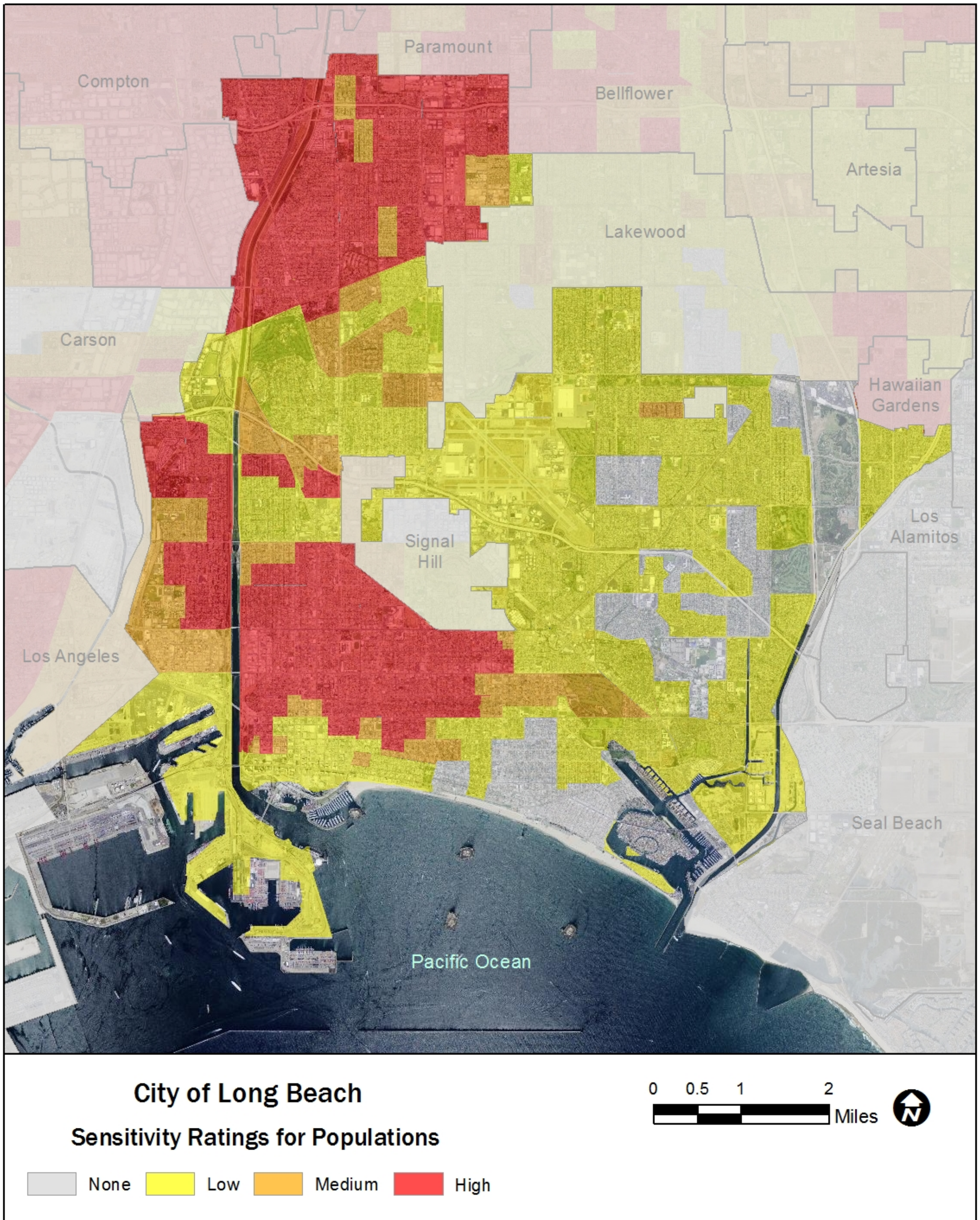


Figure 8. Indicators of Social Vulnerability



Disclaimer: The Sensitivity Ratings for Populations Map and the associated analyses are intended as planning level tools to illustrate populations that have high sensitivity to climate stressors.
Data source: Climate Smart Cities Los Angeles Results; AECOM, 2017

Section 4. **Financial Cost Analysis**

This section provides an overview of the analysis undertaken to develop high-level (rough order of magnitude) estimates of the financial costs of taking no action to mitigate coastal storm and SLR impacts as well as the anticipated costs of adaptation actions and the potential benefits conveyed by such investments. Additional discussion and analysis are included on non-market values that may be impacted under future coastal hazard conditions. More detailed results from this analysis can be found in Appendix C.

4.1 Financial Cost Methodology

The scope of the financial costs analysis is informed by considerations that include, but are not limited to, the type and number of impacts being considered, time and resources, data quality and availability, and programmatic policies. This analysis is focused on a broad but standard set of financial cost categories[6] that are often considered in natural hazard risk assessments. Because this analysis assumes that different types of financial consequences are expected from temporary event-based storm flooding compared to permanent progressive tidal inundation from SLR, separate assessment methodologies and categories of impacts were evaluated in some cases. The financial cost categories for tidal inundation and coastal storms and impacts evaluated in this analysis are listed in Table 5 below.

Table 5. Financial Cost Categories

Cost Category	Tidal Inundation (MHHW) Financial Cost Type	Coastal Storm Event Financial Cost Type
Direct Property	Market value loss	Structure repair cost
Business and Employment	Sales loss Wage loss	Sales loss Wage loss
Fiscal	Sales tax loss Property tax loss Transient occupancy tax loss	Sales tax loss Property tax loss
Non-Market	Recreational value loss	Not applicable
Public Infrastructure[7]	Replacement costs	Replacement costs

[6] In this analysis, the concept of financial costs broadly includes both economic and fiscal impacts.
[7] Infrastructure impacts could also be considered a form of fiscal impact but have been reported separately in this analysis.

The methodologies used in this analysis primarily draw upon technical guidance documents and other economic and planning memoranda developed by federal agencies such as the Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA). Much of this technical guidance and memoranda have been developed by federal agencies to support the considerations of benefits and costs relevant to decision-making around infrastructure investments, including actions designed to mitigate the risks from natural hazards. The asset inventory, vulnerability profiles, and adaptation actions developed for the City of Long Beach CAAP were used to develop order of magnitude financial cost estimates for the impact categories evaluated. These high-level estimates were informed by a series of assumptions and/or key considerations, as described in Table 6 below.

Table 6. Financial Cost Analysis Key Concepts

Key Concept	Description
Assignment of Temporary vs. Permanent Impacts	This analysis assigns temporary impacts to assets that are exposed to flooding from coastal storms and assigns permanent impacts to assets that are exposed to tidal inundation from SLR. This distinction is relevant to the cumulative impacts that could occur in the future and the potential timing of investments in adaptation.
One-time vs. Recurring Impacts	Permanent progressive impacts from tidal inundation can include both one-time losses as well as recurring annual losses. In this analysis, a one-time loss relates to the market value or real property value at risk, whereas a recurring annual loss captures the output (e.g., wages) and fiscal revenues (e.g., taxes) associated with vulnerable assets.
Primary vs. Secondary Impacts	The analysis focuses on primary or direct impacts, rather than secondary or indirect and induced impacts, that can occur from changes in economic activity. For example, business and employment impacts reflect effects to firms that operate along the Long Beach waterfront and do not include effects to suppliers of these firms.
Geography of Impacts	This analysis is focused on evaluating financial impacts to the City of Long Beach and the State of California, though there are additional regional impacts that could be expected that are not explicitly analyzed or reported.
Static Built Environment	This analysis superimposes potential future physical conditions on the existing built environment. While it is likely that the built environment in the City of Long Beach will undergo changes between the present year and the end year of analysis in 2100, modeling such changes was beyond the scope of this analysis.

4.2 Non-Market Values

Economic value, which includes “non-market” value, is distinct from the concept of economic impacts. Economic value measures the net value that a resource provides to society and is comprised of both use and non-use values. Economic impacts measure the flow of spending through an economy and the associated jobs and wages, among other items, associated with this spending.

Future coastal hazards pose a broad range of economic risks to coastal communities. Generally, these risks are estimated with the market value of goods and services where market prices are available, allowing for the measurement of economic vulnerability in a relatively straightforward manner. However, coastal environments, including public trust lands like beaches and wetlands that are vulnerable to SLR, provide a number of important ecological, social and cultural services that do not have an explicit market price, but do have economic value. Economists have devised a number of nuanced techniques to estimate “non-market” values of coastal resources. These methods, which generally require extensive study, can help illustrate additional economic values that are relevant to consider when making investments in adaptation and can help to illustrate the manner in which such actions can result in tradeoffs in the built and natural environment.

Much study has been dedicated to identifying direct recreational use values provided by coastal environments. To do this, economists often use techniques to estimate consumer surplus, which accounts for the difference between what a consumer pays for a resource compared to what they are willing to pay for that resource. While coastal environments provide additional indirect use values (e.g., ecological services), as well as non-use values (e.g., cultural), there is less agreement on how to measure these values. For the purpose of this analysis, non-market impacts were limited to beach recreation where credible and transferrable use values were available.

The City's beaches are recreational areas that provide significant economic value to users and contribute to spending in the local, regional, and state economy. If no action is taken, the gradual rise in sea level over time will result in permanent inundation and narrowing of the City's beaches. As documented in the academic and management literature, the narrowing or eroding of beaches can result in less visitation and loss of associated expenditures on items like sundries, parking, food and lodging, as well as less utility or economic value to visitors resulting from preferences related to the beach width and crowding.

Non-market recreational value and economic impacts tied to beach visitation were estimated for the City's beaches using standard methodologies that have been broadly applied in California. In particular, estimates of impact were informed using the benefits-transfer framework that underpins the Coastal Sediment Benefits Analysis Tool (developed for the USACE and State of California) as well as published beach visitor recreational values (CCC 2015), spending profiles (King and Symes 2001), and annual visitation levels recorded by the City's Fire Department lifeguards (CLB 2017).

4.3 Additional Financial Costs

This analysis was focused on financial costs that are expected to be of greatest magnitude and/or are commonly evaluated in an assessment of this type. However, there are additional financial consequences that could be expected which were not monetized due to resource constraints. These impacts include, but are not limited to, utility services, traffic and transit services, and public and essential services impacts. Collectively, these services support businesses continuity, the movement of goods and people, as well as the ability to respond to and meet critical community needs in the face of disaster.

Additionally, the Long Beach waterfront hosts several marinas and parking facilities that provide recreational opportunities and access to the coast and generate significant economic and fiscal impacts to the region and state based on revenue generation exceeding $22 million per year. The City's beaches and shoreline parking lots are most threatened by permanent impacts from tidal inundation following a rise in sea level while the City's marinas are most vulnerable to future coastal storms.

Also relevant, in the event that actions are not taken to mitigate impacts from future coastal hazards, there could be less demand for lease agreements that provide significant revenues to the City of Long Beach, most notably the Tidelands Capital Improvement Division.

4.4 Physical Scenarios Evaluated

The hazard scenarios used to account for potential future impacts in 2030, 2050 and 2100 are listed in Table 7 below. These scenarios mirror three of the four coastal storm scenarios described in Section 2 for the purpose of the City's Vulnerability Assessment; for this financial cost analysis, only the higher 2100 SLR scenario was evaluated. For the tidal inundation impacts, this analysis was focused on MHHW, rather than a King Tide (see Section 2.2 "Mapping Layers"). The hazard maps used to delineate exposed assets were extracted from the USGS CoSMoS model as well as the National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Viewer.

Table 7. Physical Scenarios

Time Horizon	Tidal Inundation Impacts (MHHW)	Coastal Storm Impacts
2030	~11 inches of SLR	100-year coastal storm + King Tide + ~11 inches of SLR

2050	~24 inches of SLR	100-year coastal storm + King Tide + ~24 inches of SLR
2100	~66 inches of SLR	100-year coastal storm + King Tide + ~66 inches of SLR

4.5 **Cost of Inaction Summary Results**

Summary results for the cost of inaction for each of the three time horizons are presented in Table 8 below. The results are illustrative of the impacts that could be expected if the tidal inundation and storm flooding conditions modeled in 2030, 2050 and 2100 were to occur today in the City of Long Beach; this is essentially the superimposition of future physical conditions on the existing built environment and economic activity it supports.

Tidal inundation impacts from SLR are considered permanent in terms of their financial impact and will result in one-time direct property impacts and annual recurring business and employment and fiscal impacts. The additional impacts from storm flooding represent the losses from a single storm and are not adjusted for the probability of the storm occurring. Results are organized to prevent double counting any losses. For example, if there is exposure to future tidal inundation from SLR, the loss is accounted for in tidal impacts and not accounted for when estimating storm impacts, even if that same parcel or asset may be exposed to storm conditions simultaneously.

All results are presented in 2018 dollars, and no adjustments have been made to account for future price inflation, cost escalation or financial discounting. It is important to note that results reflect discrete outcomes in future years and do not account for cumulative impacts that could occur from 2030 to 2100.[8] Additionally, the results from the various impact types are not added together in a deterministic fashion as some of the results reflect estimated impacts while others reflect the amount of exposure (when estimating the degree of impacts was not feasible).

Table 8. Summary of Future Year Financial Cost Analysis Results (2018 Dollars)

SUMMARY OF ONE-TIME STORM FLOODING AND TIDAL INUNDATION IMPACTS						
Impact/Exposure Type	**2030 Conditions** *~11" of SLR*		**2050 Conditions** *~24" of SLR*		**2100 Conditions** *~66" of SLR*	
	Daily Tidal Exposure	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**
Direct Property Impact	$0	$2,400,000	$0	$4,400,000	$69,900,000	$19,600,000
Business and Employment Impacts	*$0*	$41,000	*$0*	$50,000	*$3,600,000*	$1,300,000
Fiscal Impacts	*$750,000*	$31,000	*$3,300,000*	$57,000	*$5,900,000*	$230,000
Non-Market Impacts	*$12,000,000*	Not Applicable	*$48,900,000*	Not Applicable	*$74,100,000*	Not Applicable
Public Infrastructure Exposure	$1,500,000 - $4,700,000	$21,500,000 - $82,000,000	$4,200,000 - $12,000,000	$36,400,000 - $175,700,000	$36,800,000 - $181,200,000	$32,600,000 - $123,700,000

Notes:
Direct property impacts exclude parcels with no structures.
Fiscal impacts include losses tied to spending by beach recreational users.
Infrastructure shows the full replacement cost values for a similar asset in the same location; no determination is made on the degree of impact. Low and high costs were included to present a range.
Italicized text represents losses that would recur annually from permanent impacts.

[8] Results have been rounded.

Table 8 shows the summary of impacts to property, business and employment, fiscal revenues, non-market resources, and public infrastructure for the years evaluated. Impacts were modeled at the asset or parcel level and then aggregated to the City level. Results in Table 8 indicate that future coastal storms pose greater financial risk to the Long Beach waterfront property compared to gradual tidal inundation from SLR in 2030 and 2050. By 2100, tidal inundation from a rise in sea level of 66-inches poses the more significant financial risk than additional impacts from a 100-year coastal storm.

Significant impacts to public trust lands in the City of Long Beach result from impacts to the beaches along the open coast and bays. These permanent impacts result from the gradual rise in sea level, which over time without any intervention will result in a reduction in beach width and loss in total recreational area available to users. As the beach narrows, fewer people are assumed to visit the beach, resulting in a loss of non-market value (beach recreational value) as well as decreased spending and fiscal revenues tied to beach visitor spending on items like food, gas, parking and lodging. Single-year non-market value losses for the City's beaches are estimated at over $10 million by 2030, and nearly $50 million and $75 million by 2050 and 2100, respectively. Further, a majority of the reported fiscal impacts are tied to beach recreational spending losses. These results demonstrate the importance of considering impacts in the formulation of adaptation actions not only to the built environment, but to the natural resources that support economic and fiscal benefits to the City of Long Beach and the State of California.

The second most significant category of impact is to direct property, which can include real property (i.e., structures) as well as the land upon which structures are built. Properties that intersect with public trust lands are not expected to be vulnerable to tidal inundation from SLR in 2030 or 2050. Storm impacts to direct property were estimated at $2.4 million in 2030 and $4.4 million in 2050. By 2100, a tipping point is reached where tidal inundation impacts significantly exceed storm impacts. An estimated nearly $70 million in property is impacted by tidal inundation from SLR, with an additional $20 million of impacts estimated for a 100-year storm event.

Fiscal impacts, which result from both direct property and business and employment impacts, represent the third largest category of impact. Most of these impacts are associated with tidal inundation from SLR and are considered permanent as they permanently change how property and associated economic activity can occur. As such, these impacts are expected to occur annually, and as sea level continues to rise from 2030 through 2100, these impacts would likely increase annually as well (but not necessarily in a linear manner). As mentioned above, lost spending from beach recreational users drives much of these losses. Fiscal impacts (including the byproduct of beach visitor spending) from tidal inundation range from $750 thousand in 2030 to nearly $6 million in 2100. Storm-induced fiscal impacts are much lower, ranging from $31 thousand in 2030 to $230 thousand in 2100. While these impacts are less than those reported for both non-market and direct property impacts, they are of special relevance to the City of Long Beach and the State of California in that they are estimates of annual losses of revenues that could be used for a variety of purposes, including funding adaptation.

The combined impacts to business and employment from both future tidal inundation and a 100-year storm are estimated to be lowest in magnitude relative to the other cost categories studied. Tidal inundation impacts, similar to those reported for fiscal impacts, are assumed to recur annually due to the permanent lost use of property that supports this economic activity. Impacts from tidal inundation, which are not expected to occur under the 2030 or 2050 scenarios, were estimated at $3.6 million in 2100. Business and employment impacts from storms are expected to occur in each scenario, ranging from approximately $40 thousand in 2030 to $1.3 million in 2100.

The infrastructure values reported in Table 8 are significant but should be considered differently from the other financial cost results reported. These values represent the full replacement cost of the respective assets that intersect with the modeled hazard scenarios. Making a determination on the extent of impact or the amount of the full replacement cost that could incur damage was beyond the scope of this analysis; these special use assets have distinct, site-specific damage thresholds that would need to be evaluated in a feasibility-level analysis. For storm-induced impacts, it is likely that the potential impacts that could be expected may be less than the full replacement costs listed. For future tidal inundation, impacts could be greater than those reported if these assets need to be relocated or permitted, and/or incur additional real estate costs. As shown in Table 8, the value of infrastructure assets exposed to a 100-year storm is far greater in magnitude in 2030 and 2050 than assets vulnerable to tidal inundation. Storm exposure ranges from a low-end estimate of nearly $22 million in 2030 to a high-end estimate of nearly $176 million in 2050. Tidal exposure ranges from a low-end estimate of $1.5 million in 2030 to a high-end estimate of $12 million in 2050. By 2100, tidal exposure is of greatest magnitude, ranging from approximately $37 million to over $181 million, with an additional $33 to $124 million of infrastructure assets exposed to a 100-year storm.

4.6 Adaptation Actions Costs and Benefits

An analysis was undertaken to develop rough order of magnitude costs for a subset of SLR and storm flooding adaptation actions identified in the City's CAAP[9]. The selected actions were informed with input from the project team as well as from feedback from community stakeholders. These investments relate to longer-term (2050 to 2100) physical / structural actions that are commonly evaluated in the academic and management literature, including both building-level adaptation and broader systemic adaptation to keep rising seas at bay.

Additional consideration is made related to the cost-effectiveness of such investments by qualitatively comparing the costs of adaptation to the benefits conveyed by such actions. To allow for a more streamlined comparison of adaption costs and benefits, the actions were scaled to mitigate or neutralize the full extent of damages that were identified in Table 8 for projected SLR and storm scenarios between 2050 and 2100. Additional considerations related to social vulnerability, equity and partnerships as they relate to the adaptation actions can be found in Section 5.

Cost Estimating Considerations

Adaptation actions were costed using standard engineering principles, including an evaluation of relevant academic and management studies that were conducted in Southern California (e.g., Aerts et al. 2018, FEMA 2014). The order of magnitude cost estimates account for soft and hard cost components and contingencies as shown in Table 9.

Table 9. Adaptation Actions Cost Components

Cost Component	Description
Direct Costs	This includes all labor, equipment usage, permanent and temporary materials, erosion/water pollution control, and spill prevention plans.
Mobilization	This includes cost allowances for mobilization/demobilization to the project site and setup of temporary facilities and utilities; assumed to be 10% of the direct cost.
Contractor's Markup	This includes costs for site general conditions, job supervision, contractor's office overhead, profit, and bonds. This is assumed to be 25% of the direct cost.
Design Engineering and Permit Fees	A 15% allowance for engineering design fees and environmental permitting and clearance requirements.
Design Contingency	A 25% allowance for project design development during the design and construction phases of the project as more current and updated information for the project and site conditions are obtained.
Construction Contingency	A 10% allowance for changes during the construction phase for possible unforeseen conditions, schedule delays, and project change orders.
Contract Administration	A 30% allowance for contract administration and staff time to oversee the design, permitting, and construction phases.

[9] The full list of the CAAP coastal-related adaptation actions and supporting descriptions can be found in Section 5.

A total of 7 long-term adaptation actions were costed. Table 10 below includes a brief description of the action, including the location of relevance, summary information on the quantities estimated and low- and high-end cost estimates. Figure 9 below illustrates the location of the long-term actions.

Figure 9. Locations of Potential Long-Term Adaptation Actions

The full suite of long-term adaptation actions is not designed to be a collective protection system. As shown in Figure 10 below, many of the actions overlap in the areas they protect, which can serve as redundant protection if more than one overlapping action is implemented. Alternatively, one of the two overlapping actions could be chosen to provide a single source of flood protection for the specific stretch of shoreline. The following proposed actions offer redundant protection:

- Construction of a living shoreline or berm (FLD-14) provides flood protection along the backside of Mothers Beach; however, continued beach nourishment of the beach area (FLD-13) may also provide a buffer from future storm and flood impacts.
- Extending the curb along Bayshore Drive (FLD-15) prevents flood pathways from Alamitos Bay to the Western shore neighborhoods of Belmont Shore and Belmont Park. Elevating Bayshore Drive (FLD-16) will also provide protection for these areas. Continued beach nourishment of Belmont Shore (FLD-13) may also provide a buffer from future storm and flood impacts, particularly south of the East 2nd St Bridge.
- Enhancement of the wall along E. Paoli Way (FLD-17) to be designed for flood protection may protect transportation routes and infrastructure located behind the road. Alternatively, E. Paoli Way could be elevated (FLD-16) to provide the same level of flood protection.
- Extension of sheet pile walls (FLD-19) along Naples and Treasure Island may provide local flood protection for the islands. Elevating the East Corso Di Napoli, North Sea Isle Drive, and pathway near the Long Beach Yacht Club, as a part of the larger effort to elevate waterfront streets and pathways (FLD-16) would also provide protection for the inland neighborhoods on the islands.

Figure 10. Long-Term Adaptation Actions in Alamitos Bay

Table 10. Long-Term Adaptation Action Costs

Action	Action Description	3 Feet of Sea Level Rise + 100-Year Storm			5.5 Feet of Sea Level Rise + 100-Year Storm		
		Action Quantities	Action Assumptions / Considerations	Action Costs**	Action Quantities	Action Assumptions / Considerations	Action Costs**
Continue to nourish beaches	Based on findings from a beach stabilization study, beaches identified as suitable could be nourished so that they are elevated and preserved	4,252,000 cubic yards	Assumed 1 sf:1 cy ratio of beach area eroded to nourishment volume Volume allotment increase of 40% for spreading / winnowing	$55,281,000 to $97,806,000	2,184,000 cubic yards	Assumed 1 sf:1 cy ratio of beach area eroded to nourishment volume Volume allotment increase of 40% for spreading / winnowing	$28,394,000 to $50,236,000
Construct living shoreline / berm	The shoreline at Mother's Beach could be elevated to tie in with the landscape and park facilities to prevent flooding of inland areas while continuing to provide beach access	1,700 ft	3.5 ft high, 10:1 slope Includes 1 ft of freeboard	$350,000 to $430,000	1,700 ft	+2.5 ft higher, 10:1 slope	$550,000 to $680,000
Elevate / extend curb	The curb at Bay Shore Drive in Alamitos Bay could be elevated and extended to eliminate gaps that could become flood pathways	3,750 ft	5 ft high, 15 ft deep Includes 1 ft of freeboard Assumes a new wall required (could be assessed with further analysis)	$12,900,000 to $15,740,000	3,750 ft	+2.5 ft higher	$1,520,000 to $1,850,000
Elevate streets / pathways	Waterfront streets and paths could be elevated in communities adjacent to Alamitos Bay to provide protected transportation routes and flood protection for infrastructure behind the road/path	33,200 ft	6 ft high, 30 ft wide Includes 1 ft of freeboard	$28,630,000 to $34,990,000	33,200 ft	+2.5 ft higher	$19,420,000 to $23,740,000
Retrofit / extend walls	The existing wall at E. Paoli Way near the Marine Stadium may currently provide some flood protection, but it is segmented and not designed for flood protection. It could be retrofitted or rebuilt to provide protection	3,660 ft	5.5 ft high, 16 ft deep Includes 1 ft of freeboard	$13,440,000 to $16,430,000	3,660 ft	+2.5 ft higher	$1,480,000 to $1,810,000
Extend / upgrade existing seawalls	Sheet pile seawalls could be expanded to other areas of the Naples shoreline that are not being addressed by the current upgrade such as Treasure Island and areas to the east and north of the Yacht Club	5,200 ft	5.5 ft high, 16 ft deep Includes 1 ft of freeboard	$19,090,000 to $23,330,000	5,200 ft	+2.5 ft higher	$2,100,000 to $2,570,000

Action	Action Description	3 Feet of Sea Level Rise + 100-Year Storm			5.5 Feet of Sea Level Rise + 100-Year Storm		
		Action Quantities	Action Assumptions / Considerations	Action Costs**	Action Quantities	Action Assumptions / Considerations	Action Costs**
Elevate / floodproof buildings*	Buildings subject to storm flooding could be elevated, dry floodproofed to keep water coming in and/or wet floodproofed to protect from water that enters a lower level	281 building units in Tidelands (2,151 building units citywide)	Prioritized for elevate, then dry floodproof, then wet floodproof Includes 1 ft of freeboard	$15,616,000 in Tidelands ($116,596,000 citywide)	178 building units in Tidelands (1,389 building units citywide)	Prioritized for elevate, then dry floodproof, then wet floodproof Includes 1 ft of freeboard	$10,405,000 in Tidelands ($77,810,000 citywide)

Notes:
***** Building-level actions are presented both for the Tidelands and citywide. Protecting only buildings within the Tidelands will not avoid all damages presented in section 4.5, such as fiscal losses to the city from property taxes due to damages on privately-owned parcels. Building quantities reported as unique units. Though it is possible there are several units within a building,) each unit was costed as though it were a stand-alone building; these costs are likely therefore a conservative (high-end) estimate..
****** Except for elevate / floodproof buildings, costs to adapt to 5.5 feet of SLR are in addition to the costs to adapt to 3 feet of SLR. For elevate / floodproof buildings, the full cost is shown for the buildings requiring elevation or floodproofing under 5.5 feet of SLR + 100 -year storm; the building number and cost for this higher scenario is lower than it is for 3 feet of SLR + 100-year storm as it excludes buildings subject to daily tidal inundation.

Cost-Effectiveness Considerations

Conceptually, an investment is considered economically justified or cost-effective if the total costs are equal to or less than the total benefits provided. In the context of this analysis, cost-effectiveness could be determined by comparing the cost of one or more of the identified adaptation actions to the benefits conveyed by these investments. However, there are additional analysis steps that would be required to determine the cost-effectiveness of the proposed adaptation actions, including but not limited to: accounting for the probability of the modeled events occurring in each year of the analysis period, identifying the timing for project construction and the duration or useful life of the project elements, determining the effectiveness of a project's ability to mitigate impacts, and adjusting impacts to account for the time value of money using financial discounting techniques. These modeling exercises, which would be undertaken as part of a larger scale engineering feasibility analysis, were beyond the scope of this analysis. Additionally, further analysis would be required to understand what specific assets are protected by proposed adaptation actions. This additional analysis is necessary as some of the proposed adaptation actions overlap and provide redundant benefits; they also provide additional protection and/or benefits that would be conveyed to assets that are outside of the tidelands boundary, and, as a result, are not captured in the cost of inaction results summarized in Section 4.5.

Given the noted limitations to assessing cost-effectiveness, a simplified exercise was undertaken to compare the snapshot or event-based impacts for the longer-term modeled scenarios to the estimated one-time adaptation costs. As discussed, the adaptation actions were scaled to mitigate or neutralize the full extent of impacts for the longer-term scenarios, resulting in the benefits of adaptation, at a minimum, being equivalent to the estimated cost of inaction shown in Table 8 (since the cumulative impacts are not fully accounted for). It should be noted that while this approach does not allow for a deterministic comparison of cumulative costs to cumulative benefits, the findings can be an indicator of what actions may be economically justified. For the purpose of simplification, adaptation actions that provide clear, separable benefits are discussed independently (in this case nourishment and the elevation/floodproofing of structures), while the remainder of the actions are evaluated collectively given their overlapping protective benefits and the related difficulty of separating out these benefits.

The costing analysis shows that nourishing beaches comes with the highest total price tag. The cost to mitigate shoreline erosion impacts for up to 3 feet of SLR were estimated between $55 and $98 million. An additional $28 to $50 million was estimated to mitigate impacts for up to 5.5 feet of SLR. While there are significant costs to nourishing the City's beaches to keep pace with SLR, the non-market and associated beach spending impacts for a single year under 5.5 feet of SLR were estimated at over $200 million (see Appendix C, Table 30). This indicates that there could be an economic case to nourish beaches in the future. Given that beaches provide economic value to visitors who reside outside of the City, as well as economic and fiscal impacts to the region and the State, a collaborative funding approach should be considered. Maintained access to beaches will also be an important adaptation measure in addressing extreme heat, the climate stressor projected to have the greatest health impacts to the largest number of Long Beach residents.

The elevating and/or floodproofing of buildings was the second most costly adaptation action evaluated. The costs for this action were not calculated in an incremental manner similar to the other adaptation actions, rather they were evaluated based on the costs expected for the properties with structures that are vulnerable to flooding with 3 feet or 5.5 feet of SLR combined with a 100-year storm. Costs include properties that are outside of the tidelands boundary. The reason that estimated costs are greater for the 3 foot SLR scenario compared to the 5.5 foot scenario relates to the modeling approach, which excludes the application of elevating or floodproofing structures that are subject to daily tidal inundation. In effect, some of the properties that are subject to storm flooding under the 3 foot SLR scenario become vulnerable to daily tidal inundation in the 5.5 foot SLR scenario, resulting in them being excluded in the adaptation costs for the higher SLR scenario. Based on modeled results, an investment cost of $117 million is needed to provide protection from the 3 foot SLR and 100-year storm scenario, and $78 million for the 5.5 foot SLR and 100-year storm scenario. The benefit of protection from the lower SLR scenario was estimated at over $500 million and the benefit from the higher SLR scenario was estimated at over $250 million. This benefit is based on a single-storm event of similar magnitude occurring. If the modeled storms were to occur once, the investment in adaptation would be considered cost-effective for both longer-term scenarios.

The remaining costed adaptation actions provide protective benefits to the communities surrounding Alamitos Bay, where an overwhelming majority of the City's impacts are expected from SLR and coastal storms. These actions, which in some cases provide duplicative benefits of varying degrees, include: constructing a living shoreline / berm; elevating / extending curbs, streets and pathways; and retrofitting / extending / upgrading walls. The collective costs for these protective actions were estimated between $74 and $91 million for 3 feet of SLR combined with a 100-year storm, and an additional cost ranging between $25 and $31 million for up to 5.5 feet of SLR combined with a 100-year storm. While these costs are not insignificant, and duplicative in some cases in terms of their benefits provided, these systemic actions are less costly than building level adaptation in the form of elevating and/or floodproofing individual structures. Because these systemic actions are assumed to be able to mitigate the impacts from the lower and higher longer-term scenarios evaluated, the protective benefits to structures alone detailed in the discussion above on elevating and/or floodproofing structures would indicate that they are cost-effective if the modeled storm conditions were to occur even once. Systemic actions would also reduce business and employment impacts, which are estimated at nearly $5 million for the 5.5 foot SLR and combined 100-year storm scenario, and provide an additional protective benefit to infrastructure assets valued over at $100 million. Again, it is important to note that full collective implementation of these actions is expected to provide some duplicative benefits and as a result is not expected to be necessary. Nevertheless, even if fully implemented these collective actions could be considered cost-effective. The distributed nature of benefits to both public and private property could justify a funding strategy that shares the cost burden for adaptation between the public and private sector, though additional analysis should be undertaken to more closely link the benefits of adaptation to specific beneficiaries for a more equitable assignment of the burden of payment.

Section 5. **Short-Term and Long-Term Adaptation Actions**

This section includes excerpts of *draft* coastal adaptation actions (also referred to as “adaptation strategies”) that have been identified to improve the ability of Long Beach and its residents and businesses to adapt to climate change and related impacts of flooding due to sea level rise and intensifying storm events, now and in the future. Adaptation actions are listed under three distinct buckets: (1) Governance; (2) Informational; and (3) Physical / Structural. The draft adaptation actions report is available for review.[10]

These adaptation actions were developed based on the 2018 Long Beach Climate Stressors Review, the Long Beach Climate Change Vulnerability Assessment, and through soliciting feedback from a Scientific Working Group, a Business Working Group, and from over 9,000 Long Beach residents reached at over 50 CAAP community engagement opportunities between June 2018-June 2019. They have been vetted by all departments across the City as well as the City Council. A range of factors were considered in the design and selection of the various actions, including:

- The projected timeframe and estimated likelihood of the vulnerability
- The importance and effectiveness of each action in increasing resilience
- Technical feasibility and City implementation capacity
- Public and stakeholder feedback throughout the CAAP development process

The City of Long Beach has placed a high priority on public engagement and input to identify and select actions. Major points of public emphasis to this point in the process include selecting actions that have strong, positive, and inclusive impacts on low-income and disadvantaged communities. As a result, a significant majority of the actions include implementation steps that will require the City to prioritize these actions in areas of highest need. Each action includes a description, implementation steps and responsibilities, potential performance metrics and co-benefits, and any anticipated equity benefits. These actions will be further refined for inclusion in the final CAAP so that the City and community have a clear roadmap to withstand rising temperatures, flooding associated with sea level rise and intense storm events, and drought, among others.

[10] http://www.longbeach.gov/lbds/planning/caap/

Table 11. Sea Level Rise and Flooding Adaptation Actions Summary

Action #	
Governance	
FLD-01	Establish floodplain ordinance
FLD-02	Incorporate sea level rise language into citywide plans, policies, and regulations
FLD-03	Establish a flood impacts monitoring program
FLD-04	Incorporate SLR and flooding adaptation into City lease negotiations
FLD-05	Upgrade the City's existing Stormwater Management Plan
Informational	
FLD-06	Conduct citywide beach stabilization study
FLD-07	Conduct studies of combined riverine/coastal flooding and increased precipitation impacts on watershed flooding
Physical/Structural	
FLD-08	Restore dunes
FLD-09	Inventory and flood-proof vulnerable sewer pump stations
Governance	
FLD-10	Investigate sea level rise adaptation funding mechanisms and strategies
Structural/Physical	
FLD-11	Relocate/elevate critical infrastructure
FLD-12	Elevate riverine levees (as identified by FLD-07)
Structural/Physical	
FLD-13	Expand beach nourishment
FLD-14	Construct living shoreline/berm
FLD-15	Elevate/extend curb
FLD-16	Retrofit/extend sea wall
FLD-17	Elevate streets/pathways
FLD-18	Retreat / realign parking lots
FLD-19	Extend/upgrade existing seawalls
Informational	
FLD-20	Investigate feasibility of managed retreat
FLD-21	Evaluate feasibility of storm surge barrier at Alamitos Bay

5.1 FLD-01: Establish a Floodplain Ordinance

Establish a floodplain ordinance to limit, elevate, or provide flood-proofing standards for development in areas designated as vulnerable to flooding in order to minimize property impacts from flooding.

Lead: Planning and Building

Partners: FEMA, Neighborhoods located in existing and future coastal and riverine floodplains

Timeline: Short

Potential Performance Metrics:

- Established ordinance

Co-benefits:

- Reduction of flood insurance rates of 5 to 45%
- Increase in awareness of SLR issues in the City

Description:

As a participant of the National Flood Insurance Program, the City already enforces a minimum design standard of the base flood elevation (BFE) for first floor building elevations (Chapter 18.73 [Flood-Resistant Design and Construction] of the City's Building Code). Although building codes can improve the chances that a structure will survive an extreme storm, additional regulation may be necessary to ensure adequate flood protection for the area. Adoption of a Floodplain Ordinance will emphasize flood risks posed to the City and introduce regulations and programs to promote long-term flood resilience for buildings located in the floodplain.

Sea level rise will increase the height of floodwaters and inland extent of floodplains. The Ordinance will introduce incentives to help facilitate building owners located in FEMA-designated flood areas to proactively invest in resiliency improvements by either meeting or exceeding flood-resistant construction standards, even when they are not required by FEMA or City Building Code. Incentives will include City-led pursuits of FEMA grants to subsidize flood-proofing and elevating properties as well as the removal of regulatory obstacles to incorporate resiliency standards in design. This precautionary approach helps make buildings safer in the long-term, thereby decreasing the chance of future property damage. By exceeding minimum FEMA floodplain requirements, the City may also reduce flood insurance premiums through FEMA's Community Rating System (CRS).

The ordinance will include new base flood elevations informed by current science. Future updates to the ordinance will incorporate the latest science and projections and local impact monitoring. Longer-term updates may consider managed retreat if science and monitoring of local impacts warrant it.

In summary, the Floodplain Ordinance provides building owners living and working in the floodplain the option to design or retrofit buildings to reduce damage from existing and future floods and potentially reduce long-term flood insurance costs. Overall, implementation of the action would improve the ability of the City's flood-prone neighborhoods to withstand and recover quickly from coastal flooding.

Implementation Steps:

- Review Chapter 18.73 (Flood-Resistant Design and Construction) of the Long Beach Building Standards Code against (FEMA) standards to determine if existing code can be updated to include future sea level conditions or if a separate ordinance is required.
- Use sea level rise inundation maps and CAAP to develop minimum design standards to be considered for long-term flood protection.
- Ensure other building code regulations (e.g., setbacks, building heights) are consistent with higher standards developed for the Floodplain Ordinance.
- Pursue competitive FEMA grant programs to subsidize individual building owners in elevating and flood-proofing their properties

- Explore the potential beneficial impacts higher minimum design standards could have on insurance premiums

Potential Cost Level: Low

Equity Impacts:
- A floodplain ordinance will minimize property impacts from flooding in all neighborhoods, including areas socially vulnerable to climate change, as identified in the Long Beach Social Vulnerability to Climate Change Map[11]
- Subsidization programs may enable building owners in West Long Beach and other impacted neighborhoods the ability to build or retrofit to a higher flood protection standard

5.2 FLD-02: Incorporate Sea Level Rise Language into Citywide Plans, Policies and Regulations

Mainstream SLR adaptation by incorporating SLR impacts into relevant plans, policies, and regulations (e.g., General Plan, neighborhood plans, Local Coastal Program, design standards for capital projects).

Lead: Planning and Building, Public Works

Partners: Varies based on planning document

Timeline: Short

Potential Performance Metrics:
- List of relevant strategies, policies, and regulations and timeline for incorporating SLR language
- # of strategies, policies, and regulations updated consistent with the timeline

Co-benefits:
- Increase in longevity of project by considering SLR
- Increase in awareness of SLR issues in the City
- Assistance with any future applications to FEMA as well as compliance with SB 379

Description

City planning documents are tangible opportunities to integrate SLR into a citywide planning framework. Incorporating language related to SLR in City policies, plans, and guidelines can ensure that future investments by the City consider potential flood impacts and incorporate adaptation strategies, as appropriate.

Mainstreaming SLR adaptation into planning and decision-making processes requires a coordinated, citywide effort. However, most decision-making responsibilities are allocated to specific functional areas or departments and follow relatively codified procedures, particularly where specialized knowledge is required. In general, city planning documents fall into two high level categories: overarching planning documents and design guidelines. To help meet the City's goal of enhancing resilience to future climate conditions, language addressing SLR impacts will be added to both types of documents.

Overarching documents, such as the General Plan, are high level and focus on the City's priorities. It is particularly important to influence overarching plans that aim to enhance the capacity and performance of

[11] http://www.lbds.info/civica/filebank/blobdload.asp?BlobID=7150

operations and assets, often with a longer-term, strategic perspective. These documents provide the opportunity to introduce, coordinate, and generate knowledge, and present a vision of long-term resilience.

Design guidelines, such as design standards for capital projects, are detailed and provide guidance to technical practitioners. Existing building codes and minimum design standards are primarily based on historical weather data without accounting for changing climate conditions, such as the increasing frequency and magnitude of coastal flood events. Updating design criteria to consider future sea level conditions is a critical step toward integrating resilience as a core principle into the design of City infrastructure and facilities. Updating prevailing design guidelines, standards, and specifications allows the City to evaluate the risk tolerance of city assets and guides project design. Prioritizing the update of design guidelines is particularly important to ensure opportunities to influence the construction or major renovation of assets with a long design life (e.g., bridges, stormwater infrastructure, seawalls, etc.).

Implementation Steps:

- Review and identify relevant strategies, policies, and regulations that should be prioritized for language updates to consider future SLR conditions.
- Use SLR inundation maps and CAAP to inform updates currently being done by the City.
- For lower priority strategies, policies, and regulations, consider adding SLR language in coordination with planned update cycles.

Potential Cost Level: Low

Equity Impacts:

- Integration of SLR in future planning and design will increase the flood resilience to all neighborhoods, including areas that are socially vulnerable to climate change, as identified in the Long Beach Social Vulnerability to Climate Change Map[12]

5.3 FLD-03: Establish a Flood Impacts Monitoring Program

Streamline the collection and analysis of flood impact data for collecting photo and video documentation during and after storms or other flooding events so the City may compare SLR and flood projections with realities on the ground. This could be done in partnership with local schools including CSULB, LBCC and/or LBUSD.

Lead: Disaster Preparedness & Emergency Communications, Public Works, Sustainability Office, Tidelands Capital Improvement Division

Partners: Local schools, neighborhood associations, local businesses

Timeline: Short

Potential Performance Metrics:

- Established program
- # of annual crowdsourced documentations

Co-benefits:

- Site or neighborhood specific data can improve City flood response

[12] http://www.lbds.info/civica/filebank/blobdload.asp?BlobID=7150

- Increased public engagement in flood response

Description:
When flooding occurs, data for site-specific conditions can help the City to better understand how factors in the urban landscape (e.g., paved surfaces, drainage networks, and city infrastructure) exacerbate local water levels and damages associated with storm events. Although the hazard of flooding continues to affect the City every year, the ability to know when and where flooding occurs and communicate the risks to the public is limited.

A flood monitoring program that harnesses the power of citizen reporting through crowdsourcing platforms such as smartphone photos, webcams, and social media posts will connect residents with city officials and emergency managers, providing a first-hand look at flood risks throughout the City. The prevalence of smart phones and webcams have created a new opportunity to evaluate the magnitude and associated damages of flooding and offering a tool for communities to protect themselves against flood events.

Uploaded data collected by residents can be automatically geolocated and added to a map interface that is viewable by city officials and the public. During the event, the real-time data is useful for emergency managers and may improve response times. Following the event, the City can review the information to address flooding hot spots and monitor the effectiveness of implemented flood adaptation strategies. The City will establish the platform and perform annual data reporting that includes aggregate data and how the data has informed City adaptation efforts.

Implementation Steps:
- Assess internal resources for crowdsource capability and/or evaluate costs and timeline for developing a platform
- Identify and implement the preferred crowdsource platform
- Host outreach events with the schools, neighborhood meetings, etc. to train the public on the importance of the tool and how to use it
- Train City staff how to incorporate findings from the platform into infrastructure improvements.
- Complete annual data reporting

Potential Cost Level: Low

Equity Impacts:
- A crowd-sourced floodplain monitoring program will provide all residents, particularly those most impacted by climate change, with a tool to highlight local flooding in their neighborhoods. The City will be able to more effectively address acute flood incidents as well as develop and implement preventative measures

5.4 FLD-04: Incorporate Adaptation into City Lease Negotiations
Include requirements and incentives for implementing adaptation strategies into new and renewed leases on City-owned land.

Lead: Economic Development

Partners: California Coastal Commission, City lease holders

Timeline: Short

Potential Performance Metrics:
- Updated leasing guidelines
- # and type of adaptation strategies incorporated into leases

Co-benefits:

- Less service interruption to tenants located in flood zones
- Increased awareness of flood risks for potential tenants
- Avoidance of environmental impacts to the region during large flood events
- Reduced GHG emissions

Description:

Currently, a lease is required for tenants to occupy properties or land owned by the City. Because much of this City-owned property is located in areas vulnerable to flood exposure, including SLR and flood adaptation requirements into lease negotiations will provide enhanced flood resilience for tenants and may avoid adverse environmental impacts. City leases also provide a vehicle to include adaptation strategies that will address extreme heat, air quality, and drought, and achieve GHG reduction co-benefits. As such, the City will include an adaptation section in the lease applications. The new section will include a simplified map of flood vulnerability, extreme heat, and air quality zones or proximity to major emissions sources. The flood vulnerability map will include future SLR and questions regarding the proposed location, maximum life span of infrastructure on the site, potential consequences of flooding, and a description of feasible adaptation measures. Similarly, the City will establish incentives and/or requirements to address extreme heat, air quality, drought, and reduce GHG emissions, which will be based on the exposure to climate change impacts and the potential benefits of adaptation strategies.

A guidance document will be developed to assist City staff in understanding key terms used to evaluate future impacts and making informed decisions regarding lease permits. Project examples and an internal checklist for staff reviewing applications will also be included.

Implementation Steps:

- Develop simplified maps of SLR flood extents, extreme heat, and air quality overlaid on city-owned property
- Establish leasing guidelines that include incentives, requirements, or a combination thereof to incorporate adaptation (and mitigation co-benefit) components into new and renewed leases
- Insert SLR and flood section into tenant lease agreement
- Train City staff on how to perform evaluations effectively and answer relevant questions from the applicant

Potential Cost Level: Low

Equity Impacts:

- Several areas of City-owned property available for lease may be located in disadvantaged communities. Including adaptation (and mitigation co-benefit) considerations into lease negotiations may will increase overall resiliency and adaptive capacity

5.5 FLD-05: Update the City’s Existing Stormwater Management Plan

Update the City's existing Stormwater Management Plan to account for flood risks associated with climate change and develop a funding/implementation plan for fully funding storm drain and pump station improvements.

Lead: Public Works

Partners: LA County

Timeline: Short

Potential Performance Metrics:

- Updated Stormwater Management Plan

- Funding and implementation plan

Co-benefits:
- Increase in longevity of projects through consideration of SLR and riverine flooding
- Increase in awareness of SLR issues in the City
- Assistance with any future applications to FEMA as well as compliance with SB 379

Description
The Stormwater Master Plan includes an inventory of stormwater assets, field investigations, hydraulic modeling, and recommendations for capital improvements and expanded inventory data collection and maintenance programs. Its stated primary purpose is to protect water quality by preventing pollutant discharges to receiving waters.

In addition to protecting water quality, the City will update the Stormwater Master Plan to also prioritize efficient conveyance of excess stormwater to prevent inland flooding. Updating the Master Plan will include developing an up-to-date Hydrological and Hydraulic (H&H) model of the City's major watersheds to include new information regarding changes in climate and rising tides will help the City better understand how its infrastructure will perform under changing storm scenarios. The updated H&H watershed modeling will incorporate climate changes stressors, including both changes in future precipitation patterns and rising sea levels. The updated Stormwater Master Plan will also evaluate the existing capacity of the system to convey and drain excess stormwater and identify capital improvement projects to increase drainage efficiency and protect new and existing electrical and mechanical equipment (e.g., pump stations) from potential flood damage.

Implementation Steps:
- Review and identify sections of the Plan that could be updated with SLR language
- Review and incorporate data collected in SLR-31/RIV-03

Potential Cost Level: Low

Equity Impacts:
- Integration of SLR in future planning and design of the stormwater drainage system will increase the flood resilience to all neighborhoods, including socially vulnerable areas as identified in the Long Beach Social Vulnerability to Climate Change Map[13]

5.6 FLD-06: Conduct Citywide Beach Stabilization Study

Conduct a citywide study to assess the feasibility of a combined nourishment and sand retention program. Study will estimate sand volumes required to keep pace with SLR, costs, and potential sources of sand.

Implementation Lead: Parks, Recreation, and Marine, Public Works

Partners: U.S. Army Corps of Engineers (USACE), local universities, U.S. Geological Service (USGS)

Timeline: Short

Potential Performance Metrics:

[13] http://www.lbds.info/civica/filebank/blobdload.asp?BlobID=7150

- Completed study

Co-benefits:

- Increased recreational opportunities for residents and tourists

Description:

To maintain property protection and recreational benefits of the City's beaches, engineering intervention will be necessary. Beach nourishment refers to the introduction of sediment onto a beach and is primarily used to offset eroding conditions. Ideally, a beach nourishment project will respond to seasonal changes in wave and current conditions but is designed so the shoreline fluctuations remain relatively stable for the duration of the project design life. However, nourishment material is dynamic by nature, will be affected by large storm events and changing water levels, and will require periodic maintenance.

The City will perform a citywide beach stabilization study of how beaches may respond to sea level changes to inform sound engineering and a cost-effective approach to planning for a future nourishment schedule. Several scenarios will be considered in the modeling including volumes of sand, material placement, and the addition of hard engineering structures (e.g., groins and breakwaters) to promote the accumulation and longevity of placed sand. The goal of evaluating multiple scenarios is to determine an effective method in dealing with spatial alongshore variation and high erosion or deposition that routinely occurs in nourished beaches.

Implementation Steps:

- Establish partnerships to cooperatively complete the stabilization study for regional beaches.

Potential Cost Level: Low

Equity Impacts:

- Increased beach stability represents recreational opportunities and relief during extreme heat days for residents throughout the City including those most vulnerable to extreme heat impacts

5.7 FLD-07: Conduct Studies of Combined Riverine/Coastal Flooding and Increased Precipitation Impacts on Watershed Flooding

Carry out further studies to understand the potential influence of SLR and increased precipitation on flood risk at the riverine/coastal interface and along river channels.

Lead: Public Works, U.S. Army Corps of Engineers, County of Los Angeles

Partners: Other municipalities within the Los Angeles River Watershed and San Gabriel River Watershed

Timeline: Short

Potential Performance Metrics:

- Completed study(ies)

Co-benefits:

- Redevelopment of channels could provide recreation, open space, and/or habitat, and benefit disadvantaged communities in West and North Long Beach

Description:

While existing 100-year floods occurring along the primary riverine waterways in Long Beach are contained within their channels by existing levees, overtopping risk could be exacerbated in the future by a combination of SLR and increased intensity of precipitation. With more intense precipitation events projected as a result of climate change, increased peak flows into major drainage channels (the Los Angeles River, Los Cerritos Channel, and the San Gabriel River) could cause overtopping of levees that were previously adequate. In addition, as sea levels increase, the zone of tidal influence will move further up the channels. If a major precipitation event coincides with a high tide, flood waters will not be able to discharge the channels as quickly, possibly resulting in overtopping at the riverine/coastal interface.

Reliable modeling on how riverine floodplains will be impacted by changes in extreme precipitation patterns and SLR does not exist for Long Beach. For this CAAP, asset exposure to riverine flooding was assessed based on location within the Federal Emergency Management Agency's (FEMA) 100- and 500-year riverine floodplains. Given the large spatial extent of the existing 500-year floodplain, the area within the 100-year floodplain could increase considerably in the future as climate conditions evolve.

The City will carry out or partner on one or more studies that contain the following analysis. Hydrologic and hydraulic analysis of watersheds and drainages that flow through Long Beach, accounting for future projected changes in precipitation and SLR, will produce a more detailed understanding of future riverine flooding vulnerabilities. Analysis of urban flooding variables will be factored into this analysis such as condition of stormwater infrastructure and the extent to which its characteristics exacerbate or mitigate flooding. A combined riverine/coastal flooding analysis will be conducted to assess the potential impacts flooding at the riverine/coastal interface will have on the surrounding neighborhoods and infrastructure. Similarly, a study of the impacts of increased precipitation on watershed flooding will be used to understand how future flood conditions could increase flooding along river channels and in urban neighborhoods and inform prioritized locations and timelines for elevating levees (RIV-08).

Implementation Steps:

- Perform study of combined riverine/coastal flooding to understand how flooding at the riverine/coastal interface will impact surrounding neighborhoods and infrastructure and review. Integrate consideration of urban flooding variables into the study to understand combined impacts
- Perform study of the impacts of increased precipitation on watershed flooding to understand how future flood conditions could increase flooding along river channels
- Based on these studies, prioritize the locations and timelines for elevating levees (RIV-08) and other adaptive strategies, such as watershed restoration or green infrastructure to reduce flood impacts

Potential Cost Level: Low

Equity Impacts:

- This action could address flooding in neighborhoods socially vulnerable to climate change along the three major river channels, as identified in the Long Beach Social Vulnerability to Climate Change Map[14]
- Creatively re-developing the channels could concurrently provide new recreational benefits to low-income residents, as is envisioned in plans for the upper LA River
- Potential for improved access to funding for investment in low-income and disadvantaged communities

5.8 **FLD-08: Restore Dunes**

Convert seasonal storm berms to year-round dunes through active dune restoration. Discontinue beach grooming and plant native dune species to allow natural vegetation to stabilize dunes and hold sand.

[14] http://www.lbds.info/civica/filebank/blobdload.asp?BlobID=7150

Lead: Parks, Recreation, and Marine

Partners: Public Works

Timeline: Short

Potential Performance Metrics:
- Linear feet of dunes restored

Co-benefits:
- Restoration of dunes may provide habitat benefits
- Discontinuing beach grooming will decrease disruption to beach habitat and species
- Reduced City expenditure over time on annual sand berm engineering

Description:
The communities of Belmont Shore and Alamitos Peninsula are vulnerable to flooding from a 100-year storm surge after 11” of SLR, and to flooding from a king tide after 24” of SLR. Both areas are fronted by coastal beaches, which could provide improved protection from storm surges if strategies are implemented to support the growth of sand dunes as a buffer.

Sand dunes are formed naturally when sand or sediment blown by wind accumulates against an obstacle, generally vegetation. Healthy dune systems rely on the root systems of dune grasses and other vegetation to maintain their shape. Currently, the City of Long Beach operates a beach grooming program along Belmont Shore Beach. While grooming helps maintain the pristine appearance of the beach, flattening the sand each day prevents dunes from forming naturally, and clearing the buildup of seaweed deprives beach vegetation of an important source of nutrients.

Due to the lack of natural dunes, the City currently engineers sand berms each year to provide protection for adjacent communities from seasonal swells. However, because these berms do not have vegetation holding them together, they are eroded by tides and wave action each year and need to be replaced.

By implementing a comprehensive active dune restoration program, the City will enable the regrowth of sand dunes as natural coastal protection along beaches that do not have a bluff behind them. Dune restoration activities will include planting native beach vegetation and discontinuing beach grooming for along the landside portion of each beach. Because residents of Long Beach have come to expect the beaches to be devoid of vegetation, educational signage will be necessary to communicate the purposes and advantages of dune restoration.

Implementation Steps:
- Implement active dune restoration strategies, including the planting of native beach vegetation and building of wooden fences to help retain sand
- Discontinue beach grooming to allow dunes and dune vegetation to form
- Protect dune restoration areas using fences and build dune crossovers for beach access
- Develop public messaging materials and signage to communicate purpose of dune restoration

Potential Cost Level: High

Equity Impacts: None identified

5.9 FLD-09: Inventory and Floodproof Vulnerable Sewer Pump Stations

Assess potential for flood damage at all sewer pump stations, and for pump stations identified as vulnerable to flooding, apply flood-proofing techniques and add emergency generators.

Lead: Public Works

Partners: Long Beach Water, Parks, Recreation, and Marine, Disaster Preparedness and Emergency Communications

Timeline: Short

Potential Performance Metrics:

- Completed inventory prioritized by highest vulnerability
- # of retrofitted sewer pump stations

Co-benefits:

- Protects water quality by preventing failure of sewer pump stations, which could have serious environmental and public health consequences

Description:
One of the City's priorities in the coming years will be hardening its wastewater infrastructure to increase the system's resilience to flood damage. Many of the City's pump stations are located in or near areas at risk of flood exposure and power outages. Pump stations rely on an uninterrupted power supply to maintain operation and power failure may cause sewage overflows and backups may result. Because the likelihood of flooding will increase over time with SLR, the City will implement protective measures through capital projects to reduce flood damage for pump stations identified as vulnerable to future flood conditions.

As an initial step, the City will perform a detailed inventory of all pump stations identified as vulnerable to future flooding. The inventory will include updated information for critical electrical and mechanical components (e.g., elevation, condition, age, etc.) and entryway elevations that could serve as a flood pathway.

Flood adaptation strategies are likely to vary for each pump station depending on local conditions (e.g., space constraints, cost-effectiveness, station criticality, projected flood depth, etc.). Potential flood-proofing strategies may include the following: elevating pump housing entryways, sealing the building and entryways to projected flood depth, elevating electrical equipment, or replacing existing pump with a submersible pump. All vulnerable pump stations should also be equipped with a flood-proof backup generator to maintain operability even during storm-induced power outages. If flood-proofing techniques are not possible due to the configuration or location of components, the entire pump station may need to be relocated.

Implementation Steps:

- Assess potential for flood damage and timing of vulnerability for each sewer pump station
- For pump stations identified as vulnerable, apply flood-proofing techniques, elevate, or relocate as necessary
- Equip all vulnerable pump stations with a flood-proof backup generator to ensure continued operation during power outages

Potential Cost Level: Medium

Equity Impacts: None identified

5.10 FLD-10: Investigate Sea Level Rise Adaptation Funding Mechanisms and Strategies

Explore a special flood district or alternative funding strategies to help pay for improvements in flood prone areas.

Lead: Planning and Building, Public Works, City Manager, Financial Management, City Auditor

Partners: None identified

Timeline: Medium

Potential Performance Metrics:

- Completed study

Co-benefits:

- Potential preservation/enhancement of public coastal access and recreational resources
- Potential for improved water quality from reduced stormwater runoff
- Job creation and economic development

Description:

The physical infrastructure required to protect coastal regions of Long Beach from SLR will be costly and require creative financing strategies and partnerships in order to be successfully implemented. There are a variety of financing options available to generate revenues to pay for maintenance, repair, rehabilitation, and improvements to reduce flood risk. This could include the establishment of a flood assessment district or establishing taxes or fees.

Special districts are local government entities created to offer specific public services, such as flood protection, within a defined area. The City could delineate special flood protection districts based on the regions protected from flooding by proposed adaptation projects. A special flood district could levy a shoreline tax on property owners within the special district to pay for protective infrastructure based on property value. A special flood district could also levee an assessment to raise money for adaptive infrastructure directly from property owners that would be protected by the project. The assessment paid by each property owner within the special flood district would be based on avoided damages to their property.

While residents may be initially averse to additional fees and taxes, the City can generate support for these strategies by communicating that the cost of inaction is significantly higher. A special flood district tax requires approval by 2/3 of property owners within the district while an assessment requires approval from a majority of property owners within the district, weighted proportionally by the assessment each owner would pay. However, for assessments, the district must quantify the avoided damages to attribute to each property in order to determine the proportion of the assessment each property owner should pay. Other funding mechanisms such as an increase in Transient Occupancy Taxes have been established in other cities and dedicated to shoreline adaptation strategies.

The City will conduct an evaluation of the feasibility of the range of different options available at the time the study is initiated. Because this is a medium-term action it is likely that the range of options available to fund shoreline adaptation will expand as regional, state, and federal agencies establish more policy options in response to increased impacts of rising sea levels and related impacts.

Implementation Steps:

- Conduct a comprehensive study to assess the political and financial feasibility of different funding mechanisms that includes a process to engage potentially impacted stakeholders

Potential Cost Level: Low

Equity Impacts:

- Coastal regions of Long Beach that will be at risk from SLR are generally more affluent areas. Raising money for adaptive infrastructure from landowners, rather than relying solely on municipal funds, will avoid tax revenue from lower income areas subsidizing protection for more affluent residents

5.11 FLD-11: Relocate/Elevate Critical Infrastructure

Raise or relocate critical infrastructure to be outside the SLR vulnerability zone.

Lead: Public Works, Financial Management

Partners: Fire Department, Police Department, Long Beach Unified School District, Health and Human Services, local hospitals

Timeline: Medium

Potential Performance Metrics:

- % of facilities/infrastructure identified for retrofit/relocation and timeframe
- % of facilities/infrastructure retrofitted/relocated in identified timeframe
- # of facilities with continuity plan to maintain operations

Co-benefits:

- Uninterrupted critical services during storm events

Description:

Critical infrastructure refers to essential assets and services for the economy, society, and health of the public. This includes buildings, such as fire stations, hospitals, schools, police stations, and key government facilities, as well as critical components of transportation, wastewater, potable water, and energy distribution systems. To maintain operational continuity during or immediately following flood events, the City is prioritizing adaptation of critical facilities. The City will use the SLR inundation maps prepared as part of this CAAP, as well as subsequent studies on urban/riverine flooding recommended by the CAAP, to assess each facility's exposure to flooding, including the expected timing of flood risk. For exposed assets, the City will assess the vulnerability and value of critical infrastructure as a way to inform decisions regarding applicable approaches to adaptation. Whenever possible, the City will prioritize relocation of critical infrastructure and services to a less vulnerable area. As an alternative, the City may retrofit existing infrastructure facilities to reduce the risk of flood impacts. Examples of retrofits include: elevate and protect electrical control systems, elevate access routes, installation of a flood-proofed power generator, interventions to protect underground utilities and telecommunications from water damage, backflow prevention for building, and flood-proof building entries that may become a flood pathway.

For example, a facility (e.g., police or fire station) that needs to remain in operation during or immediately following a flood event may be flood-proofed using a permanent barrier. A facility (e.g., hospital) that needs to recover quickly after a flood event may elevate electrical or necessary equipment and have deployable barriers. In cases where it is not feasible to relocate critical facilities outside of the flood vulnerability area, the City will prioritize regrading facility access roads to be above the projected flood elevation. As an added precaution, all critical facilities located in areas vulnerable to future flooding will be required to complete a continuity plan that describes appropriate design interventions necessary to maintain operation during or after flood events.

Implementation Steps:

- Perform an asset-level vulnerability assessment for each critical facility
- For facilities identified as vulnerable, recommend flood-proofing techniques, raising, or relocating as necessary

- Prioritize implementation of upgrades based on expected timing of inundation

Potential Cost Level: High

Equity Impacts:
- Protection of access to city services and facilities in neighborhoods that are vulnerable to SLR and riverine flooding

5.12 FLD-12: Elevate Riverine Levees

Based on results of riverine flood study (RIV-02), elevate channel banks and levees to provide enhanced flood protection.

Lead: Public Works, U.S. Army Corps of Engineers

Partners: Los Angeles County, Port of Long Beach, Port of Los Angeles, Los Angeles County Flood Control District, Long Beach County Flood Control District, California Coastal Commission, California State Lands Commission, U.S. Fish and Wildlife Service

Timeline: Medium Term

Potential Performance Metrics:
- List of prioritized levees and timing for adaptation strategies
- # of priority projects implemented/completed

Co-benefits:
- Redevelopment of channels could provide recreation, open space, and/or habitat

Description:
Based on the results of FLD-07 (Conducts studies of combined riverine/coastal flooding and increased precipitation impacts on watershed flooding), portions of the existing levees adjacent to the City's channels and rivers (Los Angeles River, Los Cerritos Channel, and San Gabriel River) may be elevated or modified to provide enhanced flood protection. If feasible, the levees will be designed for multipurpose use to provide opportunities for open space integrated with commercial and residential development. Multi-purpose infrastructure can also improve the urban ecosystem and enhance living conditions for local communities. Complementary riverine modification projects may also include channel widening or watershed restoration, which would likely further enhance habitats and recreation co-benefits.

As flood protection structures along the major river channels are owned and managed by an array of public entities, including the U.S. Army Corps of Engineers, Los Angeles County, and others, modification projects will require a high degree of interagency and regulatory coordination. Therefore, design and permitting should begin well before overtopping is expected to occur.

Implementation of channel modification projects should be prioritized based on an assessment of the consequences and likely timing of flooding at each portion that is at risk. Consequences assessed should include the number of residents and businesses, as well as critical facilities and transportation assets within each flood path.

Implementation Steps:
- Based on riverine flooding studies performed in action RIV-02, identify portions of major river channels at risk of overtopping
- Prioritize at-risk portions of channel levees based on timing of potential flooding

- Perform interactive design process to seek input from stakeholders on design alternatives
- Implement channel modification projects with owners of flood control structures and project leads
- Seek creative funding options prioritize investments in communities with limited access to greenspace

Potential Cost Level: High

Equity Impacts:

- This action could address flooding in neighborhoods socially vulnerable to climate change along the three major river channels, as identified in the Long Beach Social Vulnerability to Climate Change Map.[15] Creatively re-developing the channels could concurrently provide new recreational benefits and access to green space to low-income residents and disadvantaged communities, as is envisioned in plans for the upper Los Angeles River

5.13 Long-Term Flooding Adaptation Actions

Table 12 describes potential long-term actions (between 2050 and 2100) the City could implement to increase flood resilience through the end of the century. No governance actions were identified, but several studies regarding the feasibility of managed retreat and a storm surge barrier were included as potential informational actions to increase flood protection for the region. A suite of long-term structural actions was also identified and includes approaches for elevating the shoreline and raising or relocating infrastructure currently placed in areas vulnerable to future flood exposure.

Table 12. Long-term Adaptation Actions for Sea Level Rise and Riverine Flooding

Action #	Action Title	Action Description	Location	Potential Co-Benefits	Equity Impacts
STRUCTURAL/PHYSICAL					
FLD-13	Expand beach nourishment	Based on findings from beach stabilization study, beaches identified as suitable could be nourished so that they are elevated and preserved	Bay View Beach and Peninsula Beach	Increased tourism	Beaches serve as recreational opportunities for inland residents and disadvantaged community members, particularly on hot days. If climate change exacerbates heat in Long Beach, beach access will become an even more valuable resource for inner city residents

15 http://www.longbeach.gov/globalassets/lbds/media-library/documents/caap/caap-adaptation-actions--draft-released-053119-logos

Action #	Action Title	Action Description	Location	Potential Co-Benefits	Equity Impacts
FLD-14	Construct living shoreline / berm	The shoreline could be elevated to tie in with the landscape and park facilities to prevent flooding of inland areas while continuing to provide beach access	Mothers Beach	Mothers Beach is used heavily on the weekdays and weekends by city residents and visitors for swimming, dragon boat races, picnicking, and other forms of recreation. Protecting this park and beach will protect other areas in Naples from flooding and also preserve the park	Mothers Beach provides residents park and beach access, particularly on hot days and could become an even more important resource as climate change exacerbates heat in Long Beach
FLD-15	Elevate / extend curb	The curb could be elevated and extended to eliminate gaps that could become flood pathways	Bay Shore Drive in Alamitos Bay	Long-term preservation of access to restaurants, shops, and the library on 2nd St. Elevating the curb may also provide flood protection for additional inland assets	The businesses along 2nd Ave serve many residents
FLD-16	Elevate streets / pathways	Elevate waterfront streets and paths to provide protected transportation routes and flood protection for infrastructure behind the road/path	Communities adjacent to Alamitos Bay, including Belmont Shore, Naples, and Marina Pacifica	Could also be combined with drainage improvements to reduce flooding associated with heavy rainfall	This action would protect schools and the fire department, which provide critical services for the region
FLD-17	Retrofit / extend walls	The existing wall may currently provide some flood protection, but it is segmented and not designed for flood protection. It could be retrofitted or rebuilt to provide adequate protection against SLR	E. Paoli Way near the Marine Stadium	The Marine Stadium and E. Paoli Way are a flood pathway for flooding and inundation under future SLR. Upgrading the wall here would protect Apian Way (a major connecting road) and several inland neighborhoods	Residents use Appian Way to access the beach areas and visit the Belmont Shore neighborhood. Protecting these areas will preserve access
FLD-18	Retreat / realign parking lots	Relocate, reduce size, or realign parking lots as beach narrows	Beachfront parking lots	Action would protect parking lots from erosion and less habitat impacts of beach narrowing	
FLD-19	Extend / upgrade existing seawalls	Sheet pile seawalls could be expanded to other areas of the Naples shoreline that are not being addressed by the current upgrade	Treasure Island, areas to the east near the Yacht Club, and areas to the north (which could also be protected by a berm if space allows)	Long-term preservation of access to local public beaches and businesses	
INFORMATIONAL					
FLD-20	Investigate feasibility of managed retreat	Explore managed retreat options for vulnerable shoreline infrastructure through land acquisition and relocation programs	Communities adjacent to Alamitos Bay, including Belmont Shore, Naples, and Marina Pacifica	Managed retreat may create more space for flood events and alleviate flood conditions to adjacent properties	

Action #	Action Title	Action Description	Location	Potential Co-Benefits	Equity Impacts
FLD-21	Evaluate feasibility of storm surge barrier at Alamitos Bay	Conduct a feasibility study to evaluate construction of a storm surge / tide gate barrier at entrance to Alamitos Bay	Alamitos Bay		Action would protect all inland areas along Alamitos Bay shoreline from storm surge flooding
GOVERNANCE					
No long-term governance actions identified					

Section 6. **References**

6.1 Sea Level Rise References

California Coastal Commission (2015). Sea Level Rise Policy Guidance. https://documents.coastal.ca.gov/assets/slr/guidance/August2015/0_Full_Adopted_Sea_Level_Rise_Policy_Guidance.pdf

California Department of Public Health (CDPH). 2012. Climate Action for Health: Integrating Public Health into Climate Action Planning. California Department of Public Health (CDPH) Report, 58p. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.464.9833&rep=rep1&type=pdf.

Environmental Protection Agency. Environmental Justice Screening and Mapping Tool (EJSCREEN). https://www.epa.gov/ejscreen

Griggs, G, Arvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust.

National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Prepared by the Committee on Sea Level Rise in California, Oregon, and Washington and the National Research Council Board on Earth Sciences and Resources and Ocean Studies Board Division on Earth and Life Studies.

NOAA Office of Coastal Management. Sea Level Rise Viewer. https://coast.noaa.gov/digitalcoast/tools/slr.html

Ocean Protection Council 2011. Resolution of the California Ocean Protection Council on Sea Level Rise. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf

Ocean Protection Council 2018. State of California Sea-Level Rise Guidance. 2018 Update. Prepared by: California Natural Resources Agency and Ocean Protection Council.

Point Blue. Our Coast Our Future. http://data.pointblue.org/apps/ocof/cms/

USGS. Coastal Storm Modeling System. https://www.usgs.gov/centers/pcmsc/science/coastal-storm-modeling-system-cosmos

6.2 Financial Cost Analysis References

Aerts, J. C. J. H. et al. 2018. Pathways to resilience: adapting to sea level rise in Los Angeles. Annals of the New York Academy of Sciences

Bureau of Labor Statistics, Los Angeles County. 2017. Annual Averages from the Quarterly Census of Employment and Wages.

California Coastal Commission. 2015. Improved Valuation of Impacts to Recreation, Public Access, and Beach Ecology from Shoreline Armoring. Administrative Draft.

California Department of Finance. 2016. State and County Population Projections (2010-2060).

California Department of Tax and Fee Administration. 2018a. Detailed Description of the Sales and Use Tax Rate.

California Department of Tax and Fee Administration. 2018b. California City and County Sales and Use Tax Rates (effective July 1, 2018).

California State of Board of Equalization. 2018. California Sales and Use Tax Rates by County and City.

City of Long Beach. 2018. Transient Occupancy Tax Rates.

Consumer Price Index. 2018. U.S. City Average All Urban Consumers (CPI-U): All Items.

CoStar Group. 2018.

Esri Business Analyst. 2017. Desktop Application: Business Locations and Summary

Federal Emergency Management Agency. 2016. Benefit-Cost Sustainment and Enhancements: Baseline Standard Economic Value Methodology Report.

Federal Emergency Management Agency. 2014. Homeowner's Guide to Retrofitting: Six Ways to Protect Your Home From Flooding. Third Edition.

Federal Emergency Management Agency. 2012. Final Sustainability Benefits Methodology Report.

Federal Emergency Management Agency. 2011a. Multi-hazard Loss Estimation Methodology Flood Model Technical Manual.

Federal Emergency Management Agency. 2011b. Multi-hazard Loss Estimation Methodology Earthquake Model Technical Manual.

Federal Emergency Management Agency. 2011c. Benefit-Cost Analysis Re-engineering (BCAR). Version 6.0.

King, P. 2001. Overcrowding and the Demand for Beaches in Southern California. A report prepared for the California Department of Boating and Waterways.

King and Symes. 2001. The Potential Loss in Gross National Product and Gross State Product from a Failure to Maintain California's Beaches. A report prepared for the California Department of Boating and Waterways.

Nexus Planning & Research. 2017. Comparing Sea Level Rise Adaptation Strategies in San Diego: An Application of the NOAA Economic Framework.

RSMeans. 2018. Square Foot Costs with RSMeans Data. Gordian. 39th Edition.

US Army Corps of Engineers. 2006. Depth-Damage Relationships for Structures Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana Feasibility Study. Prepared by Gulf Engineers and Consultants.

U.S. Census Bureau: ACS 2012-2016 Five Year Tables S1101, B08301, S0802

Appendix A: Climate Stressor Review

This appendix includes excerpts from a Climate Stressor Review that was prepared in support of the City of Long Beach's CAAP. Extracted narrative primarily relates to SLR, which is a primary climate stressor, as well as coastal flooding and shoreline change, which are secondary climate stressors that are the result of complex interactions between sea level, wind, waves, and natural and human-altered landscapes.

Background

In support of the City's Vulnerability Assessment for the CAAP, a review was undertaken of the most relevant climate change stressors based on the scientific literature. This climate stressor review was not intended exhaustive of all available literature, but rather highlights the historic climate trends, climate projections, and potential impacts from the scientific literature that are most applicable to Long Beach to inform the exposure component of the Vulnerability Assessment.

The review includes an assessment of primary climate change stressors or first-order local conditions that are directly affected by changes in global atmospheric and oceanic temperatures. Secondary climate stressors are conditions affected by complex interactions between primary variables and other factors are also assessed. The relevance of each stressor to Long Beach is described. Then, historic trends are provided so that future climate projections may be understood in comparison to past variability. Next, climate change projections are provided for mid-century and end-of-century. Lastly, a high level overview of potential impacts these stressors could cause based on the literature is included. The full Climate Stressor Review report is available for review.[16]

It should be noted that this climate stressor review represents accounts for the best available science at the time of writing (August 2018). As the science on climate change continues to evolve and new studies are available, this memo may require updating.

Information Sources

This climate stressor review draws on the best available data and climate science and the potential effects for Long Beach and/or the Los Angeles (L.A.) region. Where region-specific studies were not available, California and U.S. studies were reviewed. Regional and state level studies are available through the California Energy Commission's California Climate Change Center. To date, the California Climate Change Center has conducted three assessments, the latest released in July 2012, with a fourth assessment currently underway. This assessment also draws on Cal-Adapt, a web-based climate data and information portal produced by the State of California's scientific and research community. The site contains historic data (1950-2013) and projections (2010-

[16] http://www.longbeach.gov/globalassets/lbds/media-library/documents/caap/long-beach-final-climate-stressor-review-20180827

2100) from a variety of sources that have downscaled global climate models for more fine-scale resolution. National climate change studies are available through the National Climate Assessment.

Modeling Climate Change

General Circulation Models (GCM) are a tool used by climate researchers to better understand potential future changes in our global climate. GCMs incorporate the physical processes of the atmosphere, ocean, and land surface to simulate the response of the climate system to changing greenhouse gas (GHG) and sulfate aerosol emissions. These models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate and past climate changes.

The science of climate change is continuously being revised as climate models are improved and updated with new data and observations. Such revisions improve our understanding of natural climate variability and the complexity of the global response to atmospheric greenhouse gases.

Greenhouse Gas Emission Scenarios as Climate Model Inputs

Because the level of future emissions is unknown and will be affected by population, economic development, environmental changes, technology, and policy decisions, the Intergovernmental Panel on Climate Change (IPCC), developed a range of possible future emissions that is used in climate models to provide scientific consistency in climate modeling efforts.

The IPCC's Fifth Assessment Report on Climate Change (AR5), released in 2014, adopted a new set of emissions scenarios referred to as Representative Concentration Pathways (RCP). Relative to previous GHG emission scenarios, RCPs offer an enhanced representation of climate processes, including updates in data and advances in model development. The RCPs represent the change between incoming and outgoing radiation to the atmosphere caused by differences in atmospheric composition. The four RCPs – RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5 – are named after a possible range of radiative forcing in the year 2100 (+2.6, +4.5, +6.0, and +8.5 watts per square meter, respectively). Figure 11 describes each RCP scenario.

RCP8.5	RCP6	RCP4.5	RCP2.6
Describes a world characterized by rapid economic growth. CO_2-equivalent concentrations reach ~1,370 parts per million by the end of the century.	Represents a stabilization scenario. CO_2-equivalent concentrations reach ~850 ppm by the end of the century, followed by stabilization.	Represents a stabilization scenario where CO_2-equivalent concentrations reach ~650 ppm by the end of the century , followed by stabilization.	Signifies a peak and decline scenario where CO_2-equivalent concentrations peak at ~490 ppm by mid-century, followed by rapid GHG emission reduction.

Figure 11: Summary of RCP Scenarios

Downscaling of Global Circulation Models

GCMs provide estimates of climate change at a global level because the resolution—approximately 200 kilometers (km)—is typically too coarse to provide detailed regional climate projections. Therefore, model outputs are refined through additional analysis or modeling to provide finer regional detail through a process known as "downscaling." Downscaling is the term used to describe methods to generate locally relevant data from GCMs by connecting global-scale projections and regional dynamics (i.e., a 200 km GCM may be downscaled to a 25 km scale for a specific region). Downscaling GCM model output allows for more place-based projections of climate change at the state and local level; however, increased resolution does not necessarily equate to greater accuracy or reliability, as uncertainties remain in all climate projections.

Historical Events and Trends

Sea Level Rise

Sea levels have been rising globally since the end of the last Glacial Maximum around 18,000 years ago. Driven primarily by thermal expansion of ocean water and melting land ice, global seas have risen 400-450 feet in this time (Griggs et al 2017). Over the past century, a network of more than 1,750 tide gauges has been gathering data on ocean water levels. Several approaches have been used to analyze these data to calculate an average global SLR, yielding rates from about 1.2 mm/year to 1.7 mm/year (approximately 0.05 to 0.07 inches/year) for the 20th century. However, since 1990 this global rate has more than doubled and continues to increase (Griggs et al 2017). Satellite observations show accelerating rates of ice loss from both the Antarctic and Greenland ice sheets, which combined, contain enough water to raise sea levels around 200 feet (Griggs et al 2017).

These rates reflect global mean SLR values, but there is tremendous regional variability due to local and regional processes such as vertical land motion, ocean and atmospheric patterns, and other effects. Analysis of approximately 90 years of tide data from 1923 to 2016 at the Los Angeles tide station (#9410660) by NOAA indicates a long-term trend of historic mean sea-level rise of approximately 0.96 mm/yr (0.04 +/-0.01 inches/year) (NOAA 2017).

Coastal Flooding

Prior to the construction of the Port of Long Beach in 1911, the City of Long Beach shoreline was composed of extensive mudflats, barrier islands, estuaries, and sand spits (Griggs et al 2005; Hapke et al 2006). The region is part of the San Pedro Littoral Cell, which is bordered by Palos Verdes to the northwest and Newport Canyon to the southeast. Historically, the Los Angeles and San Gabriel Rivers supplied the shoreline with sand and longshore transport was generally to the southeast with sand transported offshore into Newport Canyon. Palos Verdes provided some protection from winter storm waves approaching from the northwest making the area suited to development and a port.

Extensive development of the area and shoreline has significantly altered coastal processes, which is important to consider when identifying existing and future climate risks. The last of three large breakwaters was constructed in 1942, such that the majority of the Port and Long Beach shoreline is sheltered from waves. The area is still vulnerable to storms and waves, particularly when they approach the coast from a more westerly or southerly direction (as opposed to the typical northwest winter storm waves).

Waves approaching from these directions can damage the breakwaters and propagate between gaps in the breakwaters that are used for navigation. These storms can be especially damaging during El Niño conditions, which can raise coastal sea levels 10 - 30 cm (0.33 - 0.95 ft) during the winter months (NRC 2012) and when the typical winter storm track shifts to the southwest. Multiple storms damaged the breakwaters and caused flooding and damage at the shoreline during the 1982-1983 El Niño winter. The breakwaters were again damaged when a southeaster struck the coast in January 1988. Historically, the most costly storm to impact the southern California coast is the 1939 southerly tropical storm, causing today’s equivalent of $34.1 million of damage and the only tropical storm in California’s history to make landfall (WRCC 2008; WRH 2010). The storm caused massive flooding in the low-lying areas of Long Beach (then unprotected by the breakwaters), damaging homes, and scattering large amounts of trash and debris along the beach (WRH 2010). Recently, Hurricane Marie produced waves of up to 20 feet causing extensive flooding in southeastern Long Beach in late August 2014 and caused an estimated $20 million in damages across southern California (Zelinsky & Pasch 2015). The waves significantly damaged a section of the Middle Breakwater leading to further damage within the Port of Long Beach from wave action (CLB Staff Survey 2017). While this storm did not make direct landfall in southern California, the size, period, and extreme southern angle of the waves made the event particularly damaging.

Figure 12: Port of Long Beach Damage from Hurricane Marie in 2014

Several inland locations within Alamitos Bay are protected from large storm waves but are flooded during high tides, particularly King Tides, which are the highest tides of the year. According to City staff, locations with recurrent King Tide flooding include Bay Shore Avenue, Colorado Lagoon, the Peninsula, and Alamitos Bay (Figure 13). According to a coastal flooding study by Strauss et al (2016), there were only 32 flood days between 1955-1984 compared to 133 flood days between 1985-2014 in La Jolla, California, the nearest location to Long Beach in the study. These additional flood days are largely attributed by the authors to anthropogenic climate change.

Figure 13: Examples of King Tide Flooding

Shoreline Change

Human development also significantly altered natural shoreline change patterns. This is important to consider as the wide sandy beaches along much of Long Beach can partially function as a buffer against future SLR. The channelization of the Los Angeles and San Gabriel Rivers significantly reduced the natural sediment supply to the Long Beach shoreline. Despite this, much of the sandy beach has accreted over the 20th century due to the breakwaters limiting wave-induced erosion, a system of sand retention structures including groins and jetties, and several ongoing beach nourishment and sand bypassing projects. Figure 14 shows historical shorelines derived from NOAA T-Sheets, historical photographs, and airborne topographic LiDAR data and illustrates the overall accretion trend. Long-term accretion rates range between +0.5 to 1.5 meters/year in much of the area resulting in a relatively wide, flat sandy beach (Hapke et al 2006). Although much of the sandy shoreline is currently accreting and will provide some protection against future SLR, historical shoreline trends may not be indicative of future shoreline change because the existing coastal processes, both natural and anthropogenic, may change and could be overwhelmed by more extreme future SLR.

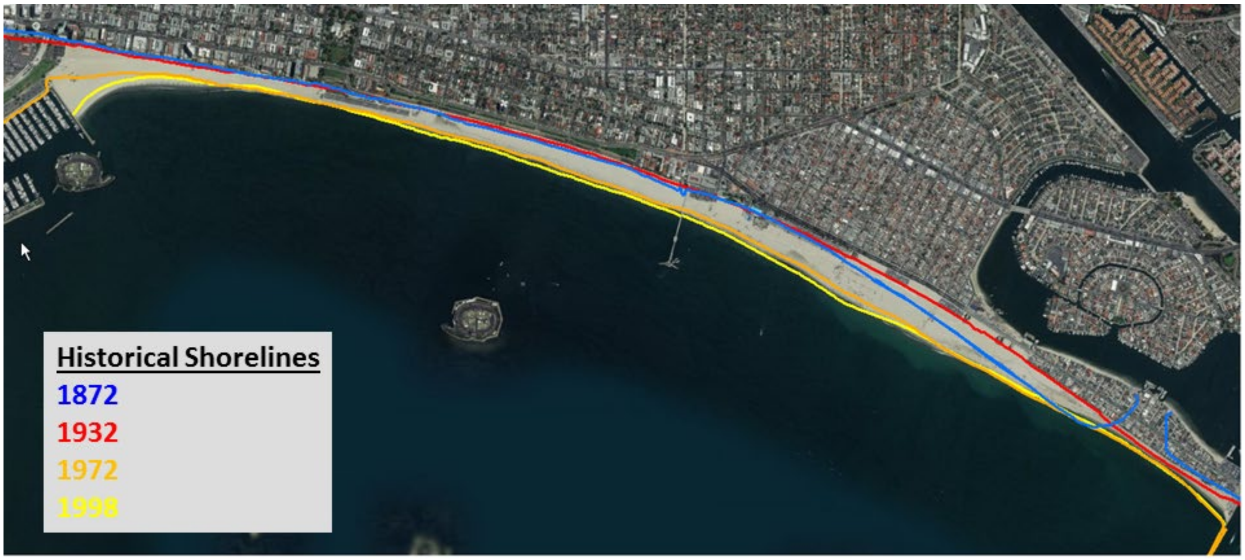


Figure 14: Historical Sandy Beach Shorelines in Long Beach
Notes: Historical high water line shorelines (1872, 1932, and 1972) are compared to a historical mean high water line (1998) and show historical accretion along the beach during the 20th century.
Source: Hapke et al (2006) – (https://pubs.usgs.gov/of/2006/1251/#data/)

The current breakwater and jetty configuration has left the southeastern tip of the Peninsula exposed to erosion, and several homes are threatened. This area is not adequately protected by the Long Beach Breakwater and waves attack the sandy beach from the south. The jetty at the San Gabriel river mouth inhibits northwest sand transport to naturally replenish this area. The City maintains a sandy beach here by bypassing sand from the accreting northwestern shoreline to the eroding southeastern shoreline (AOP 2015). In the winter and during large south swell events, an emergency sand berm is built to protect the homes from flooding.

Long Beach, once known as the “Sinking City,” has a history of subsidence primarily from oil and gas extraction from the Wilmington Oil Field. A subsidence bowl, centered around the Port of Long Beach, reached a depth of 29 feet before measures were taken to arrest the subsidence. Over 20 square miles of land adjacent to the shoreline from the Port of Long Beach to Seal Beach are affected by subsidence. Constant monitoring and control is still required by Long Beach Energy Resources (the City’s oil and gas department) to maintain stability and will continue to be so into the future (CLB 2017). The lowered land elevation from subsidence increases the City of Long Beach’s vulnerability to storm flooding, SLR, and coastal erosion.

Future Projections

Sea Level Rise

Future SLR is expected to vary regionally due to differences in atmospheric and oceanographic process and vertical land motion. Various methods have been used to predict both future global SLR and regional SLR at numerous locations around the world. Up until 2018, the state of California utilized the National Research Council (NRC) 2012 SLR projections as best available science in state policy and guidance. In 2017, a new study was released by Griggs et al (2017) with updated modeled projections along the California coastline. This study informed the development of Ocean Protection Council’s (OPC) new SLR guidance document that was adopted in March 2018. The OPC is currently reviewing the new guidance document with stakeholders and state agencies to develop an approach to administer the new guidance.

Since the Long Beach Climate Action and Adaptation Plan was initiated prior to adoption of the OPC (2018) guidance, NRC (2012) projections were adopted to inform the Vulnerability Assessment; however, for completeness, both studies are summarized and compared in this section.

NRC (2012) used multiple global climate models with different global emissions scenarios to develop regional future SLR projections for the Los Angeles area and three other locations along the west coast. The study produced a projection, reflective of an average of the models, and a range of the model projections for three future years: 2030, 2050, and 2100. Generally, regional sea levels in the Los Angeles area are projected to increase at slightly higher rates than global sea levels. Table 13 summarizes the NRC projections for the Los Angeles area while also providing a comparison with mean global SLR projections. The NRC projections for the years 2030, 2050, and 2100 are 6, 11, and 37 inches respectively.

Table 13: Mean Regional vs Global Sea Level Rise Projections Relative to the Year 2000

Year	Southern California		Global	
	Projection	Range	Projection	Range
2030	5.8 ± 2.0 in	4.6 – 11.8 in	5.3 ± 0.7 in	3.3 – 9.1 in
2050	11.2 ± 3.5 in	5.0 – 23.9 in	11.0 ± 1.3 in	6.9 – 19.0 in
2100	36.7 ± 9.8 in	17.4 – 65.6 in	32.6 ± 4.2 in	19.8 – 55.2 in

Source: NRC (2012)

Note: The low value of the range for each year was computed by subtracting twice the standard deviation from the mean in the projection column and adjusting to the difference between emission scenarios A1B and B1. The high value of the range was computed by adding twice the standard deviation to the mean, adjusting to the difference between emission scenarios A1FI and A1B, and adding the dynamical imbalance contribution (NRC 2012). Please refer to IPCC (2000) for more information on the emission scenarios.

Griggs et al (2017) completed an update to California's SLR science that informed the OPC's 2018 guidance document. Future SLR projections were developed at each tide station along the California coast. Table 14 presents SLR projections for Los Angeles, California. The study incorporated a range of global emissions scenarios ranging from aggressive emissions reductions (RCP 2.6) to no emissions reductions (RCP 8.5) through end of century. Multiple climate models for each global emissions scenario were evaluated to generate a range of future SLR predictions using a probabilistic approach. The advantage to this approach is it provides more detailed projections for asset managers to make risk-based decisions for SLR planning and design.

Table 14: Sea Level Rise Projections at Los Angeles, CA

Year (Emissions Scenario)	Inches Above 1991-2009 Mean Sea Level (in)			
	Median (50% probability of exceedance)	Likely Range (67% percent likely range)	1-In-20 Chance (5% probability of exceedance)	1-In-200 Chance (0.5% probability of exceedance)
2030	4	2 to 6	7	8
2050	8	6 to 12	14	22
2100 (RCP 2.6)	16	8 to 25	36	65
2100 (RCP 8.5)	26	16 to 38	49	80

Source: OPC (2018)

The NRC (2012) and OPC (2018) reports show similar regional SLR projections for comparable global emissions scenarios. The mid-range NRC (2012) projections for 2030, 2050, and 2100 are close to the OPC median projections. The high-range NRC projections for 2030 and 2050 are also comparable to the 0.5% exceedance

OPC values; however, the OPC 0.5% exceedance projections for 2100 exceed the NRC high-range projection. The high-range OPC projection is 80 inches compared with 66 inches for NRC; however, the 66-inch value falls within the range of high-end projections for OPC (65 to 80 inches).[17]

Coastal Flooding

For illustrative purposes only, Figure 15 shows the areas in Long Beach that may be flooded during a 100-year tide event (i.e., the expected water level including astronomical tides, storm surge, and El Niño effects, but no wave effects) with one meter (39 inches) of SLR. This SLR projection is approximately equal to the mid-range NRC and OPC projections for 2100 and has a roughly 20% chance of being met or exceeded by 2100 under a high emissions scenario (RCP 8.5) according to OPC (2018). The figure illustrates a “bathtub” type analysis, where the floodwaters are simply projected inland to where ground elevations exceed the future 100-year flood level. The projected extent of inundation indicates the portions of Long Beach most susceptible to flooding impacts under a likely end-of-century SLR scenario.

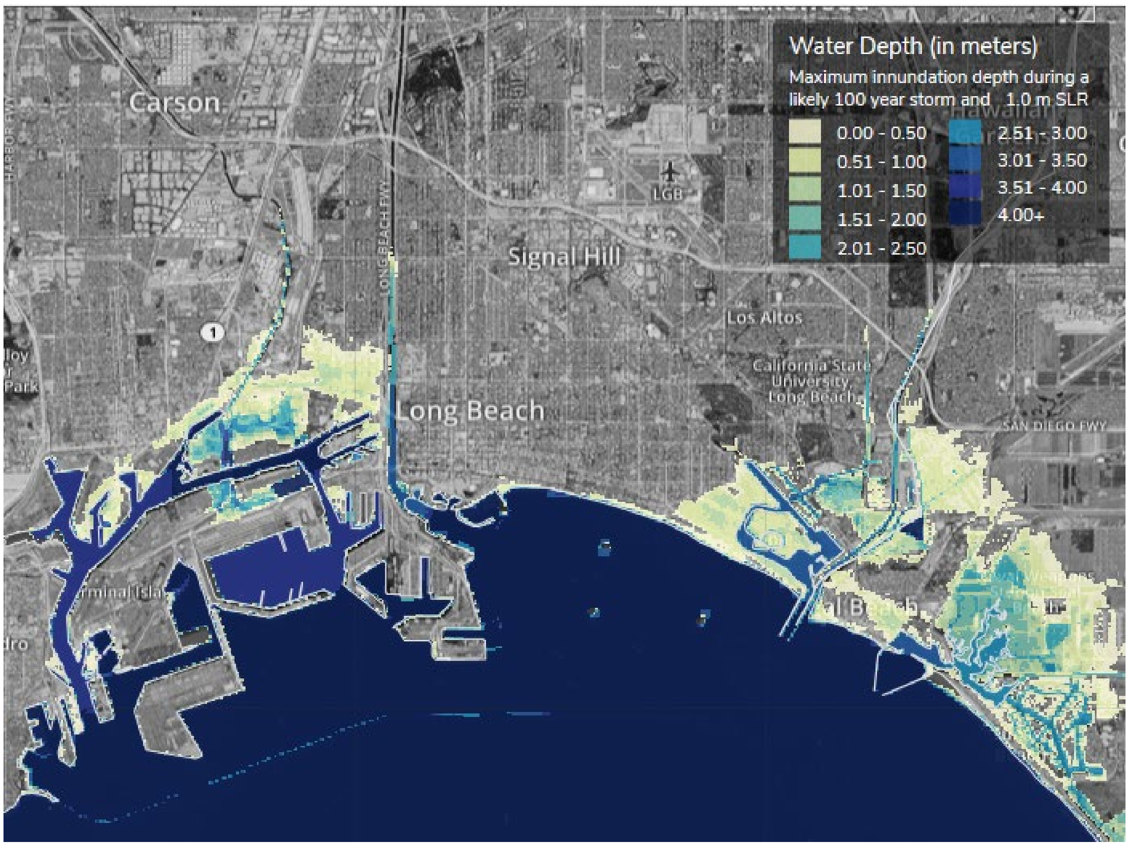


Figure 15: Projected Flooding During 100-year Tide Event with 1-meter SLR

[17] As discussed in Section 2.1, not only were the OPC (2018) SLR projections not yet available at the time that the Climate Stressor Review and Vulnerability Assessment were undertaken as part of the CAAP, but the SLR projections from NRC (2012) show higher potential SLR for near-term planning horizons (2030 and 2050) compared to OPC (2018). Given the differences in projections, it was determined that for the sake of being conservative in developing a plan to preserve life and property, that the more aggressive forecast (NRC, 2012) should be utilized.

Source: NOAA

Rising seas and the associated increase in coastal flooding from waves, storm surge, and tides, potentially coupled with more intense coastal storms will increase the rate of coastal erosion and alter sediment transport patterns in the region (CNRA 2009). CoSMoS, a coastal storm modeling system created by the United States Geological Survey (USGS), is another source of future wave runup, SLR, and shoreline change modeling data. The USGS has conducted shoreline change modeling using CoSMoS for multiple future shoreline management scenarios, ranging from no beach nourishments and retreat from the shoreline to systematic beach nourishments and no retreat from the coast. As an example, Figure 16 displays the CoSMoS projected future shoreline change for multiple SLR scenarios assuming no future nourishments and a retreat from the shoreline. The figure illustrates that the entire beach will generally erode, and that erosion will generally increase with higher amounts of SLR. In particular, the homes at the southeast tip of the peninsula and the facilities, parking lot, and park at Junipero Beach could be threatened under higher SLR scenarios.

Figure 16: Projected Shoreline Change due to Multiple Sea Level Rise Scenarios Assuming no Future Beach Nourishments
Source: USGS CoSMoS (https://www.sciencebase.gov/catalog/item/57f1d4f3e4b0bc0bebfee139)

Among scientists, there is general consensus that climate change will affect the intensity, frequency, and paths of coastal storms. However, there is yet to be a clear consensus on what the nature of these changes will be in the North Pacific Ocean (NRC 2012). “Storminess” is an overarching term used by the NRC to include physical processes such as frequency and intensity of storms, shifts in storm tracks, magnitude of storm surges, and changes in wind speed and wave height. Evidence of observed changes in storminess in the 20th century historical record as well as future modeled projections have been found by researchers, but the interpretation of these results is difficult due to natural climate variability. Further research is needed to determine the validity and relevance of these storminess projections, particularly for the southern California shoreline.

References

AOP 2015. City of Long Beach Climate Resiliency Assessment Report. Prepared by the Aquarium of the Pacific (AOP), for the City of Long Beach, California: 88p.

City of Long Beach (CLB) 2017. "Subsidence" Long Beach Gas & Oil Department. Available at: http://www.longbeach.gov/lbgo/about-us/oil/subsidence/

Griggs, G, Patcsh, K., and L. Savoy. 2005. Living with the Changing California Coast. University of California Press, 58p.

Griggs, G, Arvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). 2017. Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust.

Hapke, C., Reid, D., Richmond, B., Ruggiero, P., and J. List. 2006. National Assessment of Shoreline Change Part 3: Historical Shoreline Change and Associated Coastal Land Loss Along Sandy Beaches and Shorelines of the California Coast. USGS Open File Report 2006-1219, 79 p.

IPCC (Intergovernmental Panel on Climate Change), 2000, Emission Scenarios, N. Nakicenovic and R. Swart, eds., Cambridge University Press, Cambridge, UK, 570 pp.

National Oceanic and Atmospheric Administration (NOAA). 2017. Mean Sea Level Trend, 9410660 Los Angeles, California. Center for Operational Oceanographic Products and Services. https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9410660

National Research Council (NRC). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Prepared by the Committee on Sea Level Rise in California, Oregon, and Washington and the National Research Council Board on Earth Sciences and Resources and Ocean Studies Board Division on Earth and Life Studies.

Ocean Protection Council. 2018. State of California Sea-Level Rise Guidance 2018 Update.

Staff Survey 2017. City of Long Beach Climate Action and Adaptation Plan Department Questionnaire.

Strauss, B. H., Kopp, R. E., Sweet, W. V. and Bittermann, K. Unnatural Coastal Floods: Sea Level Rise and the Human Fingerprint on U.S. Floods Since 1950. Climate Central Research Report, pp. 1-16.

WRCC. 2008. California’s Top 15 Weather Events of the 1900’s. Western Regional Climate Center (WRCC) website, posted September 2008 (accessed 12/16/2015). Available online at: http://www.wrcc.dri.edu/extreme-events/california/.

WRH. 2010. A History of Significant Weather Events in Southern California, Organized by Weather Type. NOAA’s Western Region Headquarters (WRH) website, updated February 2010 (accessed 12/16/2015): 199p. Available online at: www.wrh.noaa.gov/sgx/document/weatherhistory.pdf.

Zelinsky DA, Pasch RJ. 2015. Hurricane Marie (EP 132014) 22-28 August 2014, National Hurricane Center Tropical Cyclone Report. NOAA and National Weather Service (NWS) Report # EP132014

Appendix B: Asset Exposure by Sector

This appendix includes excerpts of asset exposure by sector to SLR and coastal flooding extracted from the from the City's Vulnerability Assessment. A descriptive overview is provided for each asset sector, as well as a discussion of exposure and tables with supporting quantitative information. Additional information on sensitivity and adaptative capacity of exposed assets can be found in the City's Vulnerability Assessment. The full Vulnerability Assessment report is available for review.[18]

Buildings and Facilities

The Buildings and Facilities sector include two asset-types: City-owned buildings and facilities and privately-owned buildings.

Asset Overview

The Buildings and Facilities sector includes City-owned buildings and facilities and privately-owned buildings. Depending on the height and use, buildings may be constructed out of wood, masonry, concrete, and/or steel and glass. In addition to the building structure, this assessment considers their mechanical, electrical, and plumbing systems.

City-owned buildings and facilities include critical emergency response facilities, such as fire and police stations as well as buildings that serve vulnerable populations, such as health resource centers and schools. In addition to over 150 schools, there are over 160 City-owned buildings and facilities in Long Beach. Privately-owned buildings include residential, commercial, and industrial structures. Private hospital buildings were also assessed.

Exposure of City-Owned Buildings and Facilities

Table 15 shows that a total of 10 City-owned buildings and facilities are projected to be exposed to annual king tides with 11 inches of SLR. These buildings are located along the Alamitos Bay Marina or within the Harbor District. Two of these 10 buildings are fire stations, which are critical for emergency response. One of the fire stations is located in the Harbor District while the other fire station is located along the Alamitos Bay Marina.

A solid waste facility is also exposed to annual king tide flooding with 11 inches of SLR. This facility is the Southeast Resource Recovery Facility, which is owned by a joint powers agreement between the Sanitation Districts and the City of Long Beach and is located within the Harbor District. Several Marine Safety and Park, Recreation, & Marine facilities are also projected to be exposed to king tide flooding with 11 inches of SLR.

With 11 inches of SLR, in addition to the 10 buildings exposed to king tide events, seven additional buildings are projected to be exposed to the 100-year storm surge. These are a fire station, the Belmont Shore Library, the Naples Bayside Academy, and four Marine Safety and Park, Recreation & Marine Facilities.

[18] http://www.lbds.info/civica/filebank/blobdload.asp?BlobID=7362&_sm_au_=iVVQTZkVkj47rV5D

With 66 inches of SLR (2100 high-range), up to 26 City buildings are exposed to annual king tides and an additional 13 are projected to be exposed to the 100-year storm surge.

The City's Emergency Communications and Operations Center is not projected to be exposed to the studied levels of SLR and storm surge.

Table 15: Number of City Buildings and Facilities Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24'' SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Fire Station	2	1	3	1	4	1	4	3
Health Resource Center	0	0	0	1	1	0	1	0
Library	0	1	1	0	1	0	1	0
Marine Safety	3	2	5	0	5	3	6	2
Park, Rec, and Marine	3	2	4	1	5	3	7	2
Police Facility	0	0	0	2	2	0	3	0
Schools	0	1	1	2	3	0	3	5
Solid Waste Facility	1	0	1	0	1	0	1	0
Other	0	0	0	0	0	1	0	1
Total	**10**	**7**	**15**	**7**	**22**	**8**	**26**	**13**

Exposure of Privately-Owned Buildings

With 11 inches of SLR, approximately 1.3 million square feet of buildings are projected to be exposed to annual king tides. Approximately half of these buildings are residential (624,100 square feet) and half are commercial (689,600 square feet). These buildings are primarily located in Marina Pacifica and along Shoreline Drive south of Ocean Boulevard. An additional 9.5 million square feet of buildings, primarily residential, are exposed to flooding from a 100-year storm surge with 11 inches of SLR. These buildings are primarily located in Naples Island, Belmont Shore, and the Peninsula.

Excluding buildings within the Harbor District, industrial buildings are not exposed to annual king tides until 37 inches of SLR, and none are exposed to the 100-year storm surge until 24 inches of SLR.

Without adaptation, by 2100, up to 17 million square feet of buildings are exposed to annual king tide flooding and an additional 4 million square feet are exposed to the 100-year storm surge.

No hospitals are projected to be exposed to the evaluated levels of SLR and storm surge.

Table 16: Square footage of Privately-Owned Buildings Exposed to Sea Level Rise and 100-year Storm Surge*

	2030	2050	2100	2100
	(11" SLR)	(24'' SLR)	(37" SLR)	(66" SLR)

	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Residential	624,100	8,520,200	7,226,300	3,661,800	10,458,200	1,599,900	11,923,200	3,112,900
Commercial	689,600	930,500	1,106,800	741,900	1,875,200	698,800	2,189,900	837,400
Industrial	0	0	0	1,186,800	2,035,500	866,200	2,946,100	69,100
All others	0	117,300	112,800	48,500	165,200	17,000	185,000	3,700
Total	**1,313,700**	**9,568,000**	**8,445,900**	**5,639,000**	**14,534,100**	**3,181,900**	**17,244,200**	**4,023,100**

Note: Excludes buildings located in the Harbor District

Parks & Open Space

The Parks and Open Space assets include City parks, beaches, and wetlands. These asset types are not mutually exclusive. For example, several City-owned parks feature wetlands and several beaches include parks. Assets that overlap different asset-types have been noted below.

City Parks

Asset Overview

The City of Long Beach has over 200 parks citywide. City parks range in type from active recreation parks with playgrounds, courts, playing fields, and/or boating facilities while others are more passive with lawns, paths and/or native habitat. Other parks are more urban and include hardscaped plazas or promenades. In addition to various types of landscaping sensitive to saltwater exposure, parks often include electrical components, such as lighting.

Exposure

With 11 inches of SLR, portions of 17 parks are projected to experience annual king tide flooding while an additional five are projected to experience temporary flooding due to 100-year storm surge (Table 17). Out of the 17 parks that are projected to be exposed to king tide flooding with 11 inches of SLR, one (Rosie's Dog Beach) is projected to be 50% exposed to flooding, three are projected to be 20% exposed, and the remaining parks are projected to be 10% or less exposed.

In Southeast Long Beach, several parks are projected to be exposed to annual king tides by 2030. Active recreation parks include Marine Stadium, Leeway Sailing Center, Bayshore Playground, and Jack Nichol, and Rosie's Dog Beach. Urban parks with hardscaping include Belmont Pier and Plaza. Parks with native habitat include Jack Dunster Marine Reserve.

The Downtown Long Beach area also has several parks that are projected to experience annual king tide flooding with 11 inches of SLR. These are primarily passive recreation parks, featuring pedestrian paths and lawns, such as Rainbow Harbor Esplanade, Shoreline Aquatic, and Downtown Marina Mole. The Jack Dunster Marine Reserve features natural habitat for public recreation and education and is also projected to begin to experience flooding due to annual king tides when combined with 11 inches of SLR.

Table 17: Number of City-Owned Parks Exposed to Sea Level Rise Combined with King Tide and 100-year Storm Surge

	2030 (11" SLR)	2050 (24'' SLR)	2100 (37" SLR)	2100 (66" SLR)

	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Number of Parks	17	5	20	8	31	7	36	5

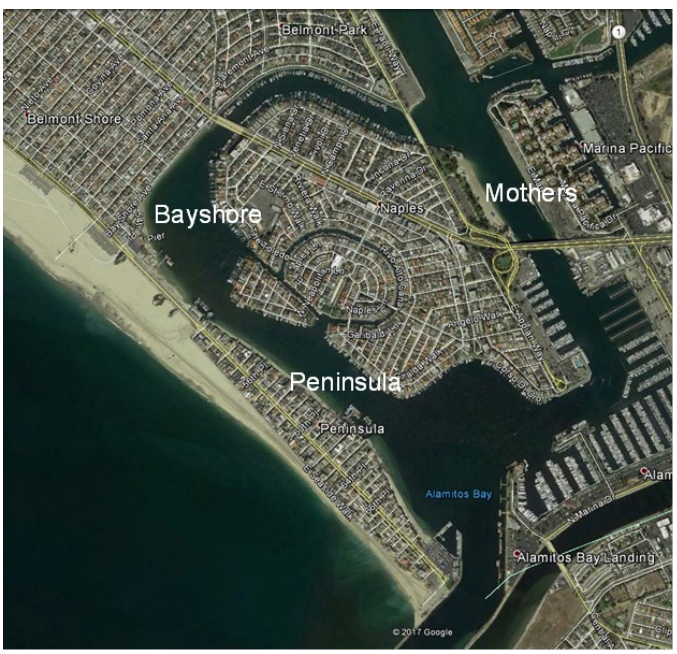
Beaches

Asset Overview

Long Beach has four open coast beaches: Alamitos, Junipero, Belmont, and Peninsula, which are shown in Figure 17. Long Beach has three beaches within Alamitos Bay: Bayshore, Peninsula, and Mothers, which are shown in Figure 17.

Figure 17: Open Coast Beaches

Figure 18: Alamitos Bay Beaches



Exposure

The exposure assessment for beaches focuses on beach width change at 11 inches (2030), 24 inches (2050), 37 inches (2100), and 66 inches (2100) of SLR. Change in beach width for open coast beaches was evaluated using CoSMoS 3.0 sandy shoreline projections for the “hold the line, no nourishment” scenario. Change in beach width for Alamitos Bay beaches was evaluated using permanent inundation projections obtained from the National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Viewer[19].

Beach width, as shown in Table 18, varies due to coastal dynamics and the presence of backshore features, such as parking lots that are built on the beach. When the sandy shoreline retreats up against a developed backshore feature, the beach width decreases to zero, and there is potential for complete loss of the sandy beach. Without interventions (such as beach nourishment), parts of Bayshore and Peninsula beaches in Alamitos Bay are projected to have zero width with 24 inches of SLR. All three Alamitos Bay beaches are projected to have zero width (complete loss) with 66 inches of SLR.

The open coast beaches are somewhat less susceptible to losses, but Junipero and Peninsula are projected to have zero width in some places (such as along beaches with backshore parking lots) under the 24 inches of SLR by 2050 scenario.

Table 18: Beach Exposure Assessment: Projected Beach Width

Beach	Existing Width (feet)	Projected Beach Width (feet)			
		2030 (11 "SLR)	2050 (24” SLR)	2100 (37” SLR)	2100 (66” SLR)
Open Coast					
Alamitos	200 to 400	250 to 500	200 to 400	150 to 400	50 to 300
Junipero	100 to 550	50 to 500	0 to 350	0 to 400	0 to 250
Belmont Shore	350 to 850	300 to 800	250 to 750	200 to 650	100 to 600
Peninsula	150 to 700	100 to 700	0 to 600	0 to 600	0 to 350
Alamitos Bay					
Bayshore	35 to 100	20 to 90	0 to 50	0	0
Peninsula	50 to 80	40 to 70	0 to 60	0 to 30	0
Mothers	110 to 160	95 to 145	85 to 120	75 to 105	0

Wetlands/Natural Habitats

Asset Overview

Wetlands in the City of Long Beach occur along the coastline, rivers and waterways, and in small scattered pockets amid developed areas. These present day wetlands are representative of remnant wetlands that historically occurred over much larger surface areas. Wetlands in Long Beach can be divided into freshwater wetlands and estuarine (part saline, part freshwater) wetlands. Riverine wetlands, a third category, are a combination of freshwater and estuarine wetlands, depending on the location in the river the wetland is, and whether it is upstream of the salt-zone (boundary line of tidal/salt water influence). Wetlands provide important

[19] https://coast.noaa.gov/slr/; Accessed September 2018.

habitat for wildlife and fish species. In addition to wildlife habitat, marshes provide coastal stability to reduce erosion, and act as nature's sponges to absorb rising tides and reduce wave energy during storm events. Marshes play an important role in carbon storage capacity, chemical nutrient uptake, and as biofiltration for pollutants that occur in surface water runoff, treating the water onsite before the pollutants spread.

There are six named wetland and natural area sites that are assessed in this evaluation: The Jack Dunster Marine Biological Reserve, the Golden Shore Marina Reserve, Los Cerritos Wetlands Complex, the San Gabriel River, the Los Angeles River, and the Colorado Lagoon. These wetlands can be divided into estuarine: Jack Dunster Marine Biological Reserve, Golden Shore Marina Reserve, and the lower stretches of the San Gabriel and the Los Angeles rivers; and freshwater: the Colorado Lagoon, and the upstream portions of the San Gabriel and Los Angeles rivers. Several additional wetlands occur throughout the City, such as the freshwater pond south of the Del Lago gated community at Loynes Drive and Highway 1, and east of Highway 1 in the Bixby Village Golf Course, along with the freshwater wetlands associated with the El Dorado Nature Center.

Exposure

With 11 inches of SLR, wetlands that occur from the coastline and harbors, upriver to the 405 on the Los Angeles River and upriver to the 605 on the San Gabriel River will be impacted. These include the estuarine wetlands associated with the Los Angeles River and the Port of Long Beach area, and the estuarine wetlands associated with the San Gabriel River and Alamitos Bay.

The Jack Dunster Marine Reserve estuarine wetlands will be exposed to annual king tide flooding with 11 inches of SLR. This area is an important remaining wetland habitat in the City of Long Beach because it is some of the last remaining wetland habitat and provides a suite of ecosystem services.

The Los Cerritos Wetlands Complex is composed of estuarine and freshwater wetlands. The northern portion of the complex north of East 2nd Street and consisting of estuarine and freshwater wetlands is exposed to SLR at 11 inches. South of East 2nd Street, in the Los Cerritos Wetlands Complex, freshwater wetlands are exposed to SLR at 66 inches. The freshwater pond south of the Del Lago gated community at Loynes Drive and Highway1 is exposed to annual king tide flooding at 66 inches.

The Colorado Lagoon is tidally connected to Marine Stadium through culverts under Marina Vista Park. An evaluation of SLR impacts within Colorado Lagoon was not possible because the CoSMoS model does not simulate flow through water control structures (such as culverts) and information on the tidal characteristics within the lagoon was not available. The Colorado Lagoon Restoration Project will remove the culverts and construct an open channel connection to Marine Stadium, introducing full tidal exchange. Components of the restoration project such as grading, foot bridge deck and supports, road crossings and elevations, etc. have been designed with considerations for SLR.

Marinas

Vulnerability Summary

Marina assets typically include boat slips, docks, showers and restrooms, pump out stations, fuel services, equipment supply stores, storage, and shipyard facilities. There are a number of public marinas along the Long Beach shoreline (such as the Alamitos Bay Marina and Long Beach Shoreline Marina) that may be impacted by SLR and elevated water levels in the future. Sailing, fishing, boating, and waterfront bars and restaurants are an important part of Long Beach's economy that could be impacted.

High water levels from king tides, storm surge, and SLR may impact marina operations in a number of ways. High tide events that overtop the marina shorelines may affect access to marina docks and boat slips. In addition, shoreline facilities such as showers, restrooms, and marina offices, etc. may be damaged by floodwaters. In addition, Long Beach Shoreline Marina is home to fire rescue, lifeguard rescue, and police boats. Higher water levels during extreme events could impact marine emergency response if these facilities are impacted. While most marina areas have floating docks and can therefore accommodate moderate water level fluctuations within their design range, during extreme water level events, docks may float off their pilings or gangways may become separated from docks and limit access.

During combined wave and high tide events, protective structures such as breakwaters may become less effective as waves overtop the crest of these structures and allow waves to enter protected areas. The Long Beach Shoreline Marina has an offshore detached breakwater and an attached breakwater at Grissom Island that could lose effectiveness in the future due to SLR unless their crest elevations are raised. There is also a breakwater within the Alamitos Bay Marina that could be overtopped by high tides and boat wakes during future high-water level events as a result of SLR.

Transportation Assets

The transportation asset sector includes roads, bike paths, and bridges.

Roads

Asset overview

Roads in Long Beach consist of highways, arterials, and neighborhood streets. Roads are constructed from asphalt or concrete. Roads also include lighting and other electrical equipment.

Exposure

With 11 inches of SLR, four miles of road are projected to be exposed to annual king tides. The majority of the roads that will be impacted at 11 inches are in the Long Beach Harbor District. Impacted roads in other areas are generally only slightly affected along portions in close proximity to existing water levels. Impacted areas include stretches of Seaside Freeway, Highway 47, Pier A Way and Carrac Avenue. These roads provide access to Port facilities, the NRG Power Station and other industrial operations. An additional 45 miles of road would be exposed to 100-year storm surge flooding with 11 inches of SLR.

Without adaptation, up to 98 miles of road could be exposed to annual king tide flooding by the end-of-century.

Table 19: Miles of Roads Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11” SLR)		2050 (24’’ SLR)		2100 (37” SLR)		2100 (66” SLR)	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Roads (miles)	4	45	41	32	74	16	89	27

Bikeways

Asset Overview

Bikeways include Class I, II, and III bikeways. Class I are separated from the street or highway. Class II is a striped lane on a street, and Class III provides for shared use with motor vehicle traffic and is identified by signage. Bikeways are important for providing safe travel for bicyclists.

Exposure

With 11 inches of SLR, one mile of bikeway is projected to be exposed to annual king tides and an additional three miles are projected to be exposed 100-year storm surge flooding. The main bikeway that will be exposed to annual king tides with 11 inches of SLR is along Boathouse Lane next to the Jack Dunster Marine Biological Reserve (see Figure 5).

Sections of the bike path along the Alamitos, Junipero, and Belmont Shore Beaches would experience inundation at 37 inches of SLR (see Figure 5 and Figure 6).

The bike path around the Shoreline Marina is projected to experience inundation at 37 inches of SLR (see Figure 6).

Table 20: Miles of Bike Paths Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24" SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide*	Additional Exposure Due to Storm Surge	Annual King Tide	Additional Exposure Due to Storm Surge
Bike paths (miles)	1	3	3	4	6	5	10	5

Bridges

Asset Overview

Bridges are made primarily of concrete and are comprised of distinct components such as approaches, a deck, a superstructure, and sub-structure (including piers). They may also have auxiliary equipment such as streetlights and other electrical and mechanical components, and often support some utility crossings. Some bridges are owned by the City and others are owned by the State Department of Transportation (Caltrans). There are over 120 City-owned and over 110 State-owned bridges citywide. The bridges asset data used in this assessment is from Caltrans, which generally identifies the location of the bridge approach. This tends to represent the lowest part of the bridge.

Exposure

The available bridge data represents single points approximately located at the bridge approaches. Because this data is not detailed enough to accurately assess flood impacts to bridges, a simplified approach was taken to identify bridges that may be exposed to future flood hazards. A 500-foot search radius was applied to the highest SLR scenario (66" SLR + storm surge) to assess which bridges are within a zone of vulnerability and would benefit from further analysis to evaluate exposure to future SLR-related inundation and flooding. 44 local bridges and 16 state bridges were identified within this SLR vulnerability area (Table 21). More detailed asset data and further analysis is required to identify which of these will be potentially impacted at each SLR scenario – for example, by comparing projected future water levels to bridge deck or soffit elevations and reviewing structural design plans to evaluate sensitivity to marine floodwaters. This level of analysis would require a comprehensive dataset of structural details related to the bridge design, which was not feasible to compile or evaluate as part of this study

Table 21: Number of Bridges Within 500 Feet Buffer of 66" of Sea Level Rise Plus 100-year Storm Surge

	Number of Bridges Within 500ft of 66" SLR + 100-year Storm Surge (2100)	
	Local Bridges	State Bridges
Bridges	44	16

Energy Assets

The Energy asset sector includes Generation Facilities, Transmission Lines, Electrical Substations, and Natural Gas Mains.

Asset Overview

Long Beach has over 200 miles of transmission lines citywide. They are owned and operated by Southern California Edison. Transmission lines carry high voltage power from generation facilities to substations. They are most often carried on overhead lines.

Long Beach has approximately 42 substations citywide. They are owned and operated by Southern California Edison. Substations serve to transform electricity from the high voltage transmission network to the lower voltage distribution network. They consist of electrical equipment and may be on a pad outdoors or within a structure.

Long Beach has three generation facilities. The NRG Long Beach Generating Station is located in the Harbor District and is owned and operated by NRG. Hayes Generating Facility, located East of the San Gabriel River, is owned and operated by the Los Angeles Department of Water and Power. The Alamitos Energy Station, located West of the San Gabriel River, is owned and operated by AES California. It is being redeveloped and is anticipated to include improvements that would make it more resilient to SLR.

Long Beach also has several smaller storage containers and over 900 miles of natural gas mains citywide. They are owned and operated by the Long Beach Energy Resources Department and deliver natural gas to homes and businesses. Natural gas mains are located underground.

Exposure

With 11 inches of SLR, the NRG Generating Station is projected to be exposed to annual king tides. During a 100-year storm event with 11 inches of SLR, the Alamitos Generating Station would also be exposed, although it is being redeveloped.

One substation is projected to be exposed to annual king tide with 11 inches of SLR. It is called "Seabright" and is located near the Los Angeles River. With 66 inches of SLR, the "Marina" substation is projected to be inundated. It is located near the Davies Boat Launch in Alamitos Bay.

With 11 inches of SLR, eight miles of transmission lines could be exposed to annual king tides. While transmission lines are generally carried on overhead lines, the bases of the transmission towers supporting the lines may be exposed. They may not have been designed for regular inundation, which could cause access issues for maintenance purposes.

With 11 inches of SLR, one mile of natural gas mains would be exposed to annual king tide flooding with an additional 25 miles exposed during a 100-year storm surge with 11 inches of SLR.

Table 22: Energy Sector Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24" SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Generation Facilities (number)	1	1	1	1	2	0	2	0
Electrical Substations (number)	1	0	1	1	1	2	2	2
Transmission Lines (miles)	8	0	9	3	13	2	15	5
Natural Gas Mains (miles)	1	25	21	19	41	11	53	21

Stormwater Assets

The stormwater assets assessed include storm drain outfalls and storm drain carriers.

Asset Overview

Stormwater assets are part of the urban drainage system that conveys stormwater away from buildings and streets into pipes, channels, and finally through outfalls into water bodies, such as the ocean, bay or rivers. Storm drain carriers include pipes and open channels. There are over 440 miles of storm drain carriers in the City. Storm drain outfalls are the discharge point from the carrier to a body of water. There are over 400 storm drain outfalls citywide in Long Beach. Stormwater pump stations are used to pump away large volumes of water to prevent flooding. There are 55 stormwater pump stations in Long Beach.

Exposure

With 11 inches of SLR, 18 storm drain outfalls may be exposed to annual king tides. An additional five may be exposed to 100-year storm surge flooding. It should be noted that this is a preliminary assessment of potential exposure and more detailed analysis would need to be conducted to determine exact elevations of outfalls with respect to projected SLR and the outfall conditions, such as whether they have backflow prevention devices. Exposure of outfalls to SLR could result in stormwater flooding upstream as the outfall is blocked from discharging, and water backs up into the drainage system. Many of the storm drain outfalls that would be exposed earliest are around Alamitos Bay (which drain Belmont Shore and Marina Pacifica) and along the Los Cerritos Channel. Other outfalls that would be exposed earliest are around the mouth of the Los Angeles River and Queensway Bay (which drain the downtown area).

With 11 inches of SLR, one stormwater pump station may be exposed to annual king tides. This pump station is located on the northeastern side of Naples Island at E 2nd Street. An additional six may be exposed to 100-year storm surge flooding. Five of these are located around Naples Island and Belmont Shore.

Exposure of storm drain carriers to SLR reduces their capacity and can cause upstream flooding. Approximately 1 mile of storm drain carriers are projected to be exposed at 11 inches of SLR. An additional 14 miles would be exposed to 100-year storm surge flooding with 11 inches of SLR. Overland flooding of buried storm drain carriers can saturate soils and lead to increased infiltration into stormwater pipes or flooding of catch basins and reduce conveyance capacity.

Table 23: Stormwater Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24" SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Storm Drain Outfalls (number)	18	5	23	13	30	13	39	28
Stormwater Pump Stations (number)	1	6	5	4	10	2	11	3
Storm Drain Carriers (miles)	1	14	12	17	29	10	38	11

Wastewater Assets

The wastewater assets assessed include wastewater treatment plants, sewer pump stations, sewer forced main, and sewer gravity mains.

Asset Sector Overview

The wastewater system conveys wastewater from homes and businesses to a wastewater treatment plant for treatment then discharge. The majority of wastewater in Long Beach is treated at the Joint Water Pollution Control Plant, which is located in Carson. Because this plant is not located in Long Beach, its vulnerability could not be assessed as part of this study. SLR impacts to this plant would cascade to the entire wastewater system, so further study of the vulnerability of this plant is recommended. The remaining portion of the City's wastewater is delivered to the Long Beach Reclamation Plant of the Los Angeles County Sanitation Districts, which is located in Long Beach (7400 Willow Street). Where needed, pump stations move wastewater to higher elevations so that they can be transported by gravity flow (in sewer mains) to the wastewater treatment plant. Force mains convey wastewater under pressure to higher elevations from the downstream pump stations.

Exposure

With 11 inches of SLR, no sewer pump stations are projected to be exposed to annual king tides by 2030. However, with 11 inches of SLR, four pump stations are projected to be exposed to 100-year storm surge flooding. Three of these pump stations are owned by Long Beach Water Department and are located in the southeastern subarea (Marine Stadium, Belmont Shore, and Naples Island), and one is owned by the Parks, Recreation and Marine Department and is located at Shoreline Marina. With 66 inches of SLR, up to 15 pump stations are projected to be exposed to annual king tides.

With 11 inches of SLR, approximately 220 feet of force main and 280 feet of sewer mains are anticipated to be exposed to annual king tide flooding. These are located primarily around Naples Island and Marina Pacifica. By late century with 66 inches of SLR, up to 52 miles of sewer mains and five miles of force mains could be exposed to annual king tides.

The Long Beach Reclamation Plant is not exposed to the evaluated levels of SLR and storm surge.

Table 24: Wastewater Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24" SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Pump Stations (number)	0	4	2	8	9	6	14	3
Force Mains (miles)	<1	2	2	2	4	0	4	2
Gravity Mains (miles)	<1	24	18	21	40	12	52	20

Potable Water Assets

The potable water assets assessed include potable facilities, mains, and hydrants.

Asset Sector Overview

The Long Beach Water Department oversees the infrastructure that provides potable water to Long Beach homes and businesses through a system that includes a treatment plant, reservoirs, tanks, and interconnections (facilities), and main lines (mains). Potable mains are in most cases underground. Hydrants supply water for firefighting purposes.

Exposure

With 11 inches of SLR, one potable facility (an interconnection) is projected to be exposed to annual king tides. It is located in the Harbor District and is an interconnection with the Los Angeles Department of Water and Power (LADWP) (see Figure 7). With 66 inches of SLR, four potable facilities could be exposed to annual king tides. These facilities are also interconnections with the City of Seal Beach Water District, LADWP, and the Harbor Department. The Groundwater Treatment Plant is not exposed to the studied levels of SLR and storm surge.

With 11 inches of SLR, 1 mile of potable mains are anticipated to be exposed to annual king tides and an additional 25 miles are projected to be exposed to 100-year storm surge flooding.

With 11 inches of SLR, four hydrants are anticipated to be exposed to annual king tides and an additional 213 are projected to be exposed to 100-year storm surge flooding. By late-century with 66 inches of SLR, nearly 500 hydrants may be exposed to annual king tides.

Table 25: Potable Assets Exposed to Sea Level Rise and 100-year Storm Surge

	2030 (11" SLR)		2050 (24" SLR)		2100 (37" SLR)		2100 (66" SLR)	
	Annual King Tide	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide*	Added Exposure Due to Storm Surge	Annual King Tide	Added Exposure Due to Storm Surge
Potable Facilities (Number)	1	0	1	1	3	1	4	0
Potable Mains (Miles)	1	25	21	21	42	14	56	24
Hydrants (Number)	4	213	160	204	359	135	493	19

Appendix C: Detailed Financial Cost Analysis Results

The appendix includes more detailed financial cost results compared to those presented in Section 4 above. Results for direct property and business and employment impacts are organized based on land use classifications adapted from the Los Angeles County Assessor to illustrate how the magnitude of financial vulnerability from future coastal hazards varies by economic sector. Fiscal impacts distinguish between property and sales tax losses. Beach recreation impacts breakout estimates of non-market value as well as business and fiscal impacts associated with beach spending. Infrastructure asset exposure is reported for sub-sectors that include transportation, energy, wastewater, stormwater and potable water. Results are limited to assets that intersect with tidelands boundaries.

Table 26. Future Year Property Impacts (2018 Dollars)

SUMMARY OF ONE-TIME STORM FLOODING AND TIDAL INUNDATION IMPACTS TO DIRECT PROPERTY						
Impact Type	2030 Conditions *~11" of SLR*		2050 Conditions *~24" of SLR*		2100 Conditions *~66" of SLR*	
	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure
Commercial	$0	$310,000	$0	$330,000	$840,000	$78,000
Government	$0	$1,500,000	$0	$2,400,000	$14,900,000	$10,200,000
Industrial	$0	$0	$0	$0	$150,000	$42,000
Residential	$0	$610,000	$0	$1,700,000	$54,100,000	$9,300,000
Miscellaneous	$0	$0	$0	$0	$0	$0
TOTAL	**$0**	**$2,420,000**	**$0**	**$4,430,000**	**$69,990,000**	**$19,620,000**

Notes:
Impacts exclude public parking lots and parcels with no structures.
Tidal impacts account for the market value or closest proxy while storm impacts account for structure, content, and clean-up costs.

Table 27. Future Year Business Impacts (2018 Dollars)

SUMMARY OF ONE-TIME STORM FLOODING AND TIDAL INUNDATION IMPACTS TO SALES

Impact by Land Use	2030 Conditions ~11" of SLR		2050 Conditions ~24" of SLR		2100 Conditions ~66" of SLR	
	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure
Commercial	$0	$0	$0	$0	$0	$0
Government	$0	$15,000	$0	$20,000	$1,400,000	$0
Industrial	$0	$0	$0	$0	$0	$26,000
Residential	$0	$0	$0	$1,000	$100,000	$850,000
Miscellaneous	$0	$0	$0	$0	$0	$0
TOTAL	**$0**	**$15,000**	**$0**	**$21,000**	**$1,500,000**	**$876,000**

Table 28. Future Year Employment Impacts (2018 Dollars)

SUMMARY OF ONE-TIME STORM FLOODING AND TIDAL INUNDATION IMPACTS TO WAGES

Impact by Land Use	2030 Conditions ~11" of SLR		2050 Conditions ~24" of SLR		2100 Conditions ~66" of SLR	
	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure
Commercial	$0	$0	$0	$0	$0	$0
Government	$0	$26,000	$0	$26,000	$1,900,000	$600
Industrial	$0	$0	$0	$0	$0	$18,000
Residential	$0	$0	$0	$3,000	$230,000	$360,000
Miscellaneous	$0	$0	$0	$0	$0	$0
TOTAL	**$0**	**$26,000**	**$0**	**$29,000**	**$2,130,000**	**$378,600**

Table 29. Future Year Fiscal Impacts (2018 Dollars)

SUMMARY OF STORM FLOODING AND TIDAL INUNDATION IMPACTS TO PROPERTY AND SALES TAXES

Impact Type	2030 Conditions ~11" of SLR		2050 Conditions ~24" of SLR		2100 Conditions ~66" of SLR	
	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure	Daily Tidal Exposure	Additional 100-Year Storm Exposure
Property Tax Loss	$0	$30,000	$0	$55,000	$730,000	$150,000
Sales Tax Loss	$0	$1,000	$0	$2,000	$140,000	$81,000
TOTAL	**$0**	**$31,000**	**$0**	**$57,000**	**$870,000**	**$231,000**

Notes:
Sales tax of 10.25% is distributed with 7.25% for the State, 2% for the Metropolitan Transportation Agency, and 1% for the City of Long Beach.

Table 30. Future Year Beach Recreation Impacts (2018 Dollars)

SUMMARY OF TIDAL INUNDATION IMPACTS TO BEACH RECREATION

Impact Type	2030 Conditions *~11" of SLR*		2050 Conditions *~24" of SLR*		2100 Conditions *~66" of SLR*	
	Daily Tidal Exposure	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**
Recreational Value Loss (Non-Market Value)	$12,000,000	Not Applicable	$48,900,000	Not Applicable	$74,100,000	Not Applicable
Recreational Spending Loss	$19,300,000	Not Applicable	$83,500,000	Not Applicable	$128,500,000	Not Applicable
Recreational Sales Tax Loss	*$600,000*	*Not Applicable*	*$2,500,000*	*Not Applicable*	*$3,800,000*	*Not Applicable*
Recreational Transient Occupancy Tax Loss	*$150,000*	*Not Applicable*	*$770,000*	*Not Applicable*	*$1,200,000*	*Not Applicable*
TOTAL	**$32,050,000**	**Not Applicable**	**$135,670,000**	**Not Applicable**	**$207,600,000**	**Not Applicable**

Notes:
Italics indicate fiscal impacts but reported separately here.
Results only modeled for permanent progressive impacts from tidal inundation and do not include periodic storm impacts.
Spending losses were calculated in order to estimate sales and transient occupancy tax losses.
No wage losses have been estimated from a reduction in beach visitor spending because of limited data on what individual businesses are the recipients of such spending.
State tax losses account for 87% of total sales losses; local sales tax losses account for 13% of total sales tax losses.

Table 31. Future Year Infrastructure Replacement Costs (2018 Dollars)

SUMMARY OF STORM FLOODING AND TIDAL INUNDATION INFRASTRUCTURE REPLACEMENT COSTS

Asset Type	2030 Conditions *~11" of SLR*		2050 Conditions *~24" of SLR*		2100 Conditions *~66" of SLR*	
	Daily Tidal Exposure	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**	**Daily Tidal Exposure**	**Additional 100-Year Storm Exposure**
Transportation	$310,000 - $410,000	$9,000,000 - $12,100,000	$2,000,000 - $2,700,000	$10,600,000 - $14,300,000	$11,300,000 - $15,300,000	$10,300,000 - $13,900,000
Energy	$10,000 - $18,000	$800,000 - $1,200,000	$10,000 - $18,000	$3,500,000 - $5,200,000	$1,500,000 - $2,300,000	$3,500,000 - $5,100,000
Wastewater	$0	$6,000,000 - $45,200,000	$36,000 - $68,000	$15,100,000 - $127,500,000	$14,800,000 - $126,800,000	$10,400,000 - $71,100,000
Stormwater	$1,200,000 - $4,200,000	$3,800,000 - $17,800,000	$2,200,000 - $9,200,000	$4,400,000 - $20,200,000	$6,200,000 - $28,000,000	$5,600,000 - $25,000,000
Potable Water	$10,000 - $30,000	$1,900,000 - $5,700,000	$10,000 - $30,000	$2,900,000 - $8,600,000	$3,000,000 - $8,900,000	$2,900,000 - $8,600,000
TOTAL	**$1,500,000 - $4,700,000**	**$21,500,000 - $82,000,000**	**$4,200,000 - $12,000,000**	**$36,400,000 - $175,700,000**	**$36,800,000 - $181,200,000**	**$32,600,000 - $123,700,000**

Notes:
No determination is made on the degree of impact; rather full replacement cost values for a similar asset in the same location are shown.
Variability in the size, function and condition of the individual infrastructure assets made it infeasible to assign a unique replacement cost to each vulnerable asset. As such, unit cost ranges were used to illustrate conservative and less conservative estimates for similar asset types. Presented costs primarily account for hard costs of construction.