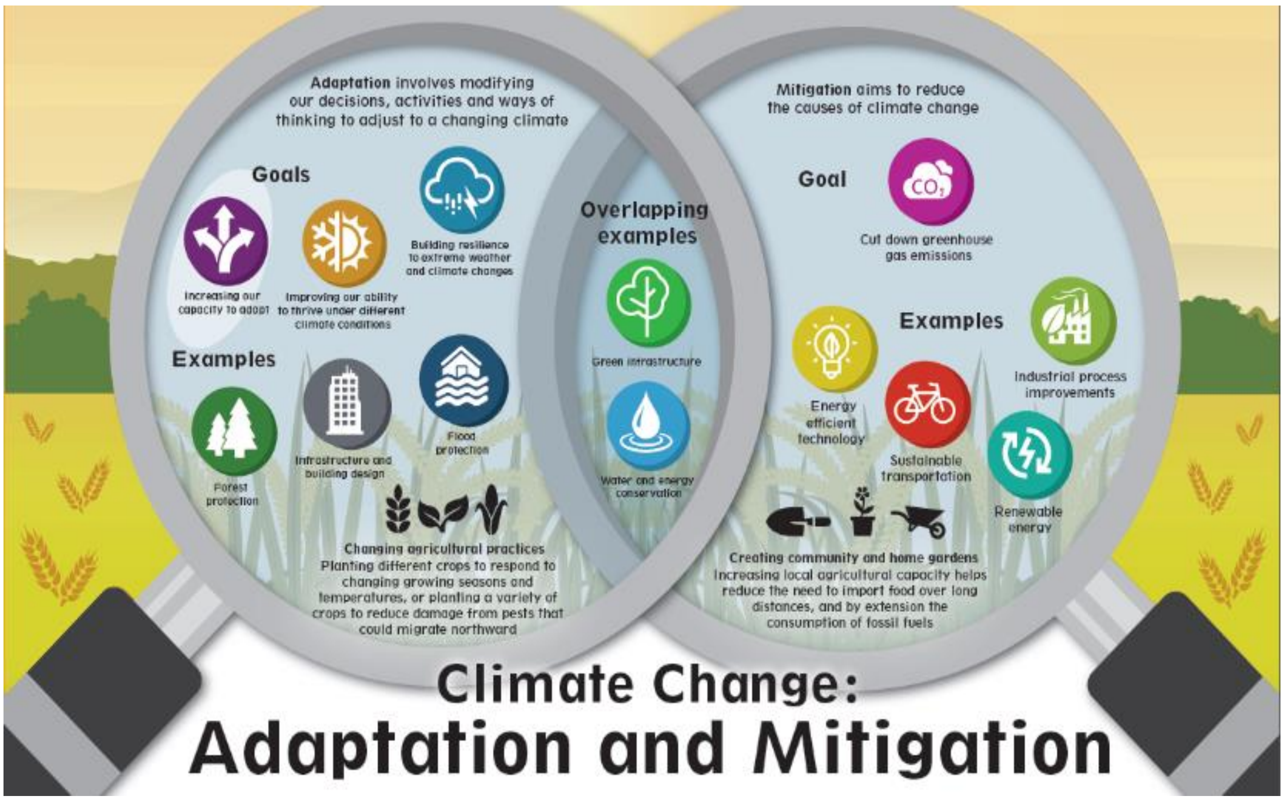
Sub-Regional Climate Adaptation Plan

South Bay Cities Council of Governments

September 13, 2019



Covering the Cities of: Carson, El Segundo, Gardena, Hawthorne, Hermosa Beach, Inglewood, Lawndale, Lomita, Manhattan Beach, Rancho Palos Verdes, Redondo Beach, Palos Verdes Estates, Rolling Hills, Rolling Hills Estates, Torrance

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Introduction

Executive Summary

> **Reduction of CO_2-Equivalent**
>
> *Many scientific bodies around the world have concluded that avoiding the most severe outcomes of climate change will require limiting CO_2-equivalent concentrations to below 450 parts per million by 2100, in order to maintain global warming below two degrees Celsius relative to pre-industrial levels by the end of the century.*

More than 10 years ago the South Bay Cities Council of Governments (SBCCOG) engaged member cities to assess and mitigate the extent to which our communities contribute to climate change by establishing their greenhouse gas (GHG) emissions inventories and providing assistance in developing city specific and a sub-regional Climate Action Plan(s) (CAP). Subsequently, 15 cities, as well as the sub-region, adopted climate action plans that identify strategies for GHG reductions. As a natural progression, the SBCCOG--again working with our member cities as well as experts in the field-- has developed this Climate Adaptation Plan. While the Climate Action Plan highlighted the greatest sources of greenhouse gases and strategies to reduce emissions, the Climate Adaptation Plan will allow cities to assess and mitigate the extent to which climate change will negatively impact South Bay communities. To support our cities in this work, the SBCCOG conducted a robust Vulnerability Assessment for the sub-region (Part 1) and selected adaptation strategies (Part 2) designed to support cities in mitigating their climate risk through education, training, planning, and outreach.

Need for and Purpose of Climate Adaptation Plan

According to the California Association of Environmental Professionals Beyond 2020,[1] scientific studies have demonstrated a causative relation between increasing man-made GHG emissions and a long-term trend in increasing global average temperatures. This conclusion is the consensus of a vast majority of climate scientists. The effects of past increases in temperature on the climate and the earth's resources are well documented in the scientific literature and are summarized in the Intergovernmental Panel on Climate Change's (IPCC) periodic reports, the latest of which is the Fifth Assessment Report, released in 2014.[2]

The IPCC's work to model and evaluate future climatic conditions indicates that if GHG emissions continue to increase at current rates, there will be substantial adverse effects to both humans and the natural environment. Many scientific bodies around the world have concluded that avoiding the most severe outcomes of climate change will require limiting CO_2 concentrations significantly by 2100, or earlier. To achieve reductions, the IPCC and organizations like the Union of Concerned Scientists have indicated that the United States and other developed countries would need to reduce greenhouse gas emissions anywhere from 78 to 95 percent below 1990 levels, with most organizations identifying a need to reduce approximately 80 percent below 1990 levels by 2050. Although the State of California has enacted legislation and executive orders[3] to curb the generation or release of additional GHG emissions, the state still faces intensifying impacts of climate change in coming decades due to the emissions already released into the atmosphere. The California Climate Adaptation Strategy indicates that California should expect overall hotter and drier conditions, with a continued reduction in winter snow (with concurrent increases in winter rains), as well as increased average temperatures and accelerating sea level rise.[4] In addition to changes in average temperatures, sea level, and precipitation patterns, the intensity of extreme weather events is also changing. In *California's Fourth Climate Change Assessment Los Angeles Region Report*[5] scientists predict the following climate changes:

> *"…California should expect overall hotter and drier conditions, with a continued reduction in winter snow as well as increased average temperatures and accelerating sea level rise."*

- Continued future warming over the LA region. Across the region, average maximum **temperatures** are projected to increase around 4-5 degrees Fahrenheit (F) by the mid-century, and 5-8 degrees F by the late century.
- **Extreme temperatures** are also expected to increase. The hottest day of the year may be up to 10 degrees F warmer for many locations across the LA region by the late century under a "business as usual" scenario. The number of extremely hot days is also expected to increase across the region.
- Despite small changes in average precipitation, **dry and wet extremes** are both expected to increase. By the late 21st century, the rainfall on the wettest day of the year is expected to increase across most of the LA region, with some locations experiencing 25-30% increases

under a “business as usual” scenario. Increased frequency and severity of atmospheric river events[a] are also projected to occur, which could cause extreme flooding in parts of the region.

- **Sea levels** are projected to continue to rise in the future, but there is a large range based on emissions scenario and uncertainty in the climate system. Roughly 1-2 feet of sea level rise is projected by the mid-century, and the most extreme projections lead to 8-10 feet of sea level rise by the end of the century.
- Projections indicate that the **wildfire** season may be extended longer throughout the year, but there remains uncertainty in quantifying the expected amount and area location of the burn.

For South Bay communities to continue to thrive in these projected future conditions, it is important to understand how climate change can manifest in the sub-region and develop strategies to adapt to the changing conditions. Development of this Climate Adaptation Plan will allow South Bay cities throughout the sub-region to:

- Be informed of how climate change will alter local weather patterns and conditions
- Understand the vulnerability of their residents and infrastructure to the impacts of climate change
- Be aware of the roles of agencies and organizations in different sectors to plan for and implement adaptation strategies relevant to their respective jurisdiction
- Develop and coordinate adaptation strategies across city boundaries
- Incorporate findings and analysis of climate impacts into local planning documents, facilitating compliance with state law including California Senate Bill 379, adopted in 2015 to ensure that climate adaptation is integrated into the general plan process

[a] An atmospheric river is a flowing column of condensed water vapor in the atmosphere responsible for producing significant levels of rain and snow in the Western United States.

<u>Alignment with California's Climate Adaptation Plan and SBCCOG's Climate Action Plan</u>

In 2009, California adopted a statewide Climate Adaptation Strategy (CAS) that summarizes climate change impacts and recommends adaptation strategies across seven sectors: Public Health, Biodiversity and Habitat, Oceans and Coastal Resources, Water, Agriculture, Forestry, and Transportation and Energy. The 2009 CAS was the first of its kind in the usage of downscaled, or locally applicable climate models. These downscaled models allow local jurisdictions to more accurately assess, prevent and respond to the effects of climate change.

Further assistance to local jurisdictions was provided by the Natural Resources Agency, in coordination with California Emergency Management Agency. These agencies developed the Adaptation Planning Guide (APG), which provides guidance to support regional and local communities in proactively addressing the unavoidable consequences of climate change. The SBCCOG utilized the APG, which provides a step-by-step process for local and regional climate vulnerability assessment and adaptation strategy development, to develop this sub-regional adaptation plan.

In 2018, the SBCCOG published its first Sub-Regional Climate Action Plan, a policy guidance document that puts forth specific strategies aimed to reduce the region's Greenhouse Gas emissions. One of the strategies presented in this report, known as the Sustainable Neighborhoods Strategy, incorporated land use approaches that aim to bring goods and services closer to households. The land use

CA Senate Bill 379…

California Senate Bill 379 (adopted 2015) requires all cities and counties to include climate adaptation and resiliency strategies in the safety elements of their general plans upon the next revision beginning January 2017.

The bill requires the climate adaptation update to include a set of goals, policies, and objectives for their communities based on a vulnerability assessment, as well as implementation measures.

components are complemented with mobility strategies in the form of electric vehicle expansion and workplace programs such as telecommuting. Other strategies included in the plan focus on energy efficiency, greening, waste reduction, and energy generation/storage.

The sub-regional Climate Adaptation Plan, therefore, prioritizes adaptation strategies that aim to bolster and add resiliency components to existing land use, mobility, greening, and energy generation/storage strategies put forth in the preceding Climate Action Plan.

Roles and Responsibilities: Regional Agencies and Local Governments

The State has acknowledged that regional agencies and utilities play an important role in protecting communities from the impacts of climate change. In Los Angeles County, the Southern California Association of Governments, Los Angeles County Metropolitan Transportation Authority, LA County Sanitation Districts, Metropolitan Water District, West Basin Municipal Water District, Los Angeles Department of Water and Power, Southern California Edison, SoCal Gas, among other agencies and local jurisdictions all have sole or partial responsibility over the protection of people and assets that are at risk from climate impacts. Several cities and regional agencies have already developed adaptation plans for their respective jurisdictions. Council of Governments, like the SBCCOG, can provide cities with resources and the technical capacity to assess the risk climate change can pose to communities, as well as develop and implement adaptation strategies aimed at reducing climate risk.

Profile: South Bay Cities Council of Governments—The Sub-region

The SBCCOG covers the South Bay sub-region of Los Angeles County -- a diverse area, exhibiting a variety of socioeconomic conditions, infrastructure types, neighborhood compositions, and geographies. Over one million people live, work, and recreate in the South Bay. The sub-region encompasses fifteen cities, as well as parts of the City of Los Angeles and unincorporated parts of Los Angeles County. It is bounded by the Pacific Ocean to the south and west, and generally by the City of Los Angeles to the north and east. The area is home to several distinct landscapes, including the *beach communities* of Hermosa Beach, Redondo Beach, Manhattan Beach, and El Segundo; the relatively flat, *inland communities* of Torrance,[b]

[b] Torrance also has a 1.5 mile stretch of coastline

Inglewood, Hawthorne, Gardena, Lomita, Lawndale, and Carson; and the *hillier Peninsula* cities of Rancho Palos Verdes, Rolling Hills, Rolling Hills Estates, and Palos Verdes Estates.

According to the 2017 5-year estimates, the population for the South Bay's fifteen incorporated cities is 758,836. The unincorporated areas of the sub-region have a total population of 96,184. The Wilmington, San Pedro, and Harbor City areas of the City of Los Angeles also fall in the sub-region boundaries, accounting for another 208,566. The total population for the South Bay sub-region is over one million.

The South Bay is a relatively affluent region, with the average median household income and average property value for all the cities totaling nearly $100,000 and $860,000, respectively (**Figure 1.1**); however, there are areas designated as "Disadvantaged Communities" (DAC) by CalEnviroScreen, an environmental health screening tool that identifies communities disproportionately burdened by and vulnerable to pollution. The South Bay's buoyant economy supports over 420,000 employees. 45% of people residing in the South Bay territory have a high-school degree or higher. The average median age of residents is just over 40, reflecting an increasingly aging community. The South Bay residents are predominantly white (54%), with 10% Black of African American, 15% Asian, and less than 2% of American Indian, Alaskan Native, or Pacific Islander. Over 30% of South Bay identify as Hispanic.

Table 1.1: City Profiles

South Bay Cities	Total Population	Avg Household Income	Employees	Avg Property Values
Carson	92927	$75,517	56722	$402,500
El Segundo	16929	$92,942	65057	$875,600
Gardena	60096	$50,807	31924	$407,000
Hawthorne	87425	$47,636	26580	$461,400
Hermosa Beach	19750	$124,849	7586	$1,220,500
Inglewood	111006	$46,389	30739	$389,600
Lawndale	33191	$54,862	5665	$417,600
Lomita	20707	$62,353	4644	$561,500
Manhattan Beach	35698	$148,899	19826	$1,694,900
Palos Verdes Estates	13591	$180,815	2682	$1,637,600
Rancho Palos Verdes	42463	$124,552	7882	$1,051,000
Redondo Beach	67950	$104,548	30243	$817,300
Rolling Hills	1684	$206,932	538	$2,000,000+
Rolling Hills Estates	8229	$131,471	4045	$1,153,700
Torrance	147190	$85,070	108979	$687,900
City of Los Angeles[c]	208566	$55,352	N/A	$425,788
Unincorporated	96184	$66,647	17225	$419,533
South Bay Subregion	**1063586**	**$97,626**	**420,337**	**$860,201**

Source: US Census Bureau, 2017

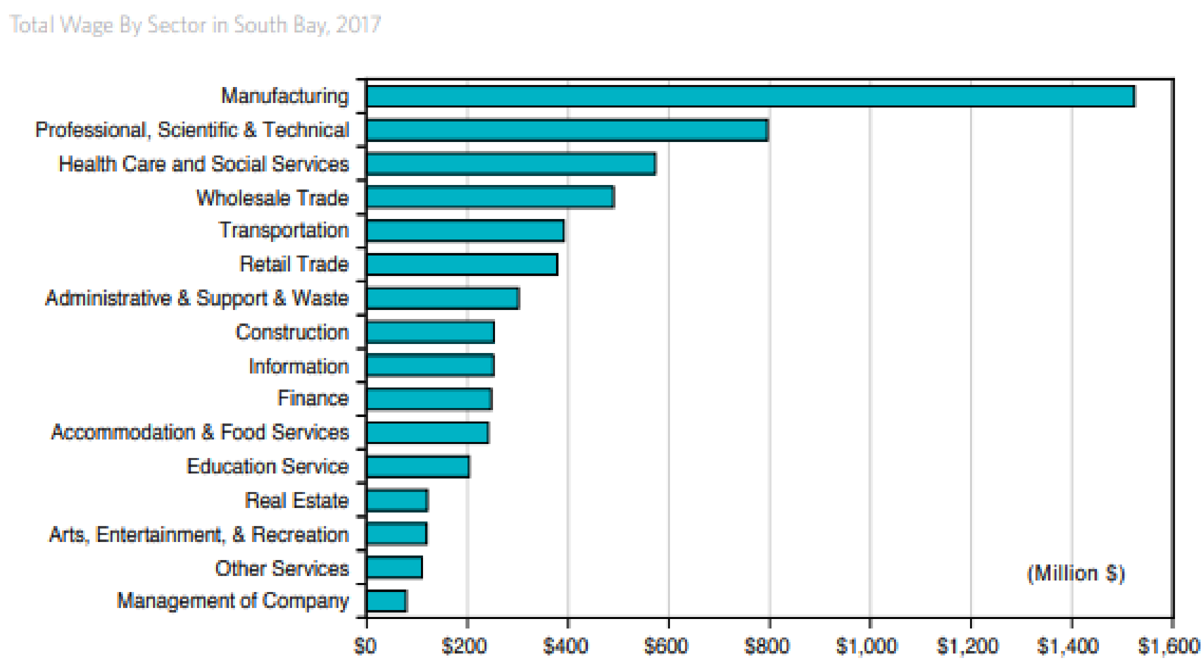
The South Bay offers an outstanding quality of life amidst a thriving economic engine. The area hosts some of the biggest names in the region's key industries, including aerospace, technology, global communications, medicine, military, and business applications. The South Bay is home to

[c] Harbor Gateway, Harbor City, Wilmington, SP

the Los Angeles Air Force Base, world headquarters for SpaceX and Mattel, American headquarters for Honda, and key divisions for Raytheon, Lockheed Martin, Computer Sciences Corporation, Boeing, Chevron, British Petroleum, Northrup Grumman, Xerox, and many others.

Figure 1.1 lists the largest industries in the South Bay, ranked by total wage payments. The manufacturing has the highest total wage payments of all industries in the South Bay ($1.52 billion) and is the largest job creator with 67,000 jobs.[6]

Figure 1.1: South Bay Total Wage by Sector –



Source: California Employment Development Department; data is the third quarter of 2017 from QCEW (Quarterly Census for Employment and Wages) calculated by zip code.

According to the California State University Dominguez Hills' 2018 Economic Forecast Report,[7] economists predict that the South Bay's growth rate will accelerate, due to the expansion of the federal government's defense budget. Additionally, SpaceX and the new Inglewood NFL stadium will continue to bolster the sub-region's economy.

Plan Overview

The Vulnerability Assessment provides information on how climate change will impact the South Bay. It serves as the foundation for developing the Adaptation Strategies. The Adaptation Strategies are a set of actions that the SBCCOG can take to help the sub-region be better prepared for the effects of climate change. Both chapters are needed to develop policy and direct resources to address changing climate conditions.

Vulnerability Assessment - The Vulnerability Assessment was developed with the assistance of subject experts[d] and includes a collection of region-specific data. Through the Assessment, sensitive populations and potentially impacted sectors were identified and analyzed to determine the sub-region's risk to climate stressors. The Vulnerability Assessment includes three components: a summary of climate projections, a social vulnerability assessment, and sector analyses.

Climate Projections - This section identifies and quantifies the climate stressors, or climate exposure the South Bay is projected to experience, using data from Cal-Adapt.org

Social Vulnerability - The social vulnerability assessment can help identify *locations* that will likely experience greater climate exposure and have heightened sensitivity to climate stressors. Vulnerable communities experience heightened risk and increased sensitivity to climate change, and have less adaptive capacity to cope with, adapt to, or recover from climate impacts. Indicators of social vulnerability were selected with the input of member-cities. This section maps indicators to highlight neighborhoods where a greater percent of the population is particularly susceptible to climate stressors based on social and economic indicators. A Heat Vulnerability Index was developed to determine the spatial distribution of heat wave vulnerability. These indices identify which communities are most at risk from these respective hazards.

Climate stressors are a condition, event, or trend related to climate variability and change that can exacerbate hazards such as increasing frequency and intensity of drought conditions

[d] Juliette Hart, USGS; Nick Sadrpour, USC Sea Grant, Elizabeth Reid-Weinscoat, UCLA Grand Sustainability Challenge; Jon Keeley, UCLA

Sector Analysis - Sectors considered in this plan include Water Management, Energy Management, Biodiversity, Coastal Management, Transportation and Climate Migration. The SBCCOG, in accordance with the Adaptation Planning Guide, examined specific sectors in order to categorize potential climate change impacts as well as identify existing plans and strategies that have been developed or implemented within the region.

Adaptation Strategy - Areas that will experience the greatest *exposure* to climate hazards in the near-term, have high numbers of *sensitive* populations, and lack the social, political, or financial *capacity* to cope with the impacts of climate change, should be prioritized for adaptation action and funding. The adaptation strategy development phase translates the Vulnerability Assessment into implementable actions that mitigate identified risk. The SBCCOG selected high-level adaptation strategies - with respect to the sectors discussed in the Vulnerability Assessment - aimed to better educate and equip South Bay cities to respond to the threats climate change poses on their communities. Only strategies for which the SBCCOG would be the implementing agency were considered and selected for this Plan.

Part 1: Vulnerability Assessment

The Vulnerability Assessment identifies the risks that climate change poses to the South Bay. Specifically, it identifies the region's potential exposure to climate change impacts, assesses the sensitivity of people and assets to climate exposures, and analyzes how the changing climate will impact different sectors.

The SBCCOG's Vulnerability Assessment includes datasets from a variety of sources. While the SBCCOG prepared some sections internally,[e] much of the discussion and analysis of climate impacts on specific sectors came from reports and plans that have been developed by subject experts and external agencies. The planning team reviewed all relevant information found in existing plans and reports and used best practices from other vulnerability assessments and adaptation plans to aid in the development of this sub-regional Vulnerability Assessment. Larger datasets and regional (county-level or larger scale) reports were synthesized and scaled to the sub-regional or city level in order to make the information relevant to South Bay stakeholders. This effort allows South Bay cities to better engage with the data relevant to their communities.

In this Vulnerability Assessment, the following climate projections and hazards were included:

- Temperature
- Precipitation
- Wind
- Sea Level Rise
- Flooding
- Drought
- Wildfire

In addition to the Vulnerability Assessment generated for the Sub-Regional Adaptation Plan, the SBCCOG has generated preliminary vulnerability assessments for each of its member cities.[f] These city assessments include a summary of climate projections, a risk assessment of critical facilities[g], and a social vulnerability analysis. The South Bay areas of Los Angeles County, the City of Los Angeles, and the Port of LA were not included in the city-specific planning exercise. References for these areas can be obtained in other plans specific to their jurisdiction.[h] City specific assessments can be found in **Appendix A** of this document.

[e] Critical facility data was collected and aggregated from a combination of open source data and verified by SBCCOG cities. The geospatial overlay analysis of critical facilities and vulnerable populations (social vulnerability) was prepared internally.
[f] Critical Facilities and Social Vulnerability are mapped with respect to relevant hazards.
[g] The assessment of critical facilities is included in city-specific vulnerability assessments given the granularity of the data.
[h] The vulnerability of the Port of LA is addressed in "Sea Level Rise Vulnerability Study for the City of Los Angeles" and the One County Sustainability Plan released in Spring 2019.

Climate Projections

As part of the technical work to prepare the Adaptation Plan, the SBCCOG recorded future projections for temperature, precipitation, and wind from Cal-Adapt. The SBCCOG also referenced scientific reports to determine the extent of sea level rise and how climate-related hazards including floods, wildfires, and drought will change in frequency and severity by 2050 and 2100.

Representative Concentrated Pathway (RCP) is a greenhouse gas concentration trajectory or forecast.

These projections are based on the standardized climate change scenarios from the Intergovernmental Panel on Climate Change (IPCC) Representative Concentrated Pathways (RCP) scenarios: the "mitigating" scenario (RCP 4.5) and the "business as usual" scenario (RCP 8.5). Guidance from the State Office of Planning and Research recommends local agencies and jurisdictions utilize the business as usual (RCP 8.5) for planning out to 2050 and utilize a risk management approach for the selection of emissions scenarios past 2060.[8] This recommendation was used to develop this vulnerability assessment.

Temperature

Climate change is expected to increase overall global temperatures.[9] Observations over the past century indicate that temperature has increased across southern California. Based on 1896-2015 temperature records for the California South Coast National Oceanic and Atmospheric (NOAA) Climate Division, which encompasses the LA region, researchers found significant trends in annual average, maximum, and minimum temperature around 0.16°C per decade. Every month has experienced significant positive trends in monthly average, maximum, and minimum temperature. Monthly average and minimum temperatures have increased the most in September and monthly maximum temperatures have increased the most in January, with each trend exceeding 0.2°C per decade. Recently, the California South Coast Climate Division has experienced sustained record warmth. The top 5 warmest years in terms of annual average temperature have all occurred since 2012: 2014 was the warmest, followed in descending order: 2015, 2017, 2018, 2016, and 2012.[10]

Consistent with projections set forth in the Los Angeles Regional 4th Climate Assessment, average temperatures are projected to increase around 4° F by the mid-century, and 7° F by the late century. (**Table 2.1**)

Table 2.1: Average Temperature Projections for the Sub-region

South Bay Cities	Historical Annual Mean (1960-1989)	Projected Annual Mean for 2020-2049 (RCP 8.5)	Projected Annual Mean for 2040-2069 (RCP8.5)	Projected Annual Mean for 2040-2069 (RCP4.5)	Projected Annual Mean for 2070-2099 (RCP8.5)	Projected Annual Mean for 2070-2099 (RCP4.5)
Carson	73.0	75.5	77.3	76.2	80.0	77.3
El Segundo	70.6	73.2	74.9	73.8	77.5	74.8
Gardena	72.0	74.4	76.2	75.0	78.8	76.1
Hawthorne	70.6	73.2	74.9	73.8	77.5	74.8
Hermosa Beach	70.8	73.6	75.0	73.9	77.3	74.8
Inglewood	71.1	73.5	75.3	74.2	78.0	75.2
Lawndale	71.6	74.0	75.7	74.6	78.4	75.6
Lomita	72.0	74.2	76.0	74.8	78.7	75.9
Manhattan Beach	70.8	73	75.0	73.9	77.7	74.9
Palos Verdes Estates	70.8	73	74.7	73.6	77.4	74.6
Rancho Palos Verdes	71.6	73.9	75.6	74.5	78.3	75.5
Redondo Beach	71.2	73.6	75.4	74.2	78.0	75.3
Rolling Hills	71.0	73.3	75.0	73.9	77.7	74.9
Rolling Hills Estates	70.8	73.0	74.7	73.6	77.4	74.6
Torrance	71.6	73.9	75.7	74.6	78.4	75.6
South Bay COG	72	74.4	76.2	75	78.8	76.1

Source: cal-adapt.org

Figure 2.1 provides annual averages of observed and projected maximum temperature values for the South Bay under the business as usual (RCP 8.5) scenario. The gray line (1950-2005) is observed data. The colored lines (2006-2010) are projections from four downscaled climate models[i] – called LOCA models. These models were selected by California's Climate Action

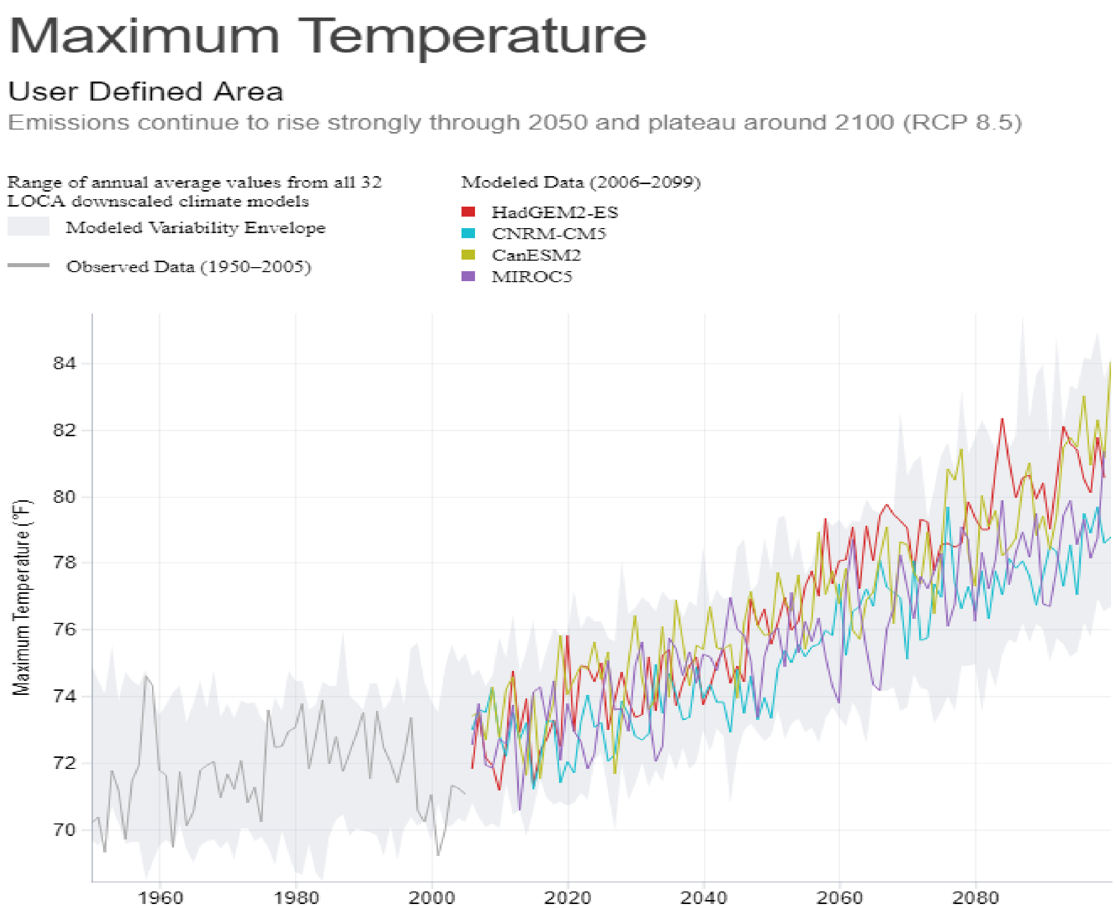
[i] The newly developed LOCA downscaling method estimates finer-scale (6km) climate detail using systematic historical effects on topography on local weather patterns.

Team Research Working Group as the most relevant for the State of California and used in the California's Fourth Climate Change Assessment. Projected future climate from these four models can be described as producing:

- A *warm/dry* simulation (HadGEM2-ES)
- A *cooler/wetter* simulation (CNRM-CM5)
- An *average* simulation (CanESM2)
- A model simulation that couples the atmosphere and ocean general circulation models together with the land and sea ice modules (MIROC5)

While there is some variation, **Figure 2.1** depicts an upward trend that is consistent for all four LOCA models.

Figure 2.1: Annual Average of Observed and Projected Maximum Temperature in the South Bay



Source: cal-adapt.org

The subregion will experience an increase in average annual heat in a variety of ways, including increased number of extreme heat days (**Table 2.2**) and warmer summer evenings (**Table 2.3**). The number of extreme heat days is projected to rise through the year 2100, where the average year could include 17 extreme heat days under a "business as usual" emissions scenario.[11]

Extreme Heat

A prolonged period of abnormally hot weather is defined as a heat wave. Heat waves can have an impact on both the environment, including habitat, and public health. Research and studies have provided evidence that the second warm night - when the interior of households is expected to rise due to outdoor temperatures[12] - have an increased negative effect on morbidity and mortality. In addition, the impacts of heat waves are geographically variable in nature as local populations adapt to the prevailing climate via physiological, behavioral, cultural, and technological adaptations.[13]

A heat wave in September 2007 lasted only one week but resulted in 18 heat-related deaths.

For this Vulnerability Assessment, an extreme heat day and warm night is defined as "when the maximum temperature exceeds the 98th historical percentile of maximum temperatures based on daily temperature maximum data between 1961 and 1990".[14] In the City of Torrance, for example, the extreme heat day threshold is 92.6 °F. Any temperature that exceeds 92.6 °F is considered an extreme heat day. The average threshold temperature of all cities in the South Bay is 91.08 °F. Between 1960 and 1991, the sub-region averaged 4.4 extreme heat days per year.

The July 2018 heat wave caused major outages impacting roughly 35,000 LADWP customers. Southern California Edison reported 19,000 outages.

Table 2.2: Historic and Projected Average Number of Extreme Heat Days[j]

South Bay Cities	Threshold Temp (F)	Observed (1961-1990)	Projected for 2020-2049 (RCP 8.5)	Projected for 2040-2069 (RCP8.5)	Projected for 2040-2069 (RCP4.5)	Projected for 2070-2099 (RCP8.5)	Projected for 2070-2099 (RCP4.5)
Carson	93.4	5	5	9	6	18	8

[j] Average of cities for sub-regional estimate was used because cal-adapt does not allow user-defined areas (SBCCOG outline shapefile) for this tool. For period 2020-2050, only RCP 8.5 per OPR guidelines were used.

El Segundo	89.9	5	5	8	6	18	8
Gardena	92.1	5	5	8	5	16	7
Hawthorne	89.9	5	5	8	6	18	8
Hermosa Beach	90.2	5	5	9	6	18	8
Inglewood	90.5	5	4	8	6	18	7
Lawndale	91.4	5	5	8	6	16	7
Lomita	92.6	5	5	7	5	15	7
Manhattan Beach	90.2	5	5	8	6	18	8
Palos Verdes Estates	91.2	5	5	7	5	15	7
Rancho Palos Verdes	92.1	4	5	7	5	15	7
Redondo Beach	90.8	5	5	8	6	17	7
Rolling Hills	91.7	4	5	7	5	14	7
Rolling Hills Estates	91.2	5	5	7	5	15	7
Torrance	91.8	5	5	7	5	16	7
Subregion Average	**91.2**	**4.5**	**5.1**	7.9	**5.4**	**16.5**	**7.3**

Source: cal-adapt.org

Table 2.3: Historic and Projected Average Number of Warm Nights[k]

South Bay Cities	Threshold Temp (F)	Observed (1960-1989)	Projected for 2020-2049 (RCP 8.5)	Projected for 2040-2069 (RCP 8.5)	Projected for 2040-2069 (RCP 4.5)	Projected for 2070-2099 (RCP 8.5)	Projected for 2070-2099 (RCP 4.5)
Carson	68.5	4	17	35	20	75	28
El Segundo	68.1	4	20	40	23	84	35
Gardena	68	4	17	35	19	77	29
Hawthorne	68.1	4	20	40	23	84	35
Hermosa Beach	67.6	4	16	33	18	75	28
Inglewood	68	4	18	39	22	84	34
Lawndale	67.9	4	17	35	19	77	29
Lomita	66.9	4	15	30	17	68	25
Manhattan Beach	67.8	4	18	36	20	80	31
Palos Verdes Estates	65.8	4	15	30	17	68	24
Rancho Palos Verdes	66.8	4	15	30	17	68	25
Redondo Beach	67.9	4	17	35	19	77	30
Rolling Hills	66.0	4	15	30	17	69	25
Rolling Hills Estates	65.8	4	15	30	17	68	24
Torrance	67.2	4	16	32	18	73	27
Subregion Average	**67.4**	**4**	**16.5**	**33.7**	**18.9**	**74.8**	**28.7**

Source: cal-adapt.org

[k] Average of cities for sub-regional estimate used because Cal-adapt does not allow users to insert user-defined area (SBCCOG outline shapefile). For period 2020-2050, only RCP 8.5 per OPR guidelines were used.

Precipitation

Most climate scientists agree that precipitation in Los Angeles is highly variable from year to year. As a result, there is some ambiguity around what the effect climate change will have on precipitation levels throughout the South Bay. From years 1961-1990 the sub-region received an average of 12.9 inches of rainfall per year.[15] Projections indicate there will be only small changes in average precipitation (**Table 2.4**); however dry and wet extremes are both expected to increase in the future. These extremes will vary from one year to another with wetter winter conditions offset by the drier spring conditions. By the late-21st century, the wettest day of the year is expected to increase in the sub-region about 20%. The overall result, however, is a projected increase in the frequency of dry years.[16]

Table 2.4: Average Precipitation Projections for the Sub-region[l]

SBCCOG Service Territory	Historical Annual Mean for 1961-1990 (Observed)	Projected for 2020-2049 (RCP 8.5)	Projected for 2040-2069 (RCP 8.5)	Projected for 2040-2069 (RCP 4.5)	Projected for 2070-2099 (RCP 8.5)	Projected for 2070-2099 (RCP 4.5)
Precipitation (inches)	12.9	13.9	13.4	13.4	15.6	13.4

Source: cal-adapt.org

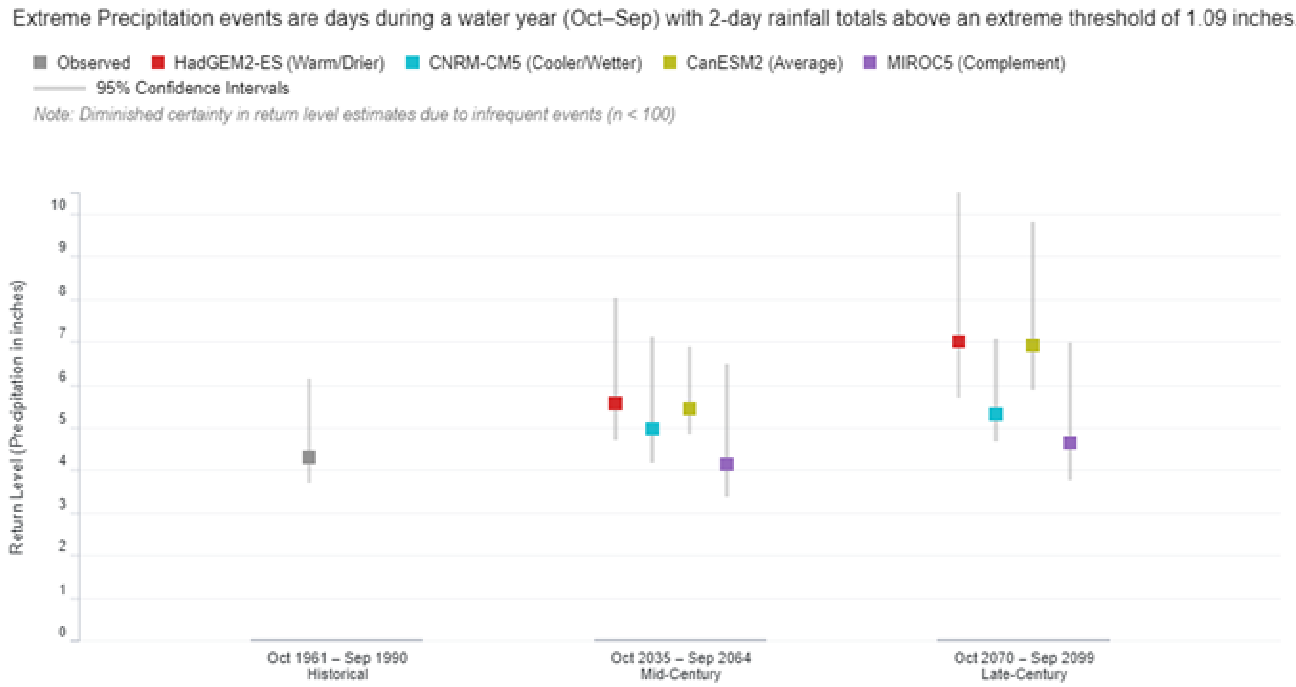
Extreme precipitation events are days during a water year (Oct-Sep) with 2-day rainfall totals above an *extreme threshold* of 1.09 inches.[m] The South Bay is projected to experience approximately 2-3 more extreme precipitation events per year by end-of-century under a business as usual scenario (2070-2099, RCP 8.5). **Figure 2.2** shows estimated intensity ("Return Level") of extreme precipitation events-- which are exceeded on average once every 20 years-- and how it increases in a warming climate over historical, mid-century and late-century time periods. Data is shown for a 6x6 km grid cell in the central South Bay[n] sub-region under the business as usual scenario (RCP 8.5) (projections for each city are similar). The gray line (1950-2005) is observed data. The colored lines (2006-2010) are projections from the four downscaled climate models (LOCA):

[l] SBCCOG boundary was used for data collection

[m] The extreme threshold sets the conditions for which a precipitation event is considered "extreme". The threshold is set to the lowest annual maximum precipitation accumulation in the historical record (1961-1990).

[n] Cities can select a grid cell that encompasses their city on cal-adapt.org/tools/extreme-precipitation

Figure 2.2: Changes in Intensity of Extreme Precipitation Events



Source: cal-adapt.org

Wind

Globally, wind speeds have fallen by as much as 25% since the 1970s.[17] This phenomenon, termed 'stilling' is a consequence of rising global temperatures; air movements are powered by differences in temperature between two locations. The bigger the difference between warm and cold air, the stronger the wind. One effect of global warming is a smaller global temperature differential.

In the South Bay, Santa Ana winds carry high-density air from a higher elevation down under the force of gravity. The Santa Ana winds blow in an offshore direction steered by the topography of the coastal hills and valleys. These winds are an important feature of the region's weather variability, and their high speed and low relative humidity can drive destructive wildfires.

In urban areas like the South Bay, a reduction in wind could contribute to increased smog and compound heat-related impacts. On the other hand, over the next 20 years higher projected wind speeds suggest a potential risk of windstorms that can disrupt power distribution among other adverse impacts. **Table 2.5** highlights how daily average wind speeds are projected to change throughout the South Bay (**Figure 2.3**) corresponding to projected temperature changes associated with different emissions scenarios.

In October 2018, Santa Ana wind gusts reaching 75 mph knocked out power to more than 30,000 Southern California Edison and 500 Los Angeles Department of Water & Power customers.

Table 2.5: Historical and Projected[o] Daily Average Wind Speeds

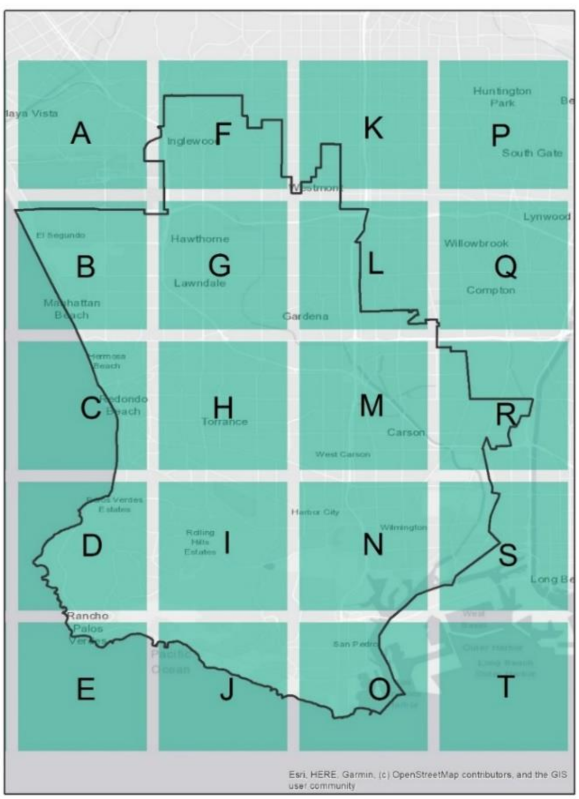
Map Grid Cell ID (Figure 4)	Location in South Bay	Historical Average Daily Wind Speed (m/s) 1950-2005	Projected Wind Speed 2006-2039 (RCP 8.5)	Projected Wind Speed 2040-2069 (RCP 8.5)	Projected Wind Speed 2040-2069 (RCP 4.5)	Projected Wind Speed 2070-2099 (RCP 8.5)	Projected Wind Speed 2070-2099 (RCP 4.5)
A	--	2.88	6.83	1.54	2.11	3.36	5.62
B	El Segundo/Manhattan Beach	3.43	6.54	1.53	2.05	3.29	4.99
C	Hermosa Beach/ South Redondo Beach	3.49	5.77	1.54	2.05	3.33	5.07
D	Palos Verdes Estates	3.43	5.77	1.60	2.11	3.47	5.40
E	West Rancho Palos Verdes	3.52	7.16	2.19	2.84	4.73	7.80
F	Inglewood	2.79	5.67	1.51	2.05	3.00	5.38
G	Hawthorne/Lawndal e/North Redondo Beach	2.68	5.21	1.49	2.02	3.09	4.78
H	Torrance	2.64	4.97	1.46	2.06	3.14	4.86
I	Rolling Hills/Rolling Hills Estates	2.64	4.85	1.48	2.16	3.19	5.04

[o] LOCA model: CanESM2

J	East Rancho Palos Verdes	3.27	5.10	1.52	2.54	3.19	5.82
K	--	2.74	5.52	1.56	2.11	2.88	5.25
L	Gardena	2.61	5.02	1.53	2.08	3.00	4.70
M	West Carson	2.55	4.76	1.48	2.12	3.06	4.77
N	Los Angeles	2.55	4.61	1.47	2.22	3.12	4.94
O	Los Angeles (San Pedro)	3.17	4.78	1.49	2.63	2.89	5.67
P	--	2.67	5.27	1.64	2.23	2.88	4.95
Q	--	2.52	4.71	1.63	2.20	2.85	4.48
R	East Carson	2.44	4.39	1.55	2.24	2.93	4.55
S	--	2.41	4.17	1.49	2.35	2.96	4.70
T	**--**	3.03	4.20	1.45	2.77	2.89	5.33

Source: cal-adapt.org

Figure 2.3: Wind Projection Grid Cell IDs



Sea Level Rise

Climate change is expected to increase rates of sea level rise around the world. Caused by thermal expansion of seawater and the melting of ice caps, global sea level rise is expected to accelerate due to increasing rates of ice cap and glacier melting. The South Bay sub-region is home to beach and peninsula cities. The South Bay's coastal areas, beaches, and bluffs are defining features for the region's recreational values and natural environment. Cities that have beaches include El Segundo, Hermosa Beach, Manhattan Beach, Redondo Beach, and Torrance. The peninsula area is home to residents of Palos Verdes Estates, Rolling Hills, Rolling Hills Estates, and Rancho Palos Verdes.

In 1988, a January storm cost $28 million in damages throughout Southern California. The largest concentration of property damage occurred in Redondo Beach.

January 1988 Storm Damage and Cleanup Cost Estimates

Locations	$ Damage
Ventura	$ 300,000
Malibu	
Zuma Beach	2,000
Manhattan Beach	1,500
Hermosa Beach	13,000
Redondo Beach	16,000,000
LA-Long Beach	
Seal Beach	25,000
Huntington Beach	4,500,000
Pacific Coast Highway	250,000
Laguna Beach	1,150,000
San Diego	6,700,000

Sea levels are projected to continue to rise in the future, but to what extent varies largely on different emissions scenarios and uncertainty to the extent warming will have on climate systems. Authors of the 4th Climate Assessment suggest that sea levels could be as high as 2.87m (9.4 ft) by 2100.[18]

The California Coastal Commission has released Guidance (2018) on how to assess and address sea-level rise risks in local communities.[19] This guidance is consistent with previous direction from the Ocean Protection Council (2018)[20] on sea-level rise scenarios to use in planning and development by coastal communities and state agencies. Specifically, the Coastal Commission recommends "all communities evaluate the impacts from the *medium-high risk aversion* scenario." As listed in **Table 2.6 & 2.7,** local governments should also include the *extreme risk aversion* scenario to evaluate the vulnerability of planned or existing assets that have little to no adaptive capacity, would be

"The damage could have been much worse if sea levels were higher, since sea levels determine the degree of damage waves can inflict on the shoreline." -AECOM Report

irreversibly destroyed or significantly costly to repair, and/or would have considerable public health, public safety or environmental impacts should that level of sea level rise occur.

While only advisory, if a community wants to construct in the coastal zone – whether a community has a Local Coastal Program (LCP) or if they're going directly to the Coastal Commission for a Coastal Development Permit – they will need to get approval from the Coastal Commission, which will in turn expect the city to have considered medium-high-risk sea-level scenarios consistent with Commission guidance documents.

<u>Table 2.6: Sea Level Rise Probabilistic Projections by Risk Aversion and Emission Scenarios</u>

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.4	0.3 -	0.5	0.6	0.8	1.0
	2040	0.6	0.5 -	0.8	1.0	1.3	1.8
	2050	0.9	0.6 -	1.1	1.4	1.9	2.7
Low emissions	2060	1.0	0.6 -	1.3	1.6	2.4	
High emissions	2060	1.1	0.8 -	1.5	1.8	2.6	3.9
Low emissions	2070	1.1	0.8 -	1.5	1.9	3.1	
High emissions	2070	1.4	1.0 -	1.9	2.4	3.5	5.2
Low emissions	2080	1.3	0.9 -	1.8	2.3	3.9	
High emissions	2080	1.7	1.2 -	2.4	3.0	4.5	6.6
Low emissions	2090	1.4	1.0 -	2.1	2.8	4.7	
High emissions	2090	2.1	1.4 -	2.9	3.6	5.6	8.3
Low emissions	2100	1.6	1.0 -	2.4	3.2	5.7	
High emissions	2100	2.5	1.6 -	3.4	4.4	6.9	10.2
Low emissions	2110*	1.7	1.2 -	2.5	3.4	6.3	
High emissions	2110*	2.6	1.9 -	3.5	4.5	7.3	11.9
Low emissions	2120	1.9	1.2 -	2.8	3.9	7.4	
High emissions	2120	3	2.2 -	4.1	5.2	8.6	14.2
Low emissions	2130	2.1	1.3 -	3.1	4.4	8.5	
High emissions	2130	3.3	2.4 -	4.6	6.0	10.0	16.6
Low emissions	2140	2.2	1.3 -	3.4	4.9	9.7	
High emissions	2140	3.7	2.6 -	5.2	6.8	11.4	19.1
Low emissions	2150	2.4	1.3 -	3.8	5.5	11.0	
High emissions	2150	4.1	2.8 -	5.8	5.7	13.0	21.9

Source: OPC Sea Level Rise Guidance

Table 2.7: Sea Level Rise Probabilistic Projections for Los Angeles (OPC 2018)[21]

Projected Sea Level Rise (in feet): Los Angeles			
	Probabilistic Projections (in feet) (based on Kopp et al. 2014)		H++ Scenario (Sweet et al. 2017)
	Low Risk Aversion	Medium-High Risk Aversion	Extreme Risk Aversion
	Upper limit of "likely range" (~17% probability SLR exceeds…)	*1-in-200 chance (0.5% probability SLR exceeds…)*	*Single scenario (no associated probability)*
2030	0.5	0.7	1.0
2040	0.7	1.2	1.7
2050	1.0	1.8	2.6
2060	1.3	2.5	3.7
2070	1.7	3.3	5.0
2080	2.2	4.3	6.4
2090	2.7	5.3	8.0
2100	3.2	6.7	9.9
2110*	3.3	7.1	11.5
2120	3.8	8.3	13.8
2130	4.3	9.7	16.1
2140	4.9	11.1	18.7
2150	5.4	12.7	21.5

Source: OPC Sea Level Rise Guidance

Flooding

Current modeling is limited in its ability to produce quantitative estimates of the effect of climate change on flooding; however, an understanding of the basic features of climate change allows for a qualitative assessment of impacts on flood-related hazards.

High frequency flood events (e.g. 10-year floods) will likely increase with a changing climate.[22] Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding.[23] With the added potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which will increase sediment loads and impact water quality.[24] As the flow of water and landscape changes, what is currently considered a 100-year flood may strike more often, leaving many communities already exposed to flood hazards at greater risk.[25]

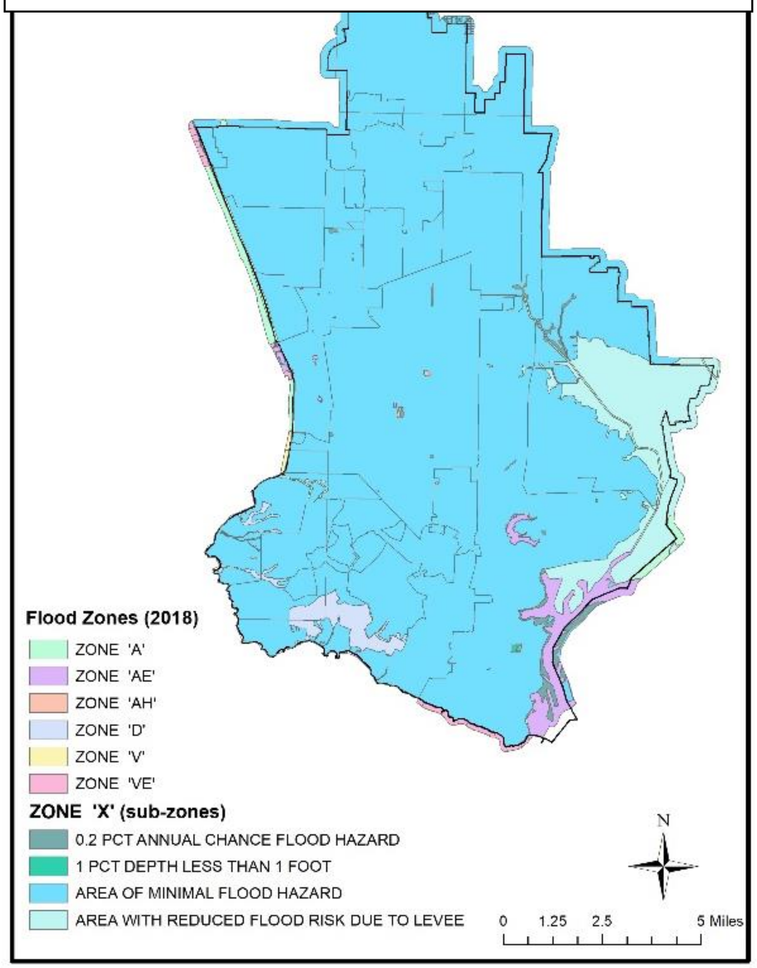
During the LA County flood of 2005, 16.97 inches of rain fell in 15 days, causing the LA River basin to overflow. The flood cost approximately $5 million in property damage and caused 17 deaths.

As shown in **Figure 2.4**, flood designations throughout the South Bay primarily fall into three categories:

High Risk Areas

- A – areas with a 1% annual chance of flooding
- AE – the base floodplain where base flood elevations are provided. AE designated areas are subject to mandatory flood insurance purchase requirements and floodplain management standards.
- AH– areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet.

Figure 2.4: South Bay Flood Zones



- V, VE[p] – coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves.

Moderate to Low Risk Areas

- X – Area of minimal to moderate flood hazard, usually between the limits of the 100 year and 500-year floods. Sub-designations are provided in Figure X to describe the risk associated with a Zone X designation.

Undetermined Risk Areas

- *D – areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted.*

<u>*El Nino*</u>

El Nino and La Nina are opposite phases of what is known as the El Nino-Southern Oscillation (ENSO) cycle. The ENSO cycle describes the fluctuations in wind patterns, sea-surface temperatures, and ocean atmosphere interactions across the Equatorial Pacific. El Nino events are characterized by higher than normal sea surface temperatures in the eastern and central tropical Pacific Ocean and can result in higher rainfall for the California coast.[26]

During the El Nino Event of 1983, Los Angeles County experienced 31 inches of rainfall between October and September (average is 14.93 inches). Across the state, the El Nino Storms cost 17 lives and over $850M worth of damage.

El Nino has a major impact on the weather and flooding conditions of the Pacific coast. During El Nino winters, storm tracks often dip further south than their normal track and directly impact Southern California with more frequent storms, increased chances of heavy rainfall and higher wave heights with accompanying floods, landslides, and coastal erosion.

A scientific paper published in Nature in 2014 used 20 climate models to assess changes in El Nino behavior assuming climate change over the next 100 years[27]. They found a consistent pattern across most models, doubling the frequency of intense El Nino events**.** The probability of a 1/20-year intense El Nino (such as those in 1982−83 and 1997−98) will increase roughly to 1/10 years. Although there remains much uncertainty over the effects of climate change on

[p] Zone V flood zones do not have base flood elevations, while Zone VE has base flood elevations derived from detailed analyses.

climate variability such as El Nino, the most damaging events in California will likely be driven by El Nino storms in combination with high tides.

Tropical Cyclones and Storms

There is a low frequency of tropical cyclones making landfall in Southern California due to low seawater temperatures and north-westward track.[28] Such cyclones usually require warm water (>26.5°C; 80°F), but the coastal waters in California rarely rise above 24°Celsius (75°F). Another reason for the low probability of hurricanes in California is the general northwestward or westward direction of tropical cyclones, steering them away from land. Climate change may affect the frequency, intensity, and location of tropical cyclones. A study by Mendelsohn et al. (2012) used four different models to estimate tropical cyclone tracks in the current and future climate.[29] They observed increasing storm power in the northeast Pacific consistently over the four models, which may indicate increased future storm activity in Southern California; however, there are currently few studies that have investigated the effect of climate change on tropical cyclones and storms for this area.

Drought

Most of the imported water used in the South Bay subregion ultimately comes from snowmelt originating in the Sierra Nevada range. Researchers at UCLA found that more precipitation will likely fall as rain rather than snow and accumulated snow will melt sooner than in modern history due to elevated temperatures.[30] As a result, runoff will occur earlier in the season and in greater volumes, making capture for use much more difficult in the future.[31] Reduced winter precipitation levels and warmer temperatures have greatly decreased the size of the Sierra Nevada snowpack (the volume of accumulated snow), which in turn makes less fresh water available for communities throughout California. By the end of this century, California's Sierra Nevada snowpack is projected to experience a 48-65% loss, corresponding to emissions scenarios RCP 4.5 and RCP 8.5, respectively, from the historical (1981-2000) April average. Continued decline in the Sierra Nevada snowpack volume is

During the 2011-2015 drought, human caused warming reduced Sierra Nevada snowpack levels by 25%.

expected, which may lead to lower volumes of available imported water. Adding to this situation, external factors such as increased demand on imported supplies outside of the Los Angeles region will likely amplify the problem and lessen the dependability of imported water sources to the region. The South Bay currently imports approximately 72% of its water supply, though water agencies in the region have taken steps to decrease their reliance on imported water by investing more aggressively in local water sources including groundwater and recycled water. Further discussion on the vulnerability of the water reliability is addressed in the sector analysis section of this plan.

Wildfire

A wildfire is an uncontrolled fire spreading through vegetative fuels and is one of the hazards in the subregion that poses a substantial risk to life and property. In addition to this direct threat, smoke released during an event can have a detrimental effect on the subregion's air quality.

In 2012, the California Energy Commission (CEC) commissioned a projection of wildfire risks for California. The report provides baseline wildfire risk, as well as projections for 2039, 2069, and 2099.[32] **Figures 2.5 & 2.6** show baseline (1977-2000) and change in wildfire risk by 2039 under a medium-high emissions scenario[q]. Highly urbanized areas (with less vegetation) are not at high risk of wildfires due to insufficient fuels to carry a fire, regardless of weather conditions.

The last major wildfire on the Palos Verdes Peninsula burned 230 acres in the Portuguese Bend area in August 2009, damaging six homes and forcing hundreds of evacuations.

In 2005, more than 200 acres were scorched near Del Cerro Park in Rancho Palos Verdes.

[q] Under the medium-high emissions scenario, it is assumed that carbon concentration in the atmosphere will reach 830 ppm by 2100

Figure 2.5: Baseline Wildfire Probability (1977-2000)

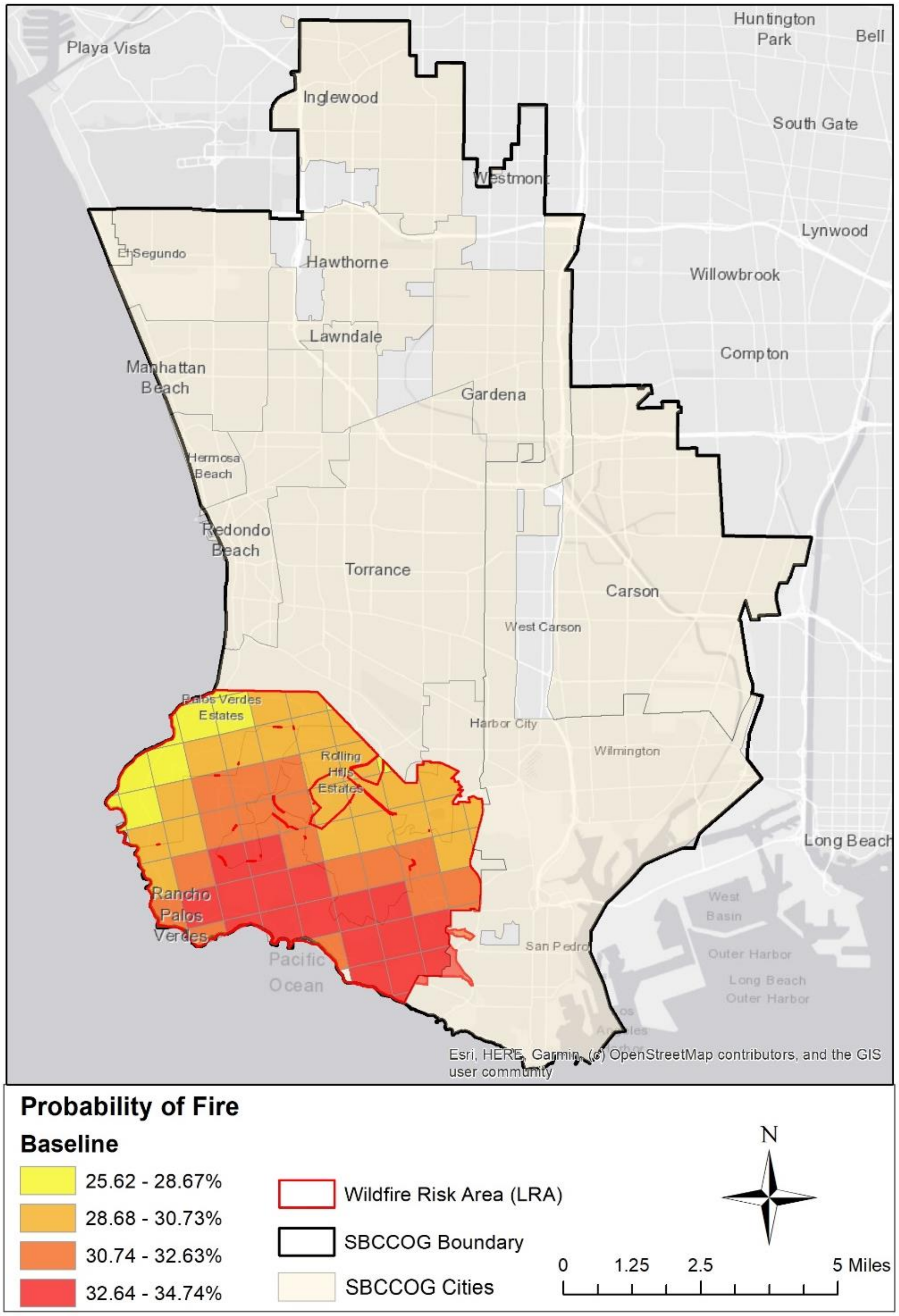


Figure 2.6: Percent Change in Wildfire Probability (Baseline-2039)

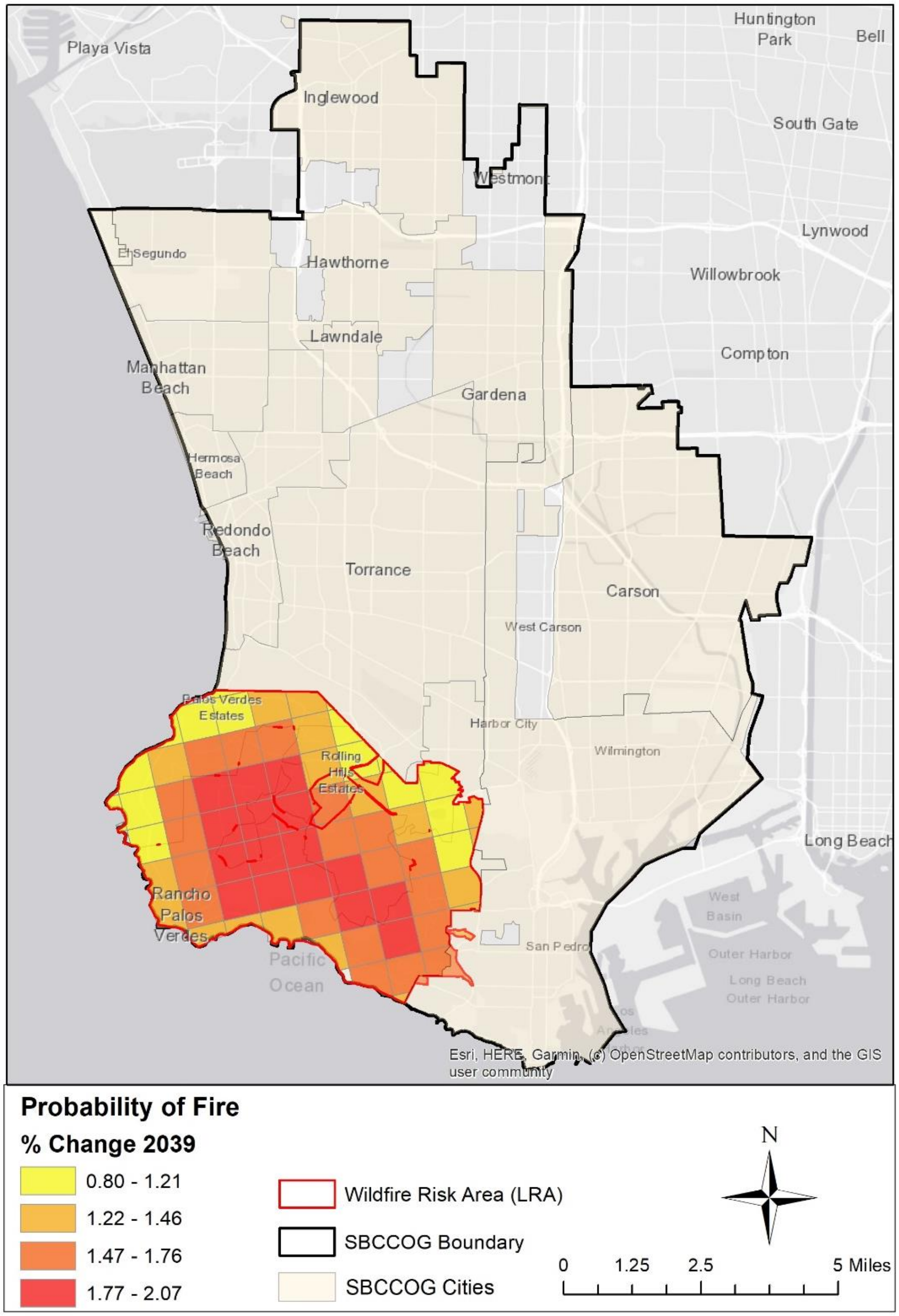


Figure 2.5 & 2.6 indicate that there will be an increased, though small, fire risk on the Palos Verdes Peninsula. The average wildfire risk for the designated area during the baseline period is 30.88%. In 2039 under a medium-high emissions scenario, that average increases to 32.37%, a negligible change.

Another scenario to consider is the overwhelming importance of Santa Ana winds, illustrated by the relation between burning patterns and climate. Scientists at UCLA found that two types of fire contribute equally to southern California historical fires from 1959-2009. Rapidly expanding, wind-driven Santa Ana fires, which occur mostly in September through December, were found to be concentrated in high-wind corridors and coastal areas. The study projects that Southern California will experience a 64% increase in area burned by 2040-2061 from Santa Ana fires relative to 1981-2000.[33]

Wildfires may start for any number of reasons, including arson, human error, or lightning, irrespective of climate change. Throughout the western United States there is a strong relationship between drought conditions and fire activity.[34] However, in southern California during the twentieth century, there was a surprisingly weak relation between drought and area burned,[35] but length of drought played a role in extending the fire season.[36] Since the temperature/humidity threshold required for a wildfire event is met every year in southern California, global warming is less responsible for increased fire frequency compared to other considerations (such as population growth) in the South Bay.

One of the difficulties in sorting out the role of climate in driving fire is that fires started by humans play a major role in the bioregion and complicate the interpretation. For example, drought indices are closely correlated to the area burned during the twentieth century. Human population growth also parallels these changes in area burned, and increased fires started by humans are likely a major contributor to the late twentieth century increase in burning. It is estimated that humans account for over 98% of all wildfires in the lower foothills and coastal zone.[37] With increasing population growth, fire suppression efforts have worked hard to keep up with increasing numbers of fires; however, twentieth-century fires have been more abundant in Southern coastal California than historically was the case. [38]

Social Vulnerability

Vulnerability is a function of exposure, sensitivity, and adaptive capacity. Specifically, social vulnerability is a function of diverse demographic and socio-economic factors that influence a community's sensitivity to climate change. In addition to describing the determinants of vulnerability, the SBCCOG has mapped different factors of vulnerability at the census-tract[r] level to identify *areas* that have greater risk of negative health outcomes for people (morbidity and mortality) from climate stressors. In consultation with member-cities, the SBCCOG developed a list of factors—or indicators--to consider in the vulnerability analysis, listed in **Table 3.1**.

Table 3.1: Vulnerability Indicators

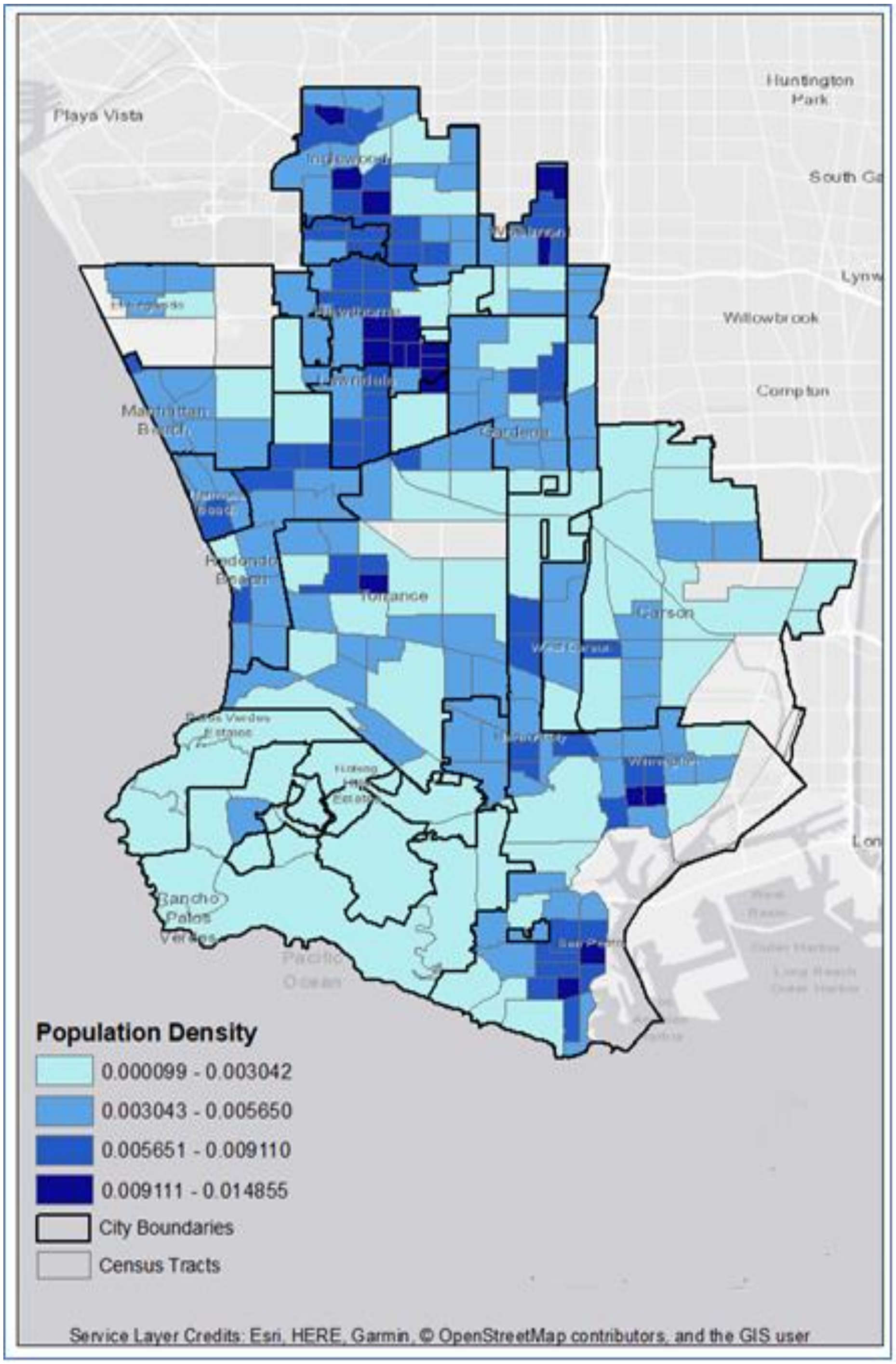
Vulnerability Type	Indicator	Data Collected	Hazard	Data Source
Exposure (increases vulnerability)	Historical Hottest Day	Temperature	Heat	UCLA--IOES
Sensitivity (increases vulnerability)	Population Density	Total Population (per square meter)	All	American Community Survey 2017 5-Year Estimates
	Poverty	Percent of population 200% below the poverty line	All	
	Children	Percent of population under the age of 5	All	
	Rent-Burdened	Percent of population spending over 50% of their income on rent	All	
	Education	Percent of population over 25 without a high-school diploma	All	
	Linguistic Isolation	Percent of households that don't speak English 'very-well'	All	
	Single Parent	Percent of households with children with single head of household	All	
	No Insurance	Percent of population without health insurance	All	
	Chronic Disease	Percent of population with COPD, coronary heart disease, asthma, and/or diabetes.	All, Heat	
	Disability	Percent of population with a disability	All	
	Access to Vehicle	Percent of households without access to a vehicle	All	
	Outdoor Workers	Percent of population (16+) who work in construction	Heat	
	Elderly Living Alone	Percent of population over the age of 65 and living alone	All	

[r] Census tracts are subdivisions of counties for which the Census collects statistical data.

	Mobile Homes	Percent of housing units that are mobile homes	Flood	
	Homeless	Percent of population experiencing homelessness	All	LAHSA Homeless Count 2018
Adaptive Capacity (reduces vulnerability)	Tree Canopy	Percent of tree canopy	Heat	National Land Cover Database
	Impervious Surfaces	Percent impervious surface	Flood	National Land Cover Database
	Access to Air Conditioning	Percent of population with air conditioning	Heat	Pacific Institute (2009-2011)
	Cooling Centers	Location of cooling centers in the South Bay	Heat	LA County LMS Data

Indicators

Although disaster impacts can vary from hazard to hazard, vulnerability indicators—or measurable variables—allow for the quantification and comparison of climate risk across the sub-region. The indicators selected to measure vulnerability focus on different thematic areas: physical, demographic, social, economic and environmental vulnerability. Understanding vulnerability factors and the populations affected is critical for crafting climate change adaptation policies and disaster response strategies. This is also important to achieving climate justice, which is a concept that no group of people should disproportionately bear the burden of climate impacts or the costs of adaptation.

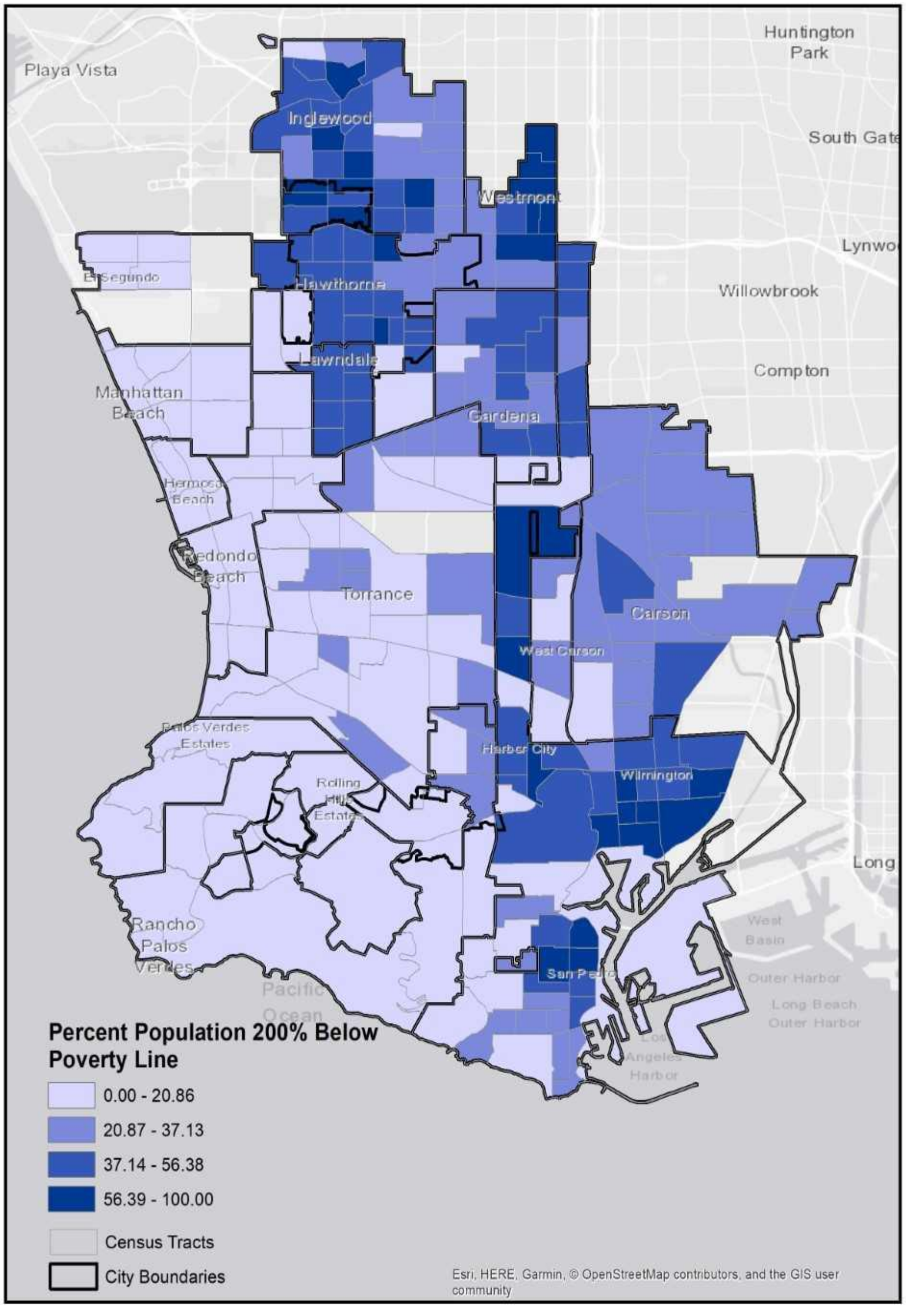


Population Density

Areas with greater population, all else being equal, are inherently more vulnerable than areas with less population. High population densities can complicate evacuation plans and the built infrastructure of cities, such as large, high-occupancy buidings, can make them particularly vulnerable to certain types of climate hazards. This map shows population per square meter by census tract.

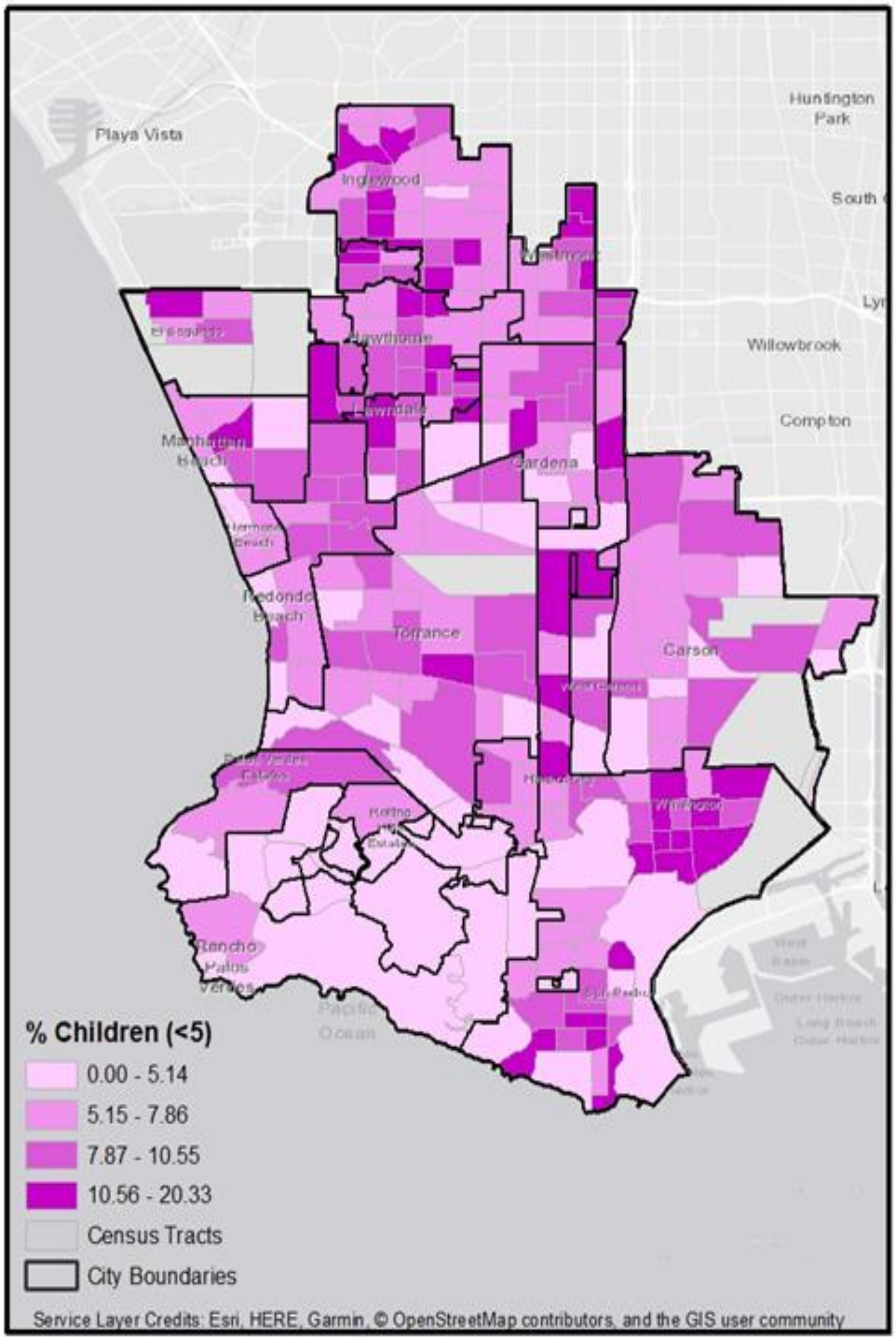
Poverty Rate

Poverty, defined as the percent of individuals 200% below federal poverty level, limits the acquisition of basic material necessities and ability to live a healthy life. It restricts people's access to housing, food, education, jobs, and transportation. Poverty is associated with societal exclusion[39] and higher incidence and prevalence of mental illness.[40] People in poverty are more likely to live in dangerous or under-resourced environments and work in hazardous conditions. They are more likely to be uninsured and to suffer from chronic diseases like diabetes and heart disease.[41] Thus, poverty is highly correlated with many other sensitivity indicators that represent heightened risk to climate hazards.



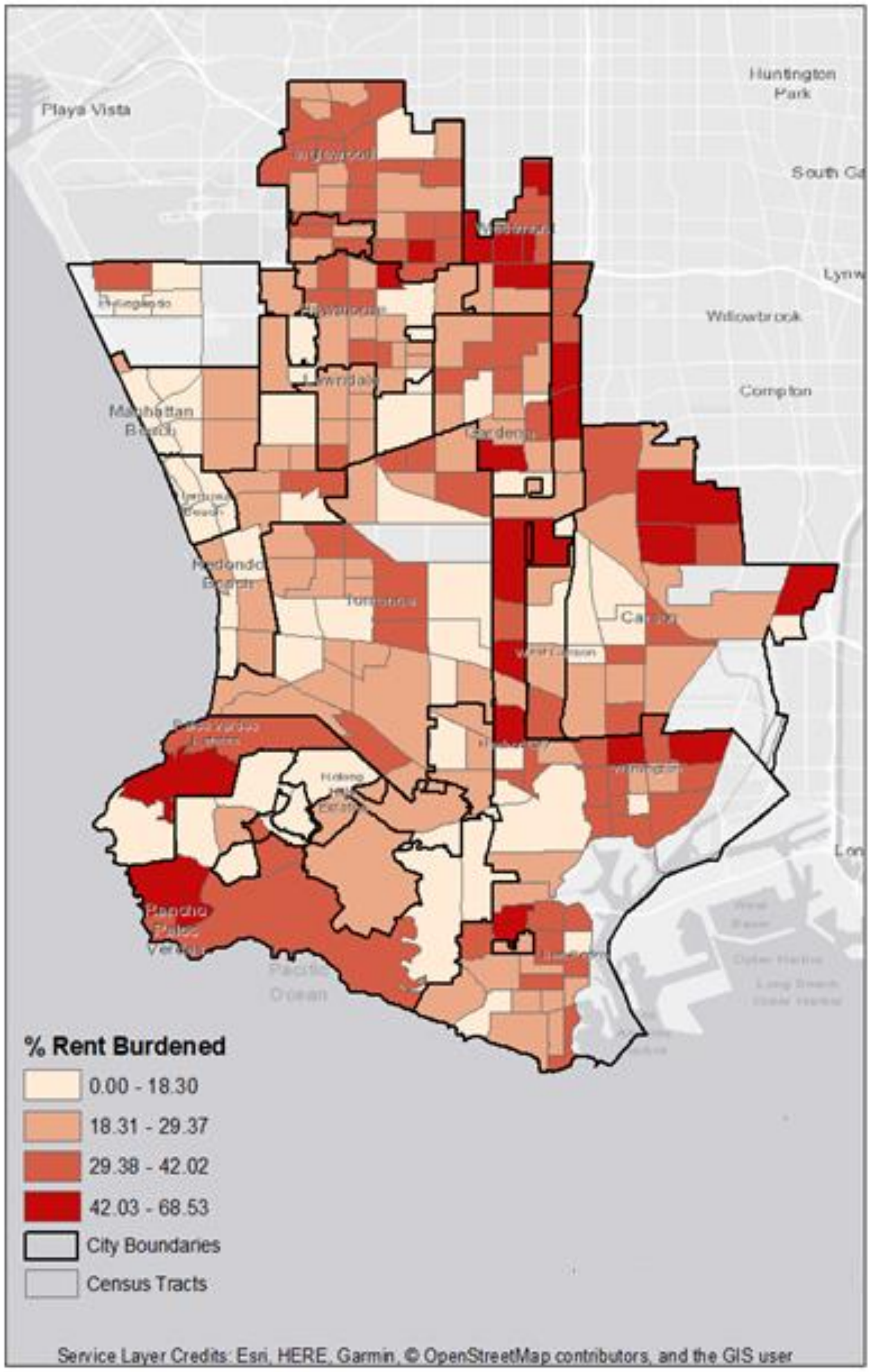
Children Under the Age of 5

Children under 5 years old are especially vulnerable to the health impacts of climate change. Due to physiological and developmental factors, children are disproportionately impacted from the effects of heat waves, air pollution, infectious illnesses, and trauma resulting from climate change.[42] Children are dependent on their caregivers for response to extreme weather events such as wildfires and floods. Children, infants, and pregnant women are vulnerable to increased heat exposure because they may not be able to efficiently thermoregulate. [43]



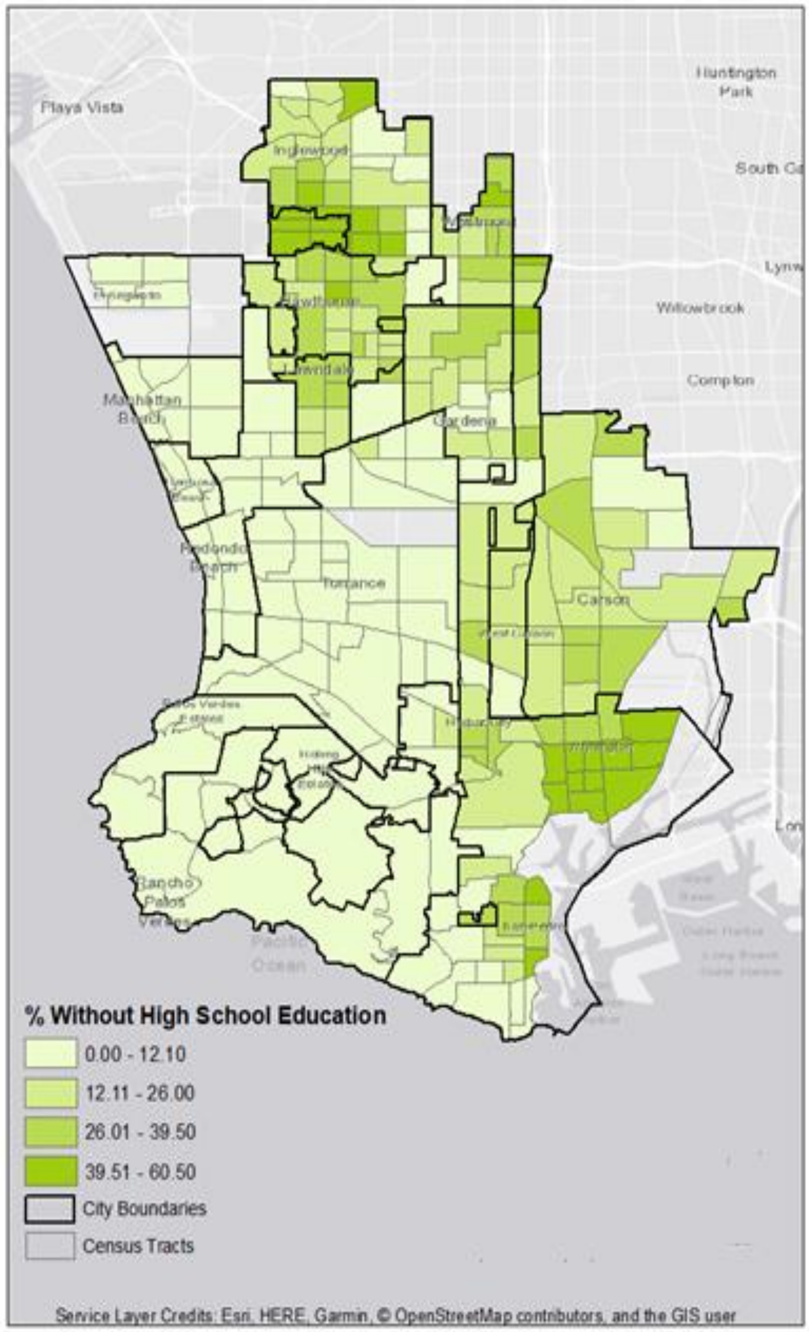
Rent Burdened Population

Rent-burdened populations are measured by the percent of the population spending over 50% of their income on housing.[44] Rent-burdened families have less savings and are often not in a financial position to pay associated costs of preparation for and recovery from natural disasters. While 91% of homeowners purchase homeowner's insurance, it is estimated that only 46% of renters buy renters insurance[45], putting rent-burdened populations at risk of losing all their household and personal items. In addition, rent-burdened populations have a greater risk of being displaced post-disaster.



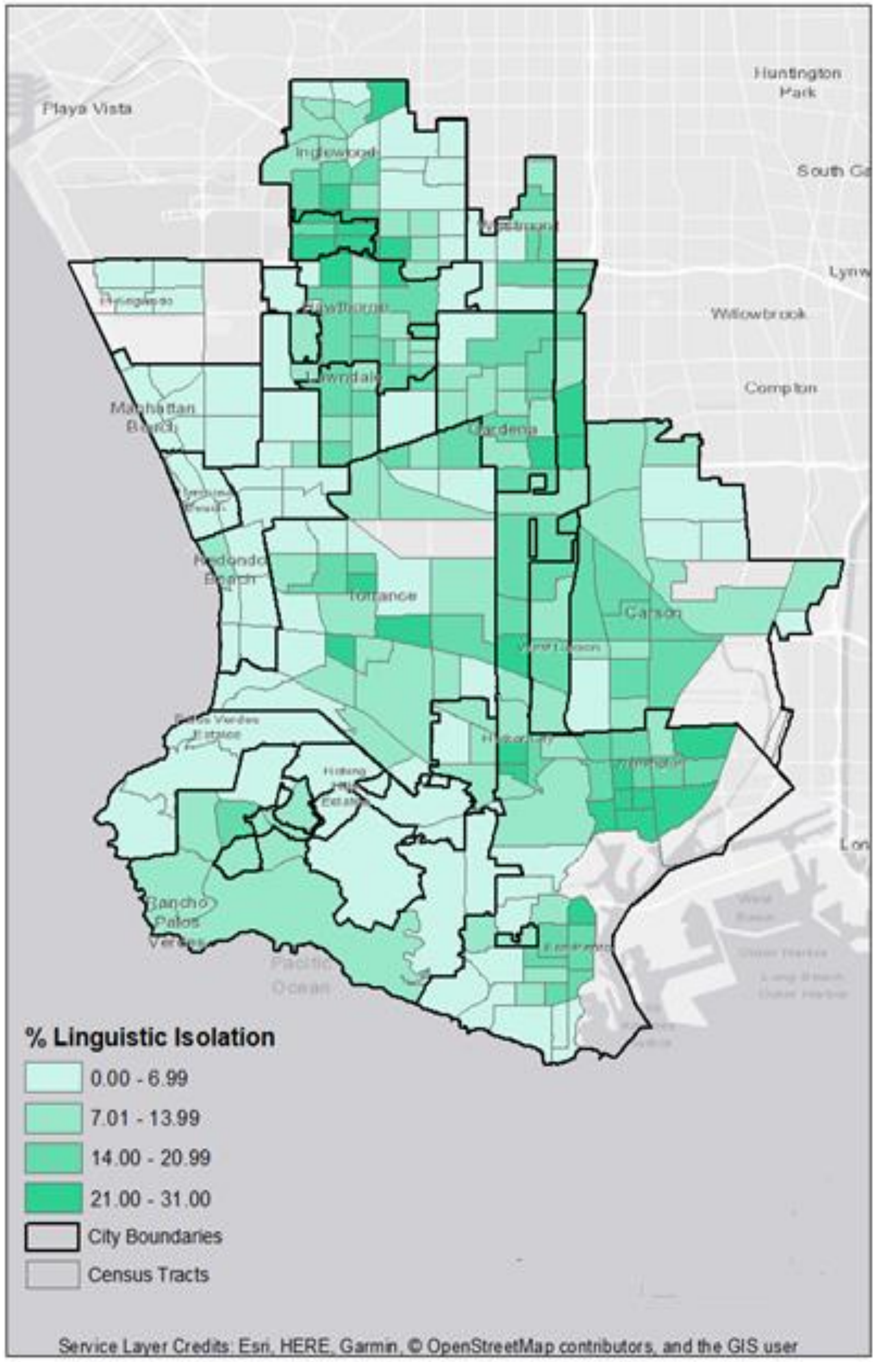
Educational Attainment

There are several reasons to expect that illiteracy and educational deficiency (measured by the percent of population without a high-school degree) can increase vulnerability to climate change related risks. Better education typically implies better access to relevant information, such as early warnings for severe weather events.[46] There is evidence that education also enhances cognitive skills and the willingness to change risky behavior while at the same time extending the personal planning horizon, contributing to the likelihood an individual will take steps to plan for and adapt to both climate shocks as well as slow-onset impacts.[47] Furthermore, research findings support that education leads to better health and higher income at the individual and household level, which contributes to the capacity of an individual to better cope or adapt to the impacts of climate change.[48]



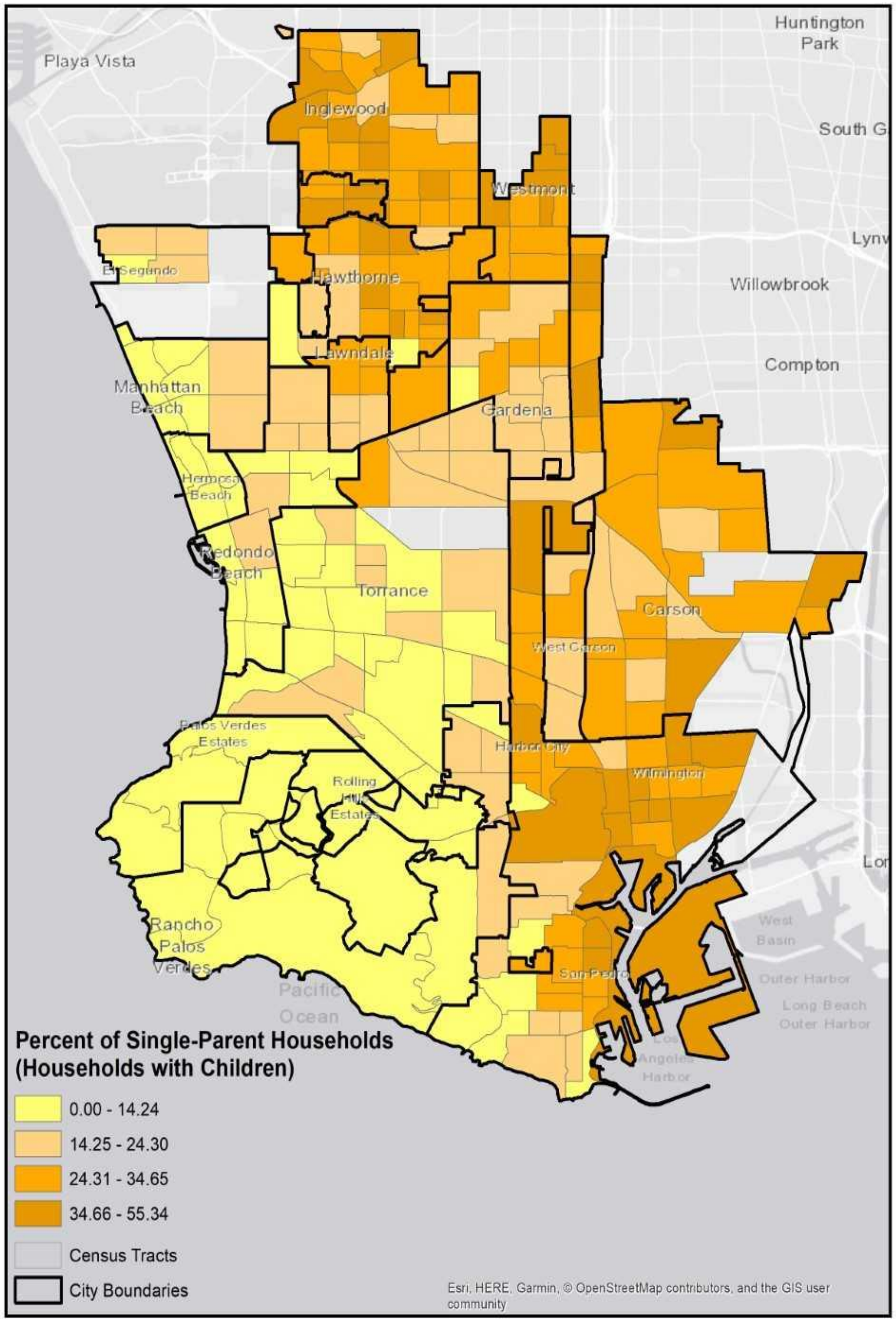
Linguistic Isolation

Climate change and increasing temperatures pose a serious public health concern for people who are linguistically isolated. According to the U.S. Census, a household is linguistically isolated when all persons 14 years of age or older speak a language other than English and no one speaks English very well. Linguistic isolation may hinder protective behaviors during extreme weather and disasters by limiting access to or understanding of health warnings. A study of extreme heat found that people who live in linguistically isolated households were at increased risk of extreme heat-related health problems, and they are more prone to making heat distress calls to 911.[49] The study also found that isolation led to structural and financial barriers to medical care, which in turn disrupted management of chronic conditions.[50]



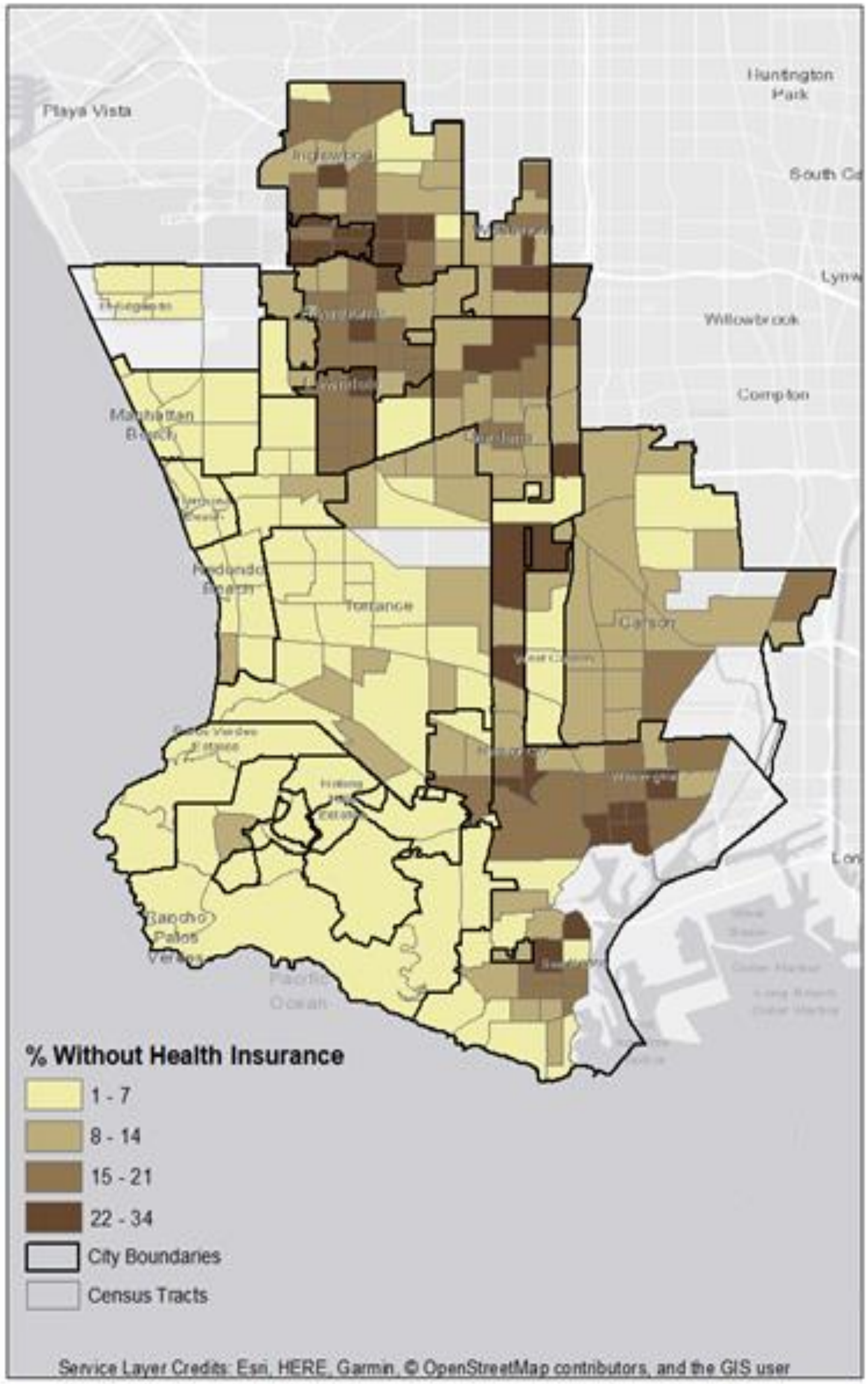
Single Parent Households

Single-parent households often have limited finances to outsource care for dependents, and thus must juggle work responsibilities and care for family members. Furthermore, they must cope with the stress of meeting basic needs and caring for their children alone, and often lack resources and emotional support. These factors affect the resilience to and ability to recover from hazards.



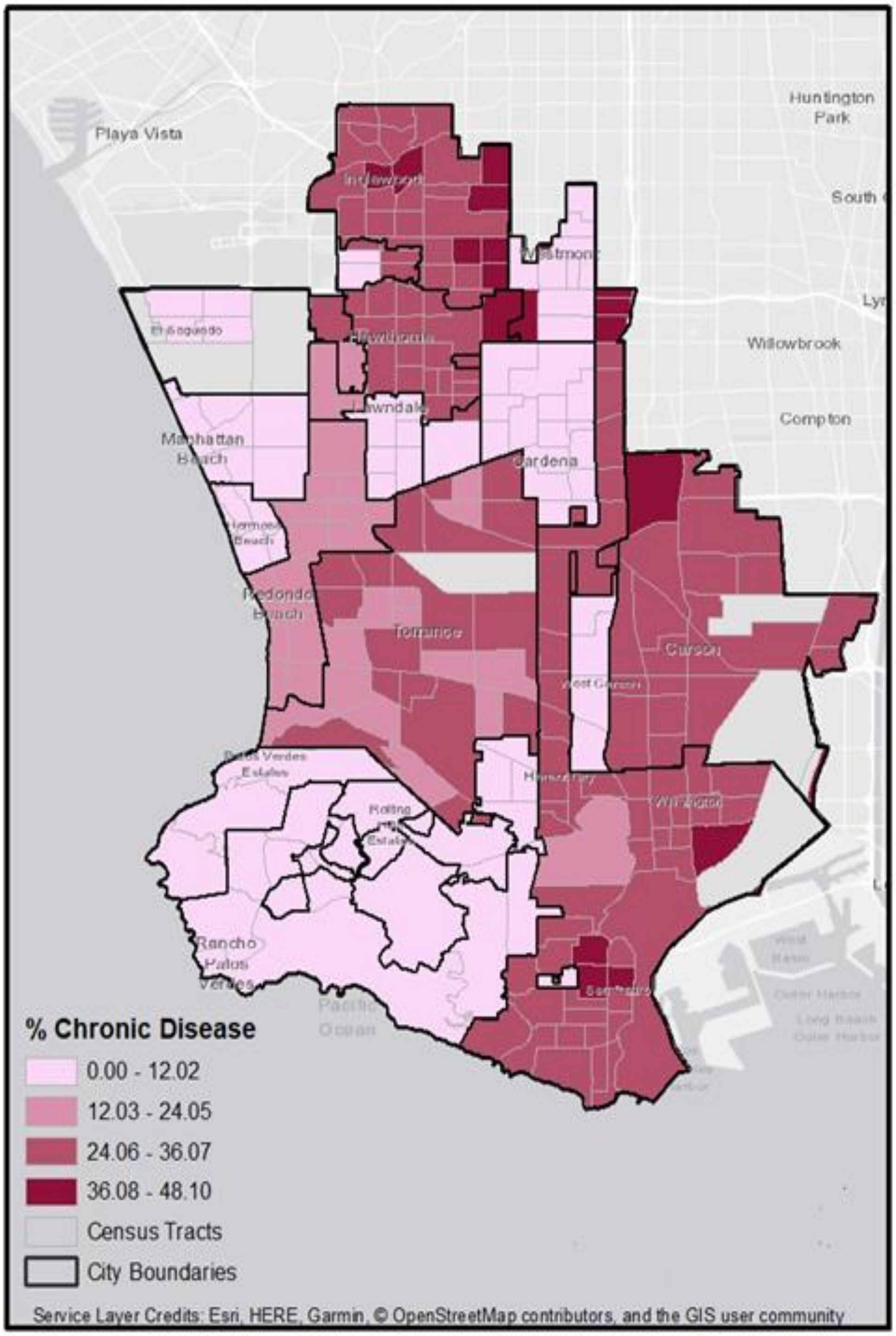
Population Lacking Health Insurance

Insurance coverage is a key determinant of timely access and utilization of health services, which is a fundamental pathway to improved health outcomes. Excessive heat exposure, elevated levels of air pollutants, and extreme weather conditions such as flooding are expected to cause direct and indirect health impacts, particularly for vulnerable populations with limited or no access to health services. A national systematic review in 2010 found that patients who were uninsured were less likely to receive critical care services than those with insurance.[51] Another study demonstrated increased risk of mortality among the uninsured compared with the insured and estimated 44,789 annual deaths among Americans aged 18-54 associated with lack of health insurance. [52]



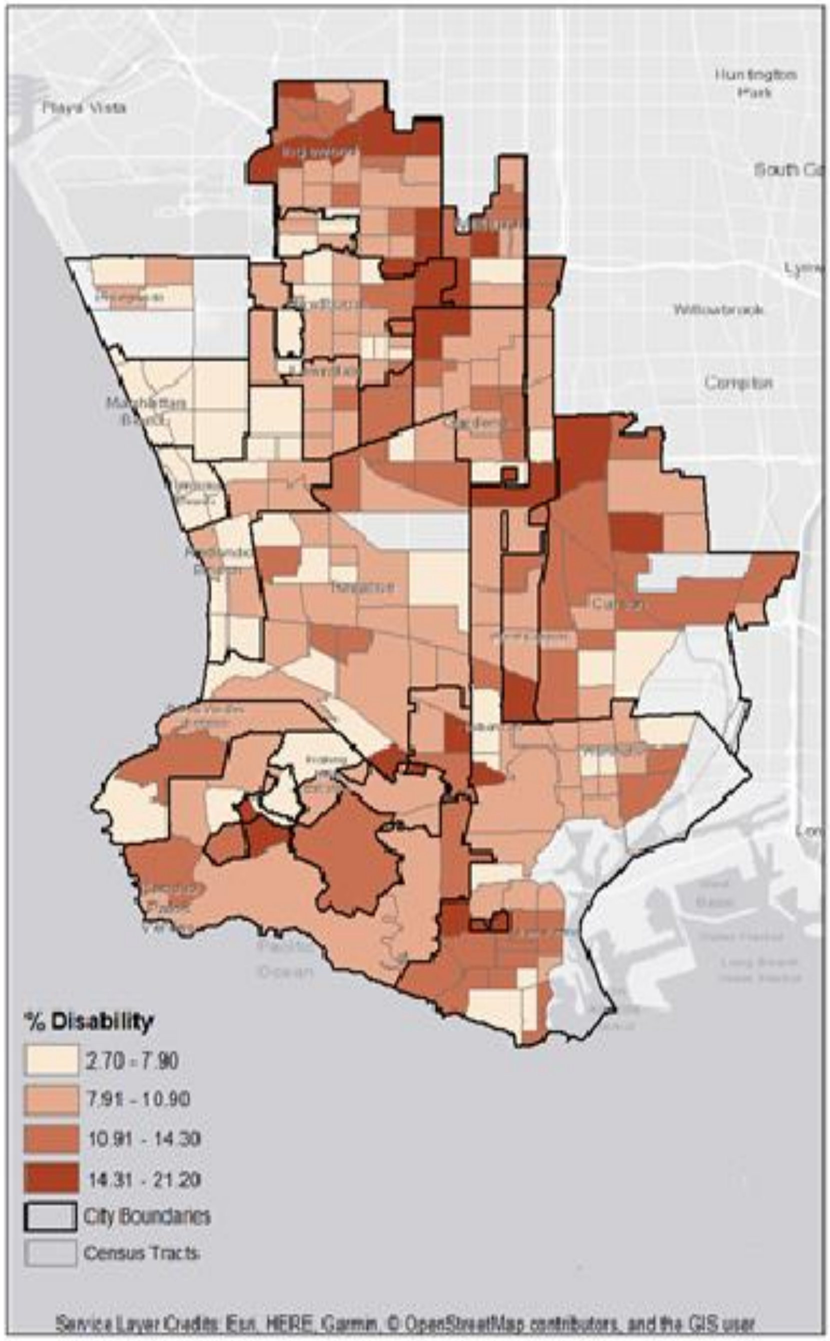
Chronic Disease

Pre-existing health conditions, including respiratory and coronary disease, can be exacerbated by extreme heat and poor air quality. Certain medications, such as diuretic and beta blocks for those with heart disease, may impair the body’s ability to regulate temperature or maintain fluid or electrolyte balances.



Disabled Population

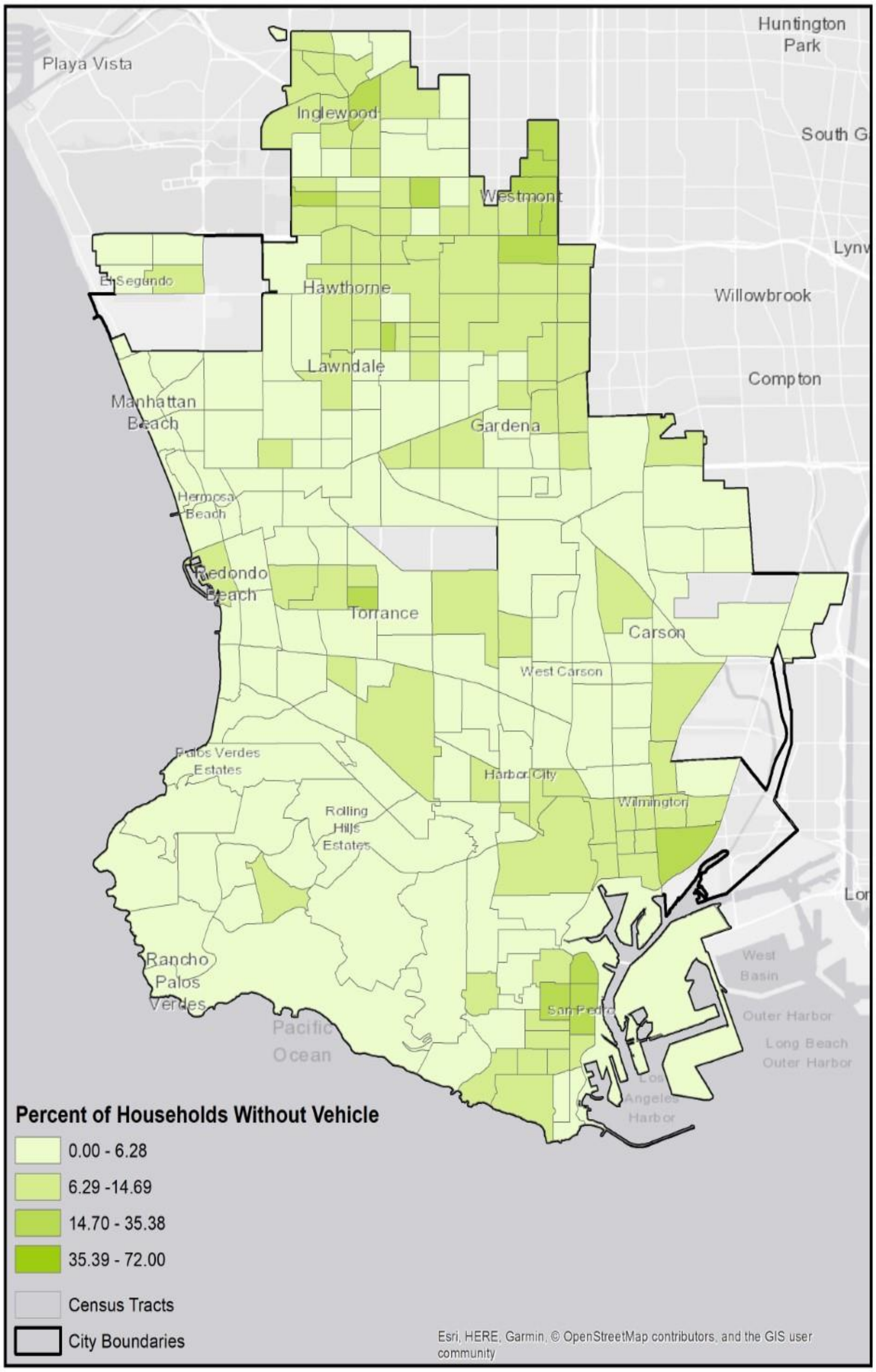
Disabled populations are defined in this assessment as a person with a physical or mental disability.[s] Climate change is expected to cause increased hardship for persons with physical disabilities due to limited resources and mobility during the phases of evacuation, response, and recovery, and will likely affect the severity and incidence of mental disabilities and mental health problems.[53] Persons with a physical disability have been found to be 1.22 times more likely to be unprepared for an emergency.[54] Increasing heat exposure can also worsen the clinical condition of people with pre-existing mental health problems. There are direct physiological effects of heat strain that can reduce the ability to work at full capacity and carry out daily activities, which can impact mental health as well as livelihood.[55] Dementia is a risk factor for hospitalizations and death during heat waves. [56]



[s] As defined by the US Census, a person with a physical disability has serious difficulty walking or climbing stairs. A person with a mental disability has a learning, intellectual or developmental disability; Alzheimer's disease, senility, dementia, or some other mental or emotional condition that seriously interferes with daily activity.

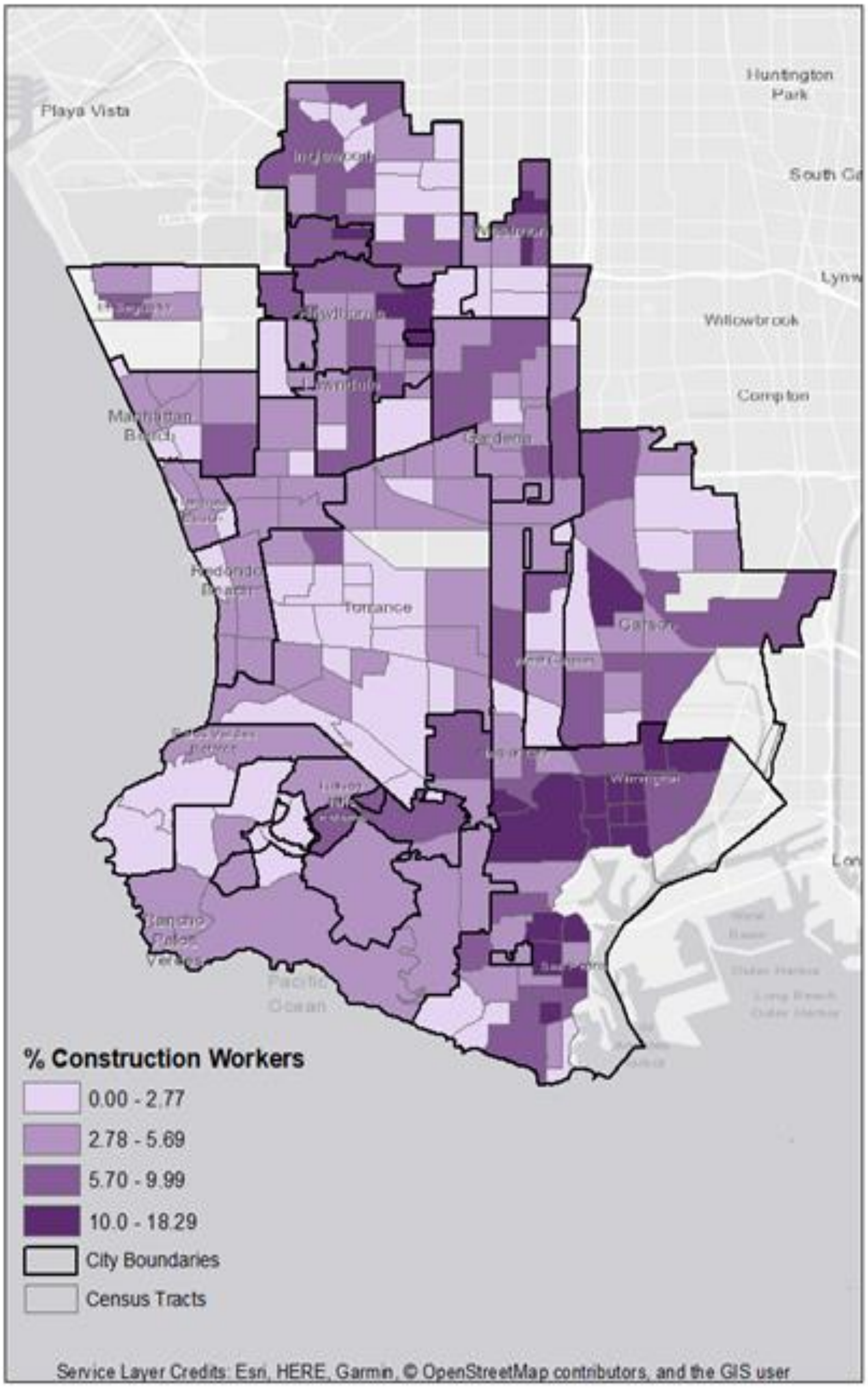
Transit-dependent Households

Vehicle ownership is a measure of mobility and access to transportation. Transportation is a critical resource for survival, because it improves access to evacuation and shelter from environmental exposures, such as wildfire, air pollution, heat waves, and flooding, allowing people to move to cooler areas or other safe areas. Flooding may require emergency evacuation of populations living in coastal and low-lying areas and may also require adequate sheltering for displaced populations.[57] Rates of vehicle ownership are generally lower in urban areas, particularly in low-income inner-city populations. Communities of color are more likely to have limited or no access to a car, increasing their risk of being impacted during heat and other extreme weather events.[58]



Outdoor Workers

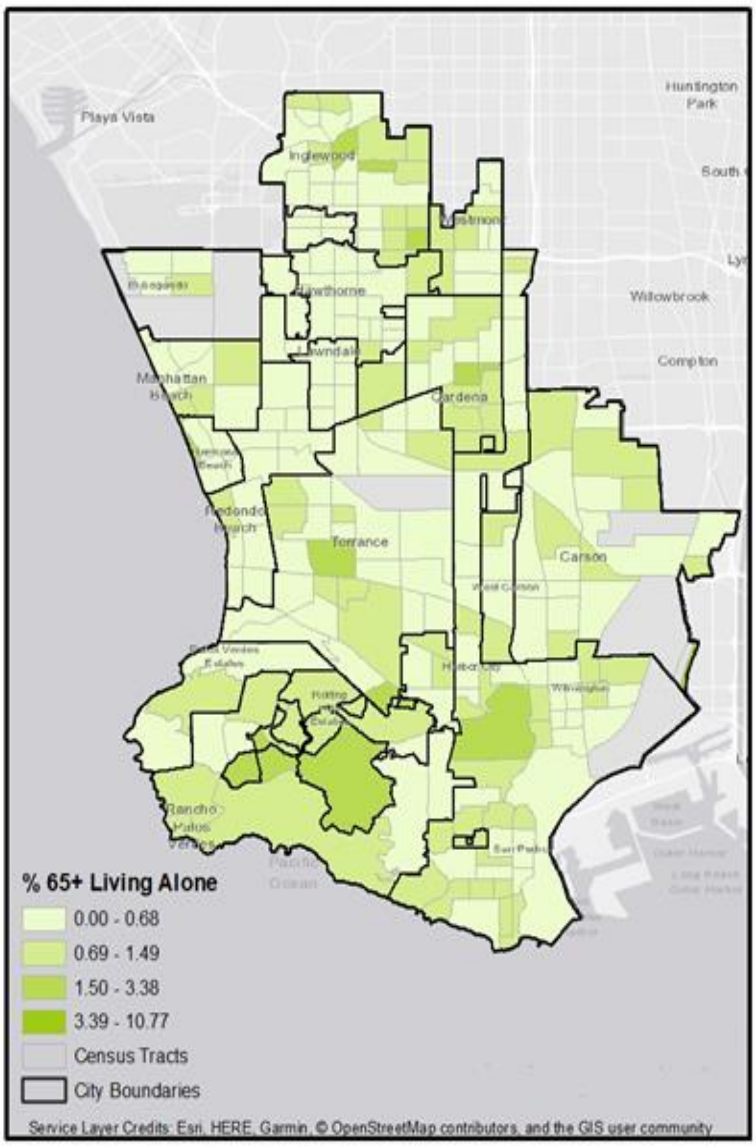
Outdoor workers are more susceptible to heat stress, which can cause a decrease in productivity and induce health risks such as dehydration, heat stroke, and long-term damage to major organs and physiological functions. Strenuous working conditions, language barriers, exposure to chemicals, and limited capacity to protect their rights influence health outcomes exacerbated by climate change.[59] Outdoor occupations most at risk of heat stroke include construction, refining, surface mining, hazardous waste site activities, and agriculture.[60] For this assessment, outdoor workers are represented by the percent of the population working in construction.



Elderly Living Alone

Several factors contribute to the vulnerability of elderly, people aged 65 and older, living alone including:

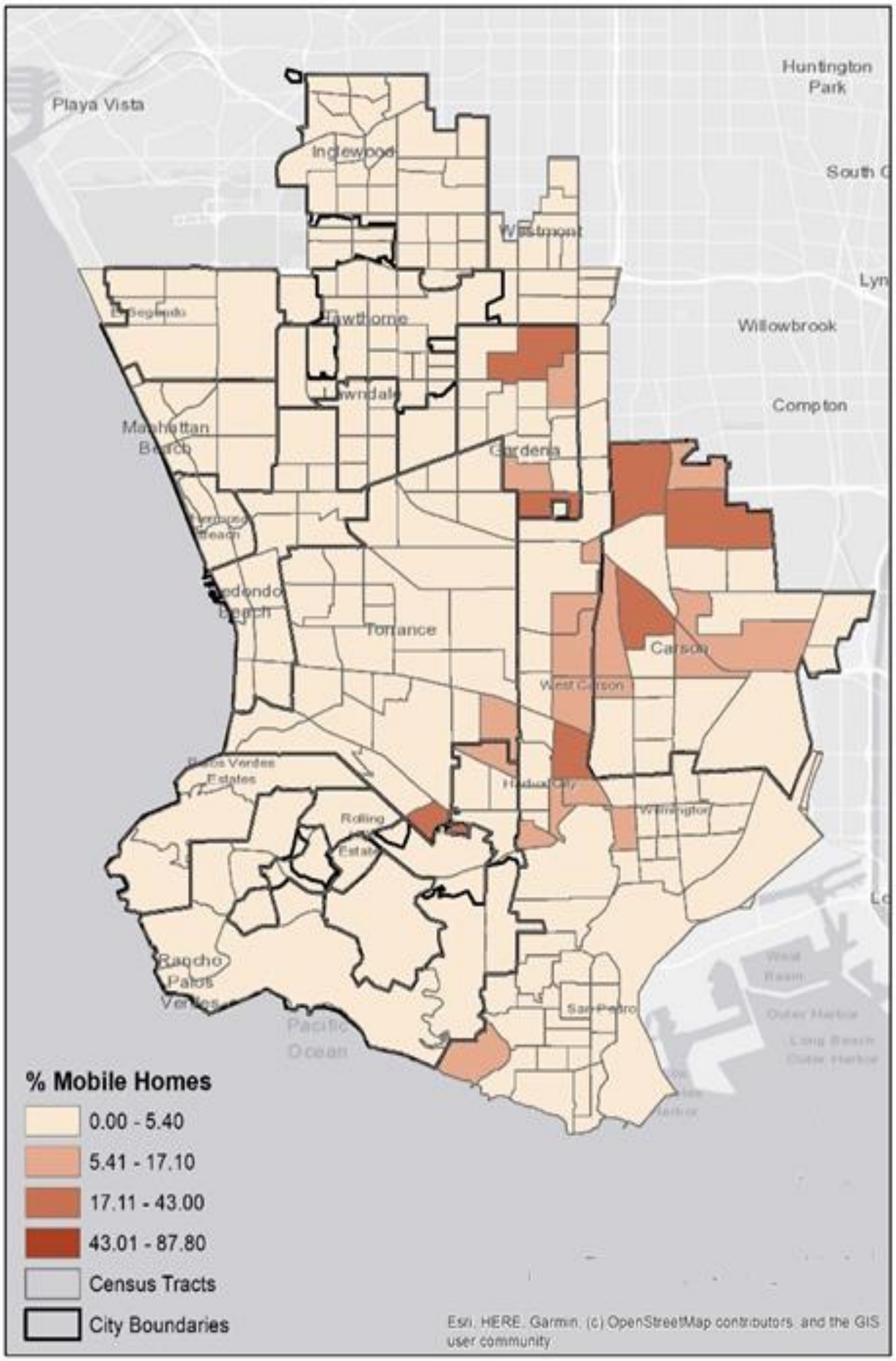
- Impaired muscle strength, coordination, cognitive ability, the immune system, and the regulation of body temperature (thermoregulation)[61]
- Pre-existing health conditions which can increase susceptibility to more severe consequences of climate change [62]
- Limited mobility (inability to evacuate) may increase risk of climate-related impacts.[63]
- Social isolation or dependent on care populations can be impacted more by heat waves and extreme weather events.[64]

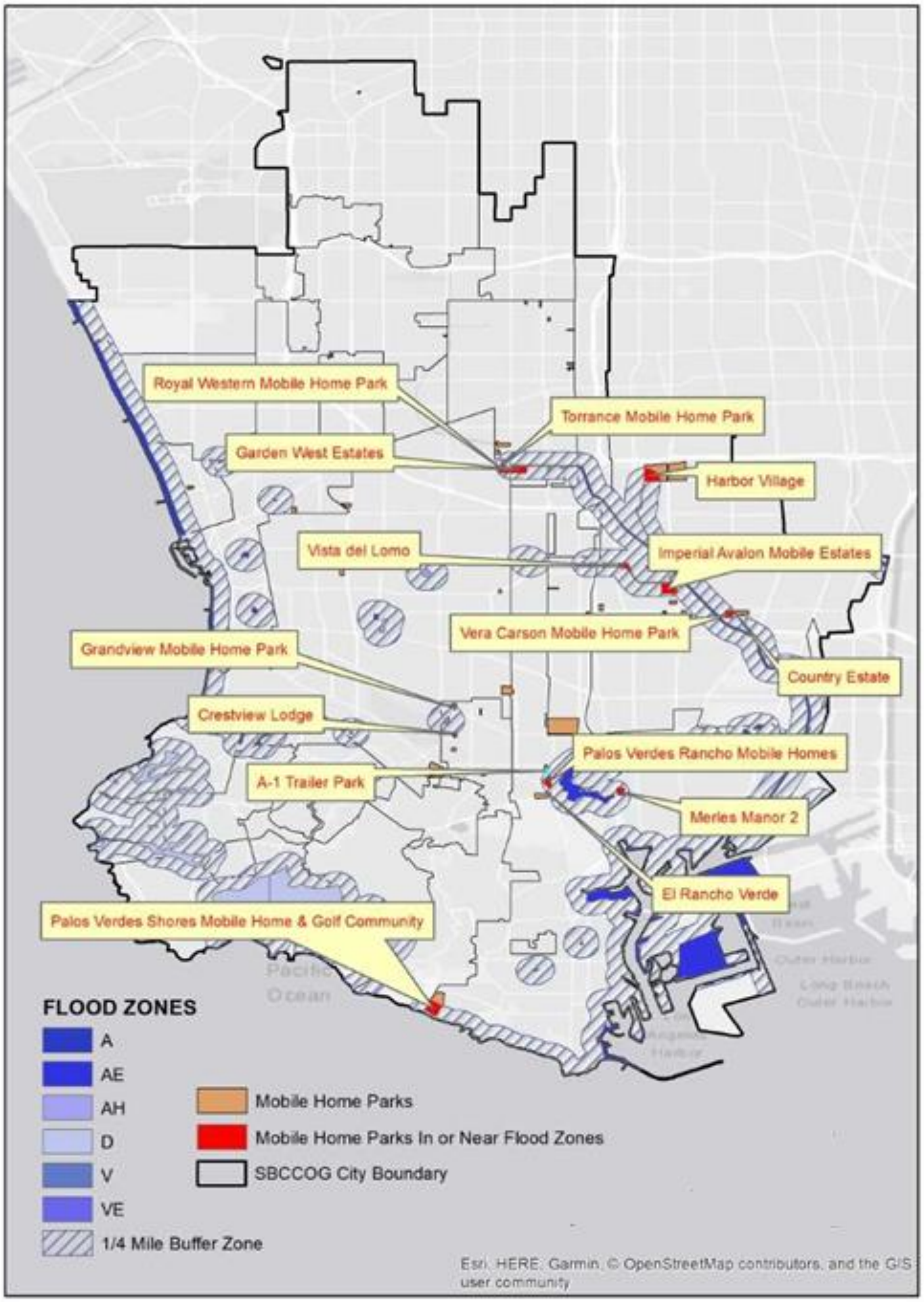


During the 2003 Southern California wildfires, respiratory hospital admissions related to wildfires increased 10% among elderly 65 years of age and older. Of the 522 deaths that occurred in Chicago during the 1995 heat wave, 73% were 65 years or older.

Mobile Homes

Mobile home or trailer park communities experience heightened risk of flood events. Mobile homes are more subject to flooding than regular homes and are structurally unsafe to stay in during extreme weather events.[65] Because of this, a great percentage of mobile home occupants evacuate than occupants of other housing. Additionally, mobile homes are less energy efficient (requiring more energy to heat and cool) due to poor insulation and are more easily damaged than other homes making them less resilient to climate hazards.[66] The SBCCOG identified the location of mobile home parks in relation to flood zones. Those mobile home parks located within ¼ mile of a flood zone are labeled in the figure below.

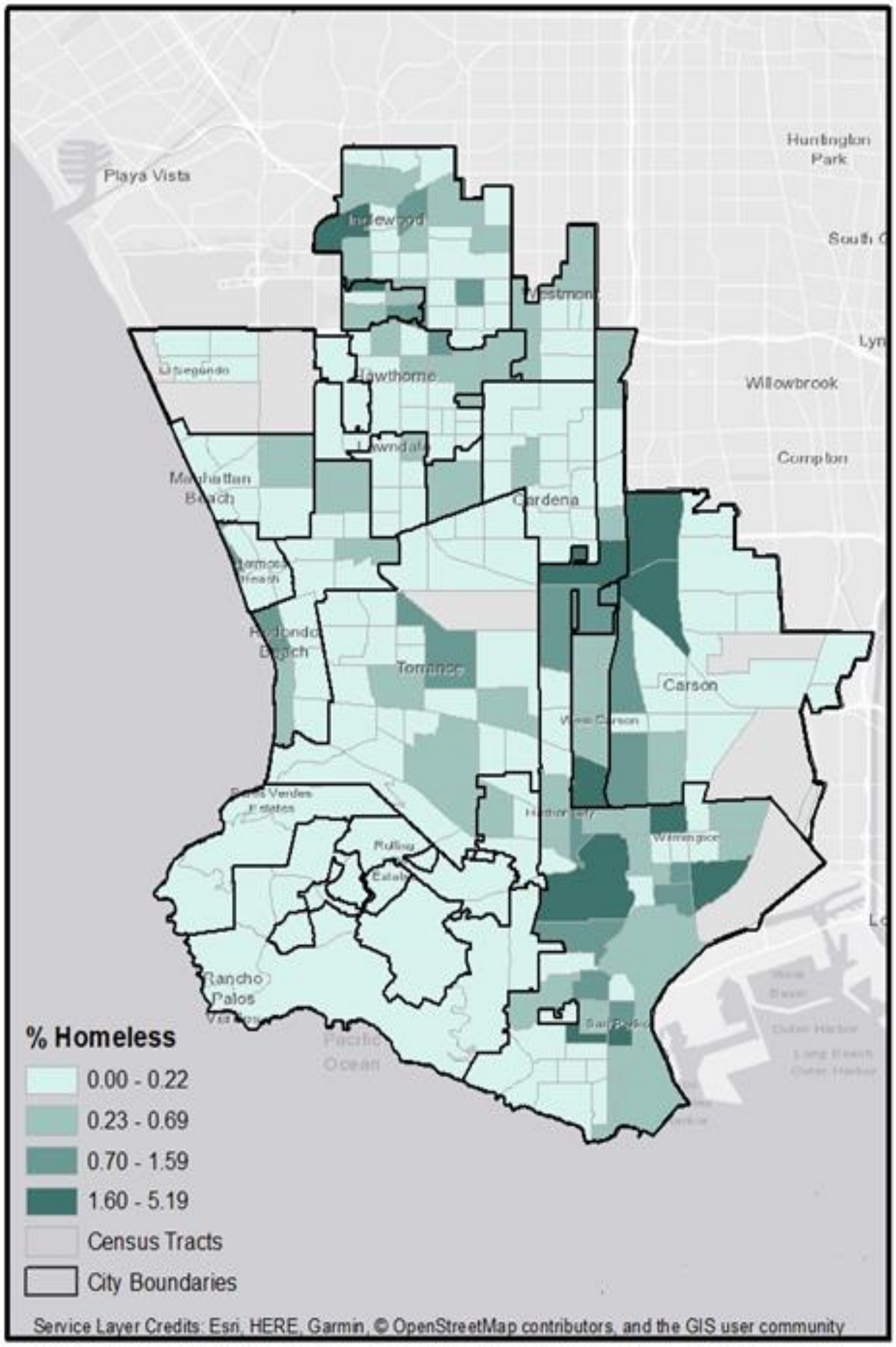




Royal Western Mobile Home Park
Torrance Mobile Home Park
Garden West Estates
Harbor Village
Vista del Lomo
Imperial Avalon Mobile Estates
Vera Carson Mobile Home Park
Grandview Mobile Home Park
Country Estate
Crestview Lodge
Palos Verdes Rancho Mobile Homes
A-1 Trailer Park
Merles Manor 2
El Rancho Verde
Palos Verdes Shores Mobile Home & Golf Community
Pacific Ocean
FLOOD ZONES
A
AE
AH
D
V
VE
1/4 Mile Buffer Zone
Mobile Home Parks
Mobile Home Parks In or Near Flood Zones
SBCCOG City Boundary
Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

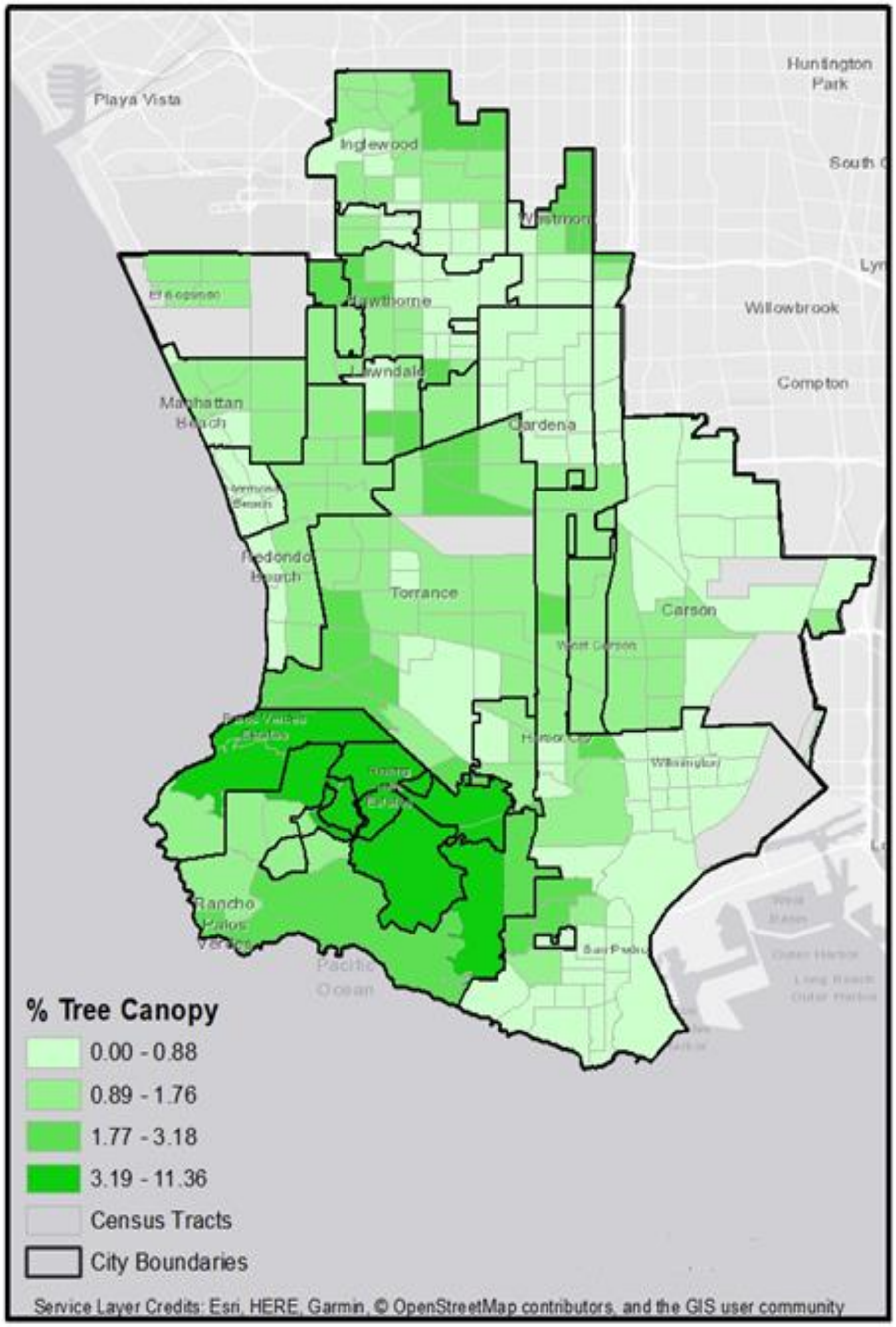
Homeless Population

The risk factors for mortality and morbidity from heat correlate closely with the characteristics of homeless individuals. Pre-existing psychiatric illness has been shown to triple the risk of death from extreme heat. Other risk factors for death during heat waves include cardiovascular disease, pulmonary disease, advanced age, living alone, being socially isolated, not using air conditioning, alcoholism, using tranquilizers, and cognitive impairment. These are all characteristics which are more common amongst homeless individuals.[67]



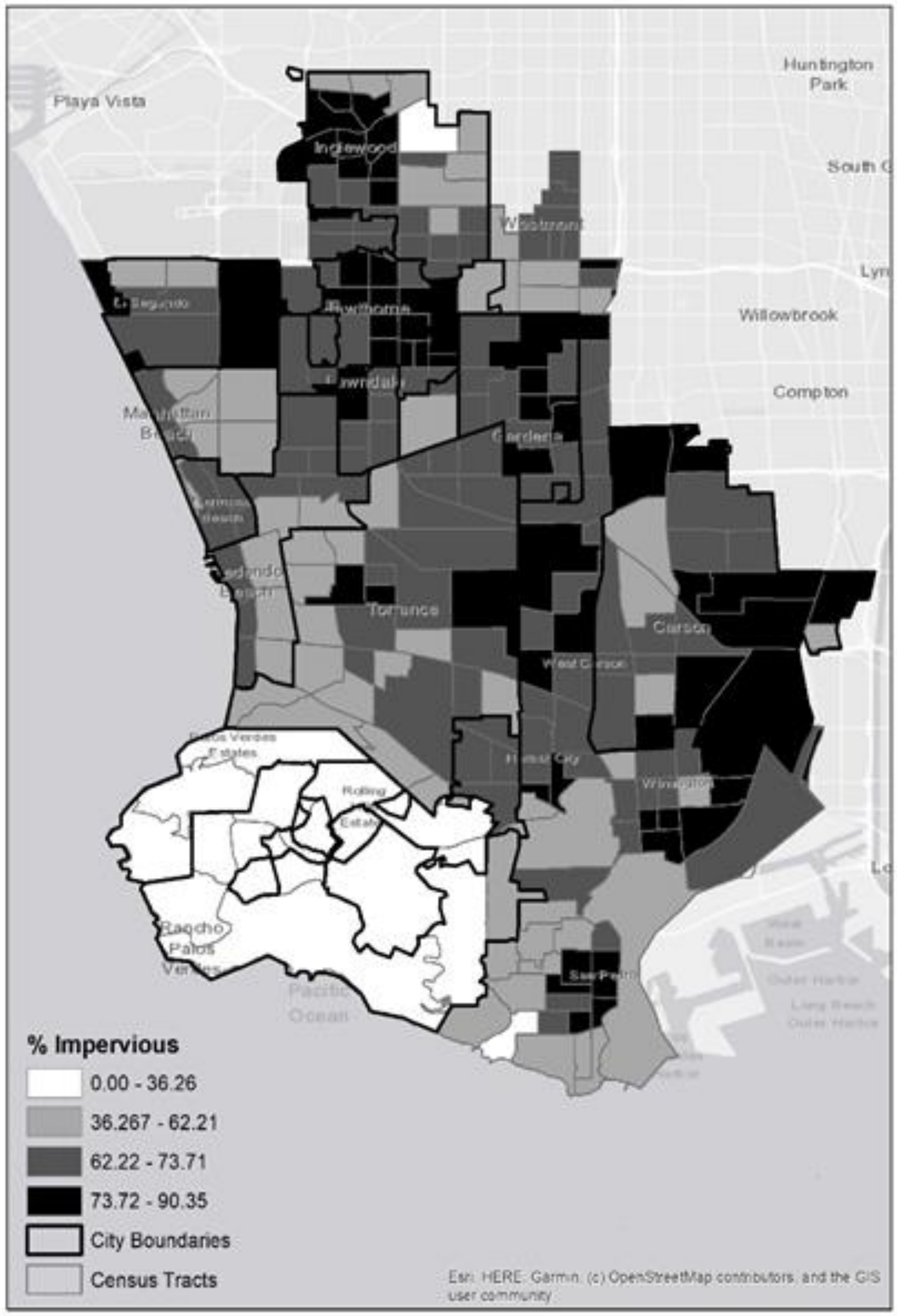
Tree Canopy

A systematic review of evidence linking urban greening and the air temperature of urban areas has shown that green sites are generally cooler than non-green sites. Meta-analysis showed that parks, on average, were 0.95 °C cooler in the day. Planting trees and vegetation properly near buildings can also save up to 25% of a household's energy consumption. Evidence links tree canopy coverage to positive health outcomes from reduced exposure to ultraviolet radiation, reduced urban heat islands, and mitigation of air pollution. [68]



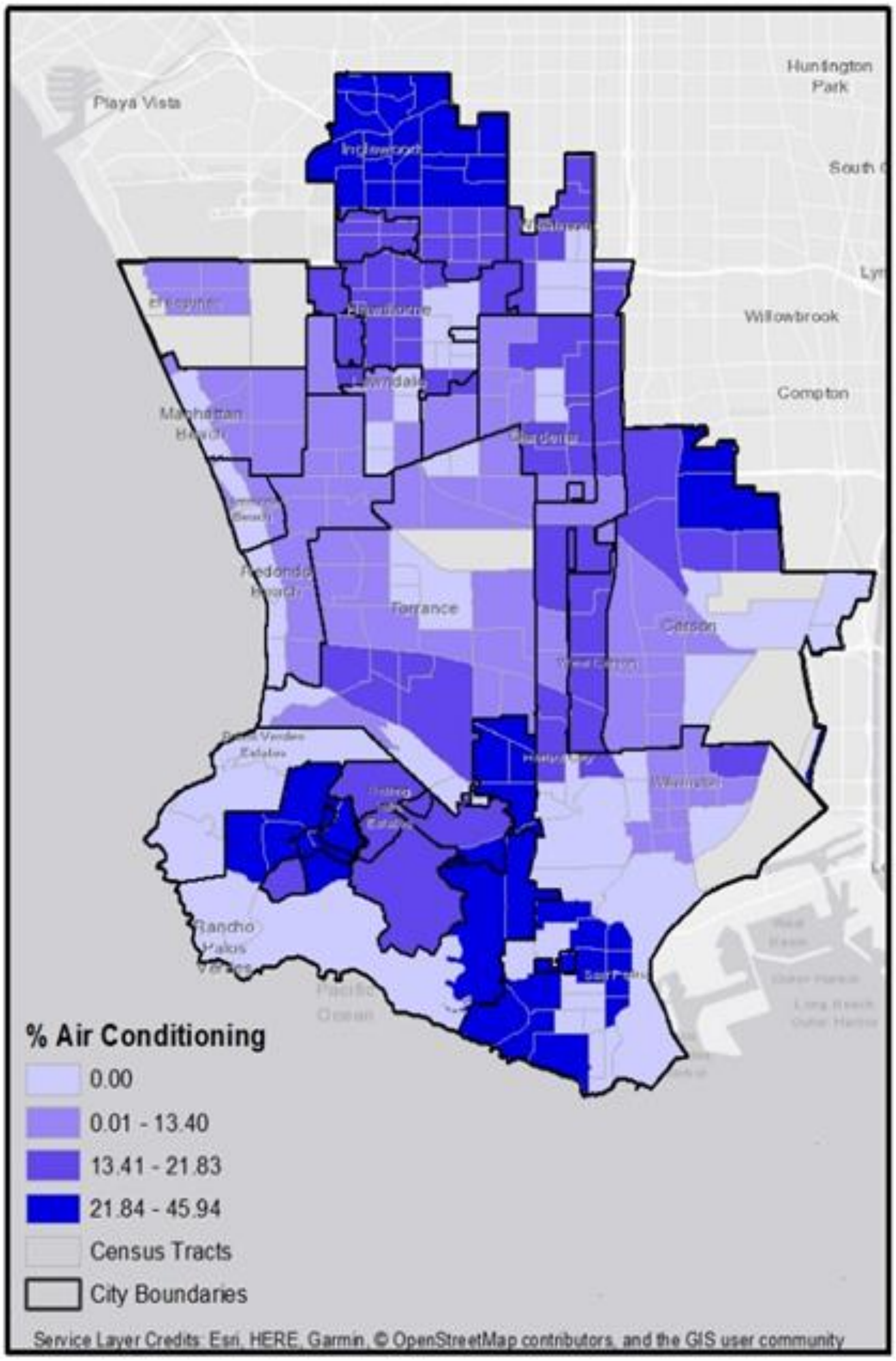
Impervious Surface

Impervious surfaces are areas covered by material that impedes the infiltration of water into the soil. Examples of impervious surfaces are buildings, pavements, concrete, and severely compacted soils. Impervious surfaces retain heat and limit absorption of water into the ground, which can lead to the urban heat island effect, a phenomenon in which urban areas are warmer than the surrounding non-urban areas.[69] Measures of impervious surfaces are important for assessing impacts from infrastructure development and built environment on urban temperatures, precipitation runoff, and water quality.[70] Communities of color are disproportionately represented in densely populated areas with more impervious surfaces, which increases their risk of exposure to heat stress.[71]



Air Conditioning

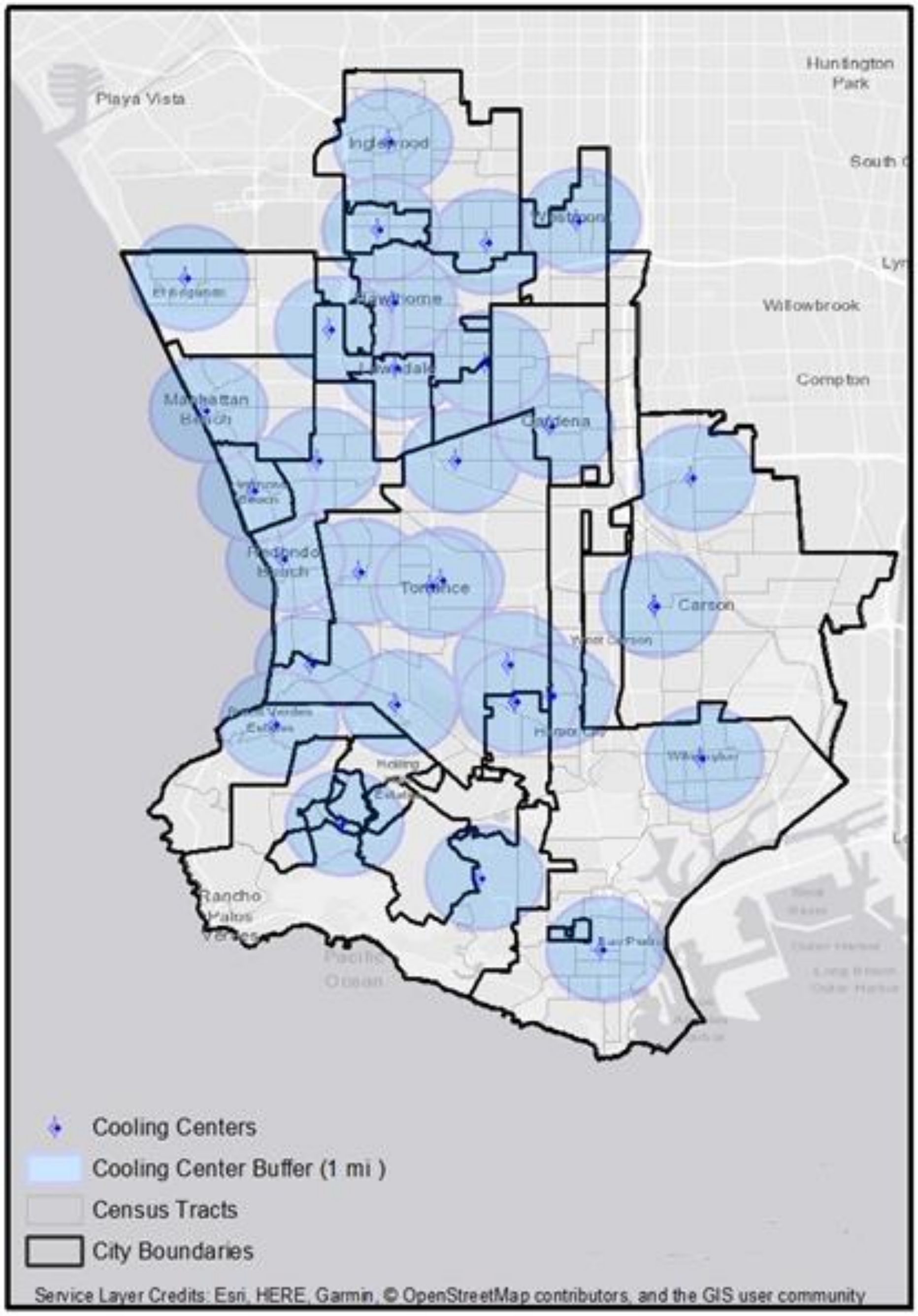
This map shows the percent of households with air conditioning.[t] Studies have shown that having working home air conditioning (AC) was the strongest protective factor against death during a heat wave, followed by access to an air-conditioned place for an extended time.[72] Research specific to California found that a 10 percent increase in AC ownership would reduce heat-related mortality by 1.4 percent per 10°C change in temperature.[73] A similar protective effect was found for the excess risk of hospitalizations.



[t] This data is based on a 2009 California Residential Appliance Saturation Study (RASS), which is conducted by the California Energy Commission. A 2019 RASS is currently underway, and this map will be updated to reflect the more recent data when it becomes available.

Access to Cooling Centers

Cooling centers offer a communal location that is free to access that allows people to find a respite from extreme heat during heat waves. The following map shows the prevalence of cooling centers (including libraries) throughout the South Bay, with a 1-mile buffer. Neighborhoods located outside of the buffer zone are not within walking distance[u] of a community cooling center.



[u] It is assumed that a safe walking distance on an extreme heat day is 1 mile or less.

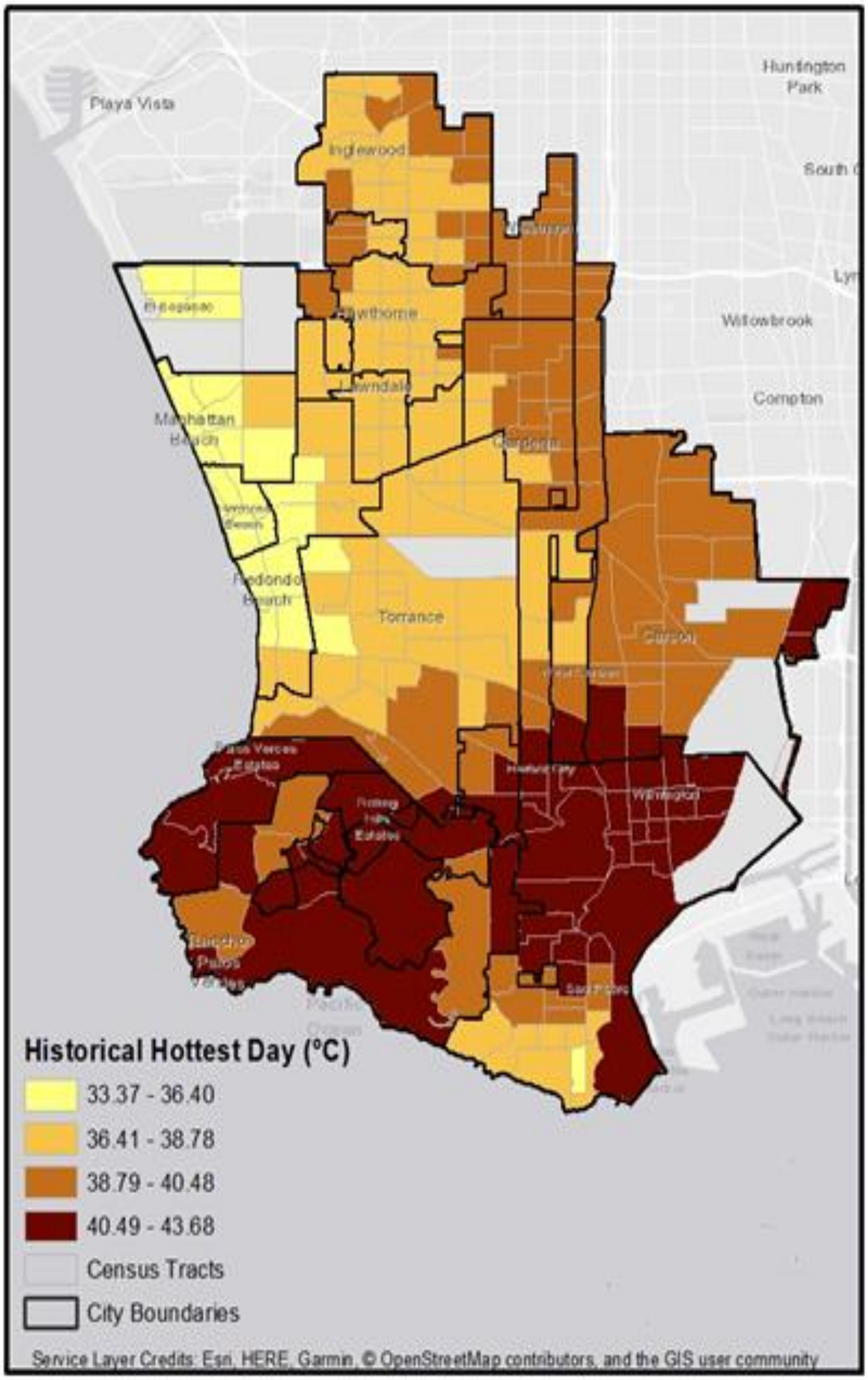
Heat Vulnerability Index

In addition to identifying individual factors of vulnerability, it is important to combine indicators with exposure data (i.e. temperature, flood zones, etc.) to identify areas of greatest risk to specific hazards. Although the South Bay is projected to experience climate stressors ranging from increased precipitation and flooding to sea level rise and wildfires, the biggest threat to human lives in the sub-region is the increasing frequency and intensity of extreme heat events. As a result, the SBCCOG aggregated selected indicators to create a heat vulnerability index. Other indices were not constructed due to data limitations and capacity constraints; however, the individual city vulnerablity assessments allow for cities to construct their own indices utilizing the methodology provided in **Appendix B**.

Due to the South Bay's historically temperate climate, most people don't view the South Bay as a place of concern for extreme heat events. Because of this commonly held perception, residents are particularly vulnerable due to the lack of physiological and technologic adaptations. It typically takes human biology two weeks to adapt to temperature extremes.[74] Since residents do not regularly experience extreme heat events for extended durations, as a population, their bodies have a more difficult time thermoregulating, which can cause heat stress and increase risk of heat related illness and sometimes death. In addition, South Bay residents are less likely to have technologic adaptations such as air conditioning. In the LA area, it is estimated that only 51% of households have central air conditioning.[75]

The SBCCOG utilized historical temperature data to identify areas of the South Bay that have relatively greater exposure to extreme heat (**Figure 3.1)**. The heat vulnerability index identifies locations that might be driving the vulnerability by combining indicators of exposure, sensitivity and adaptive capacity. Neighborhoods of high heat vulnerability include San Pedro, Wilmington, North Carson, East Gardena, Inglewood, and Westmont (**Figure 3.2**).

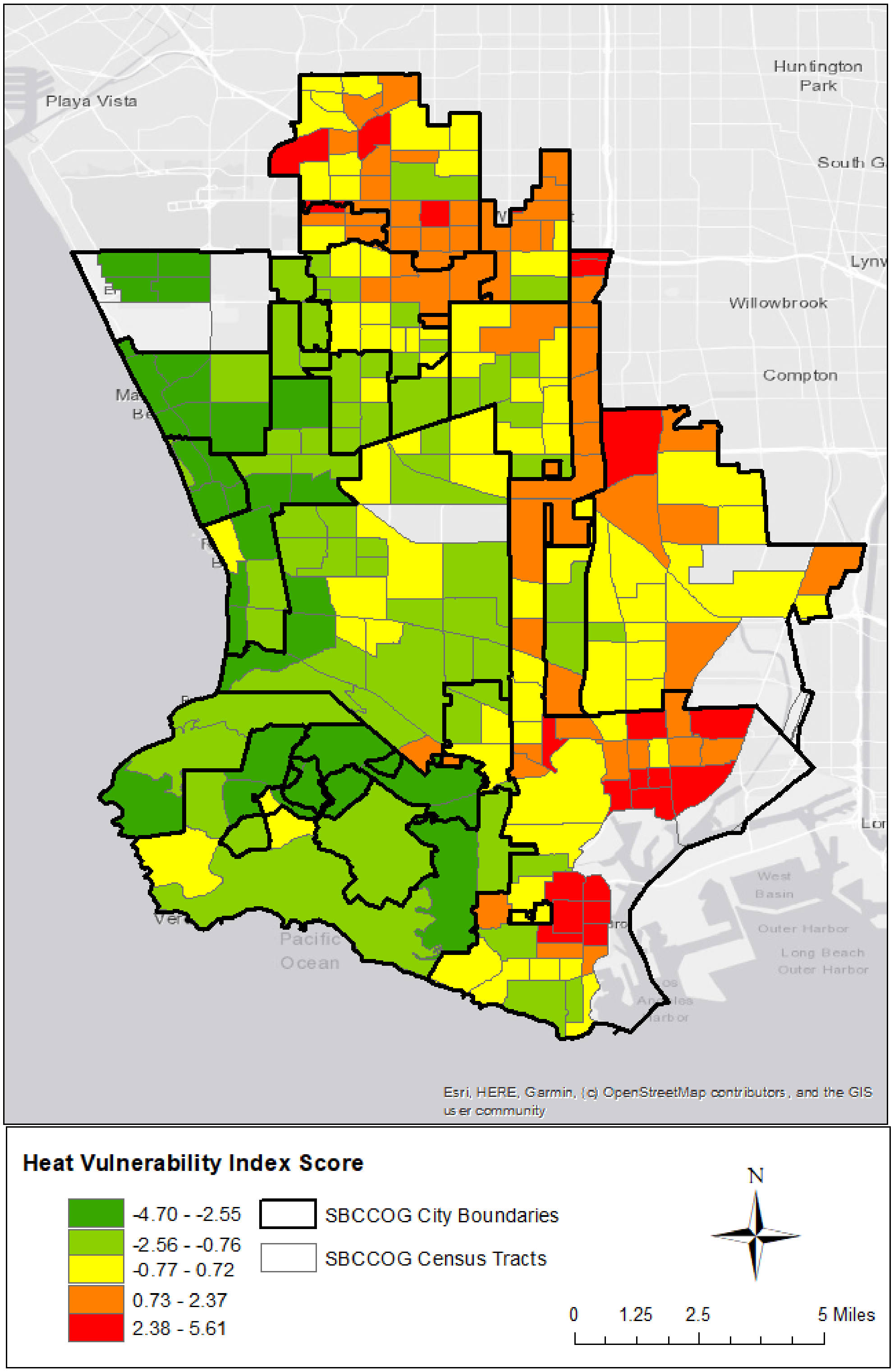
Figure 3.1: Historical Hottest Day Temperatures in the South Bay



The historical hottest day map represents the projected maximum temperature on the day that the highest average maximum temperature occurred in LA County

Degrees Celsius (°C)	Degrees Fahrenheit (°F)
33.37 - 36.40	92.06 - 97.53
36.41 - 38.78	97.54 -101.80
38.79 - 40.48	101.82 - 104.86
40.49 - 43.68	104.88 - 110.62

Figure 3.2: Heat Vulnerability Index



Heat Vulnerability Index Findings

The study of heat distribution and predictions of neighborhoods that are especially vulnerable to extreme heat in the South Bay is valuable for local government agencies to prevent potential damage to the public's health from the consequences of climate change. The heat vulnerability index identifies areas that are particularly vulnerable and identifies the most relevant ('dominant') indicators of heat vulnerability, which can aid in public health planning and adaptation strategy development. The four components generated from the analysis (listed below) explain 66.42% of the variance of the dataset. The components that explain the other 33.58% were less capable of being interpreted, and therefore discarded in accordance with the methodology described in **Appendix B**.

Variance is a measurement of the spread between values in a dataset. It measures how far each number in the set is from the average.

Component	Name	% Variance Explained	Dominant Indicators
1	**Economically Stressed Family/Household**	39.4	NOCAR
			POVERTY
			POPDENSITY
			SINGPARENT
			CHILD
			RENT50
2	**Outdoor Workers**	13.27	CONSTRUCTION
			EDU
			MAXTEMP
			NOENG
			NOINS
3	**Elderly & Disability**	7.18	DISABILITY
			ELDERLYALONE
4	**Poor Health**	6.56	HOMELESS
			NOTREES
			DISEASE
	Total Variance Explained	**66.42**	

- Component 1 (no access to vehicle, poverty, population density, single parents, and children) contributes most significantly to the heat vulnerability score. Therefore, adaptive strategies should target economically stressed family households to ensure they have proper access to adaptive measures such as cooling centers within walking distance to their homes. Outreach to families should also be considered to determine what resources are currently lacking and what could be improved to ensure families are aware of how to respond to extreme heat events.
- Component 2 (outdoor workers, correlated with low educational attainment, limited English speaking skills, and exposer to higher temperatures) also contribute significantly to the index score. As a result, adaptive strategies could include improved education to workers and employees in occupations that require greater exposure to heat. This preparedness education should be provided with appropriate linguistic and cultural considerations.
- Components 3 & 4 (disability, elderly living alone, homeless, tree canopy and disease) together explain approximately 14% of the variance. To address the vulnerability associated with this component, policymakers may consider adopting a "check-up" system using city health workers or neighborhood groups to make sure those who are isolated, physically or mentally impaired, homeless or in otherwise poor health are adequately protected during a heat event. For example, the LA County Board of Supervisors passed a motion in July, 2018 that directed the Chief Executive Office's Homeless Initiative and the Office of Emergency Management to develop a pre-planned and coordinated emergency response to significant heat events that addresses the needs of people experiencing homelessness and determines the feasibility of using county-funded homeless outreach teams to transport clients in need to cooling centers.[76]

The interactions between climate change and health are numerous. Not only will climate change have significant health impacts, but how we prepare to and mitigate and adapt to our changing climate will also influence health. Responding to climate change is a powerful opportunity to improve the health of the South Bay's residents.

Sector Analysis

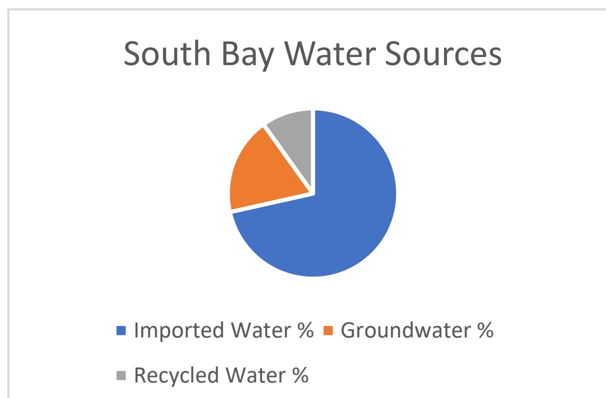
The SBCCOG, in accordance with the California Adaptation Planning Guide, identifies sectors impacted by climate change and the existing plans and strategies that have been developed or implemented within those respective sectors to address potential climate impacts. Sectors considered in this plan include Water Management, Energy Management, Biodiversity, Coastal Resource Management, Transportation, and Migration/Demographic Change. The SBCCOG considers the vulnerability of these sectors, as well as the adaptation strategies currently being adopted or implemented by relevant agencies.

Sector 1: Water Management

The following section describes the vulnerabilities, challenges, and existing strategies for water management with respect to projected increases in frequency and intensity of climatic events.

Water Supply Management

Water agencies that operate throughout the South Bay and the Greater Los Angeles region have a history of working collaboratively to access a variety of supply sources, implement new production technologies, respond to evolving regulatory requirements, and navigate changing political conditions to meet regional demand with uninterrupted supply.

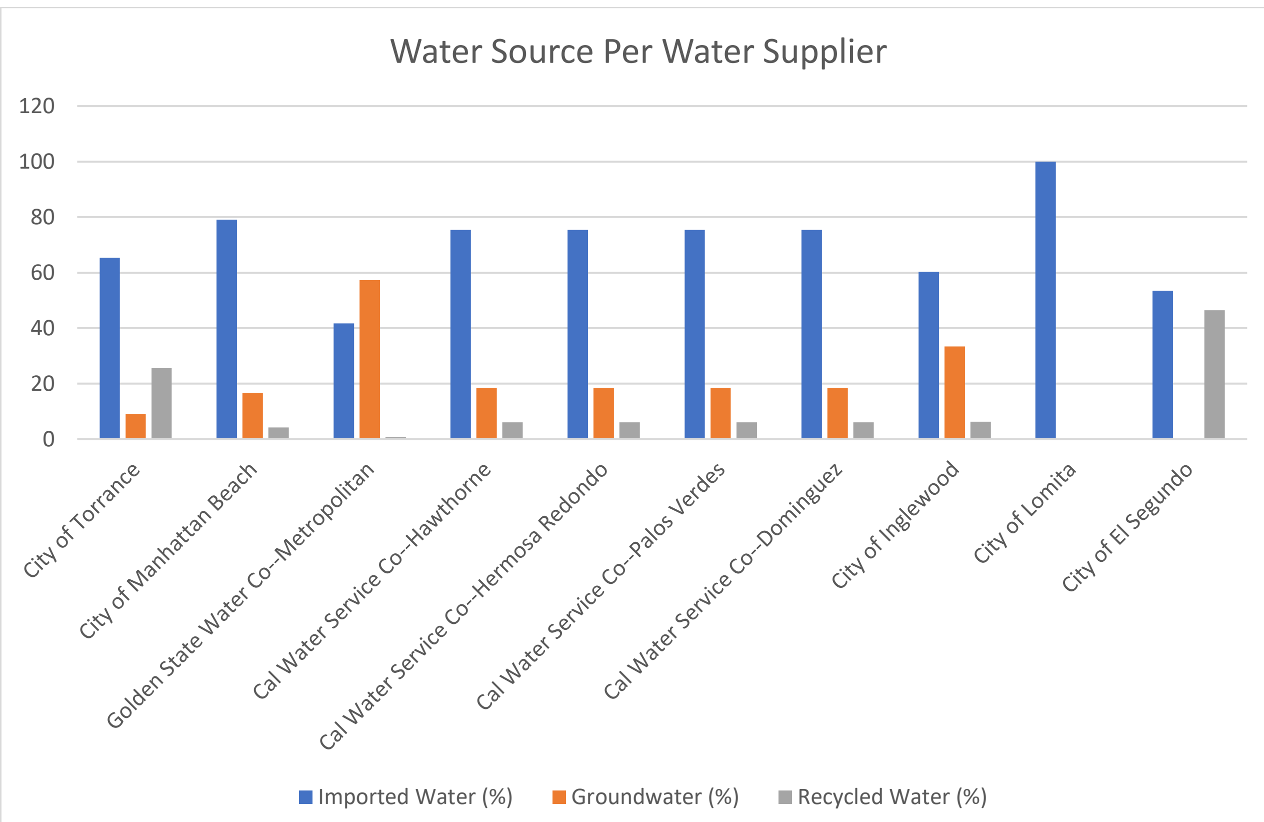


Above: Distribution of water sources for the South Bay (2010).

The Metropolitan Water District of Southern California (MWD) is the primary water contractor in the region, importing and distributing water to member agencies since 1941. MWD imports water supplies from two main sources: the Sacramento and San Joaquin Rivers through the State Water Project and the Colorado River via the Colorado River Aqueduct.[77] The imported sources rely on winter snowpack to deliver supplies year-round. Other parts of the subregion depend on groundwater resources, where replenishment of the water table is dependent on rainwater percolating through the ground.

Since Governor Schwarzenegger's 2005 Executive Order requiring biennial reports on potential climate change effects on different sectors including water resources, water planners have integrated climate change projections into water resources planning. There are eleven water suppliers[v] in the South Bay sub-region, five of which are owned and operated by two of the Investor-Owned Utilities: Cal-Water and Golden State Water Company. The other six are city retailers. **Figure 4.1** shows the distribution of water source for each water supplier in the South Bay, and **Figure 4.2** displays the reported versus the projected demand of water for each supplier.

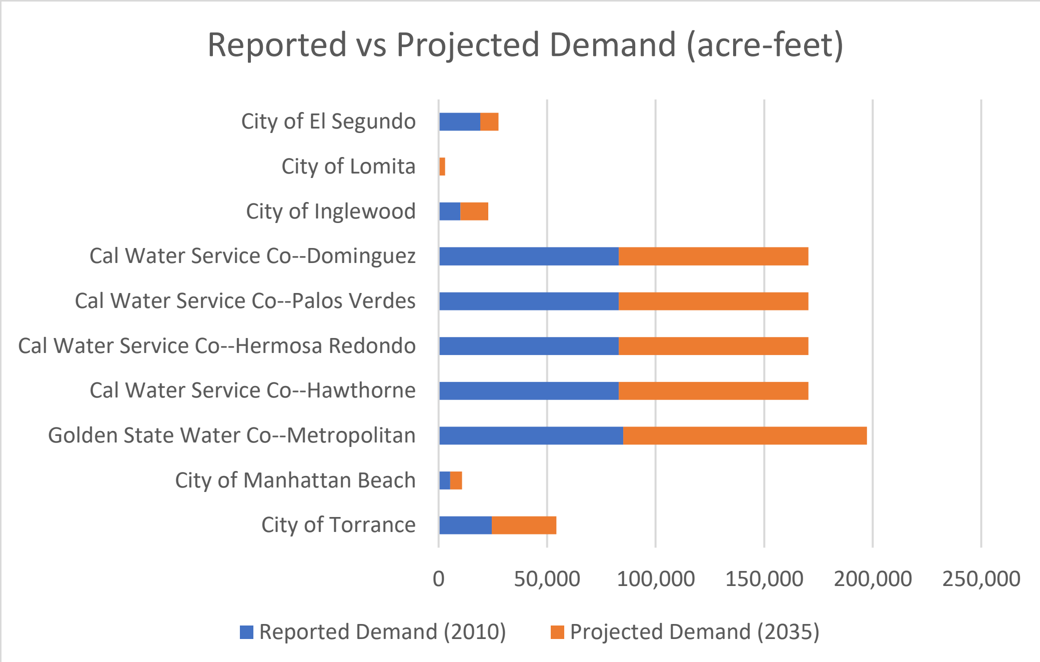
Figure 4.1: Water Source Distribution per Water Supplier (2010)



Source: Los Angeles Water Hub

[v] City of Los Angeles is not included in Figure 1, 2 & 3

Figure 4.2: Projected Water Demand (2010 to 2035)



Source: Los Angeles Water Hub

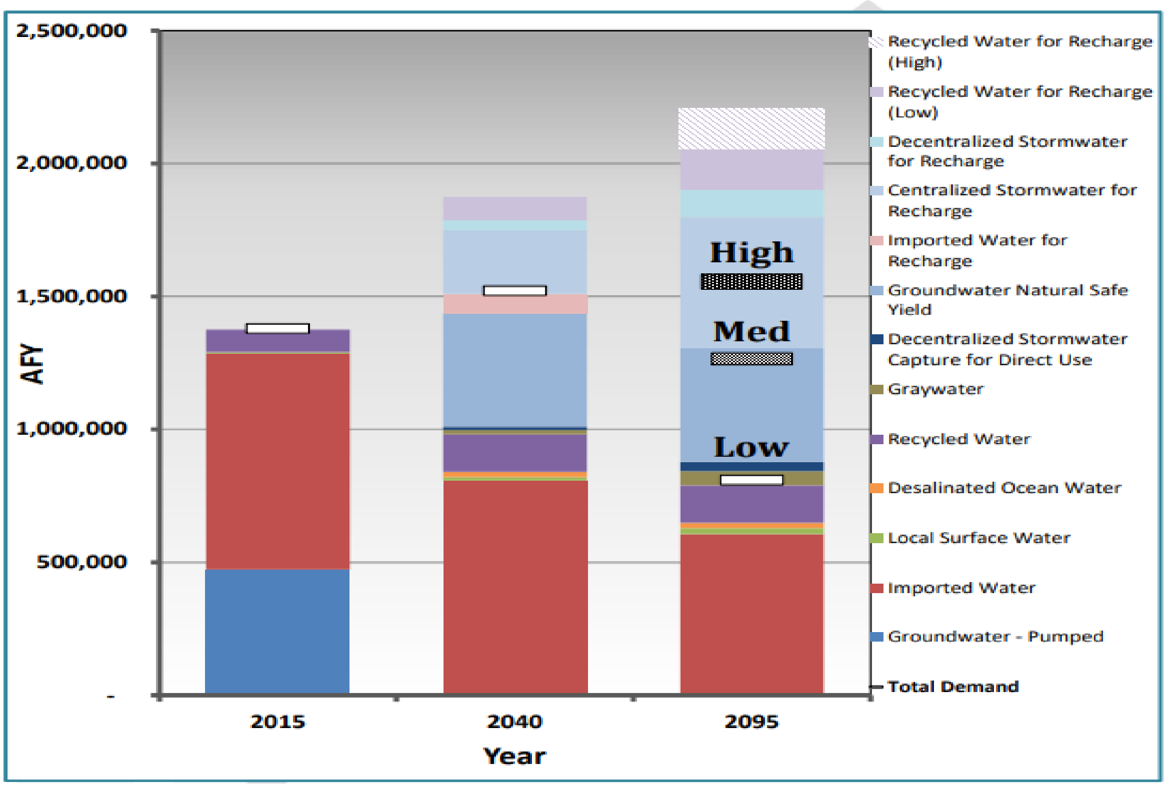
Vulnerability of Imported Water Supplies

Climate change threatens to reduce supplies from imported water sources due to potential changes in precipitation patterns that could decrease overall in frequency but increase event intensity. Several climate change studies attempted to predict the supply reliability of imported water supplies in the future. In 2011, the Los Angeles Department of Water and Power (LADWP) conducted a study on potential climate change impacts in the eastern sierra and to investigate opportunities to improve the Los Angeles Aqueduct system to mitigate potential impacts.[78] In 2018, researchers at UCLA projected that California's Sierra Nevada snowpack will experience a 48-65% loss, corresponding to a mitigation emissions scenario (RCP 4.5) and business as usual scenario (RCP 8.5), respectively, from the historical April average.[79] Continued decline in the Sierra Nevada snowpack volume is expected, which may lead to lower volumes of available imported water.The US Department of the Interior Bureau of Reclamation (USBR) and the Los Angeles County Flood Control District (LACFCD) jointly authored the Los Angeles Basin Study[80], which analyzed supply and demand in the Los Angeles Basin area. As part of this study, supply and demand throughout the county were totaled to estimate the historical 2010 and projected 2035 supply and demand. Additional assumptions, including potential climate change impacts, were made to project supply and demand out as far as 2095. The Water Resilience Draft Report (2017)[81] developed by Los Angeles County Department of Public Works (LACDPW) and LACFD updated the study to reflect the most recent data reported in the 2015 Urban Water Management Plan (UWMP).

Figure 4.3 shows the current (2015) and projected supplies and demands for the Los Angeles basin area for the years 2040 and 2095. As illustrated in the figure, total imported water for direct use decreases slightly in 2040 compared to 2015, despite an increase in total demands. The imported water supply decreases even further in 2095 compared to 2015 direct use. Imported water is considered less reliable due to legal constraints and climate change impacts. Therefore, water agencies project a decline in imported water sources based on their commitment to replace less reliable, imported water with local, recycled water and stormwater by 2095.

Figure 4.3 also shows how projected demand for 2095 compares with total projected available supply. The high demand bar for 2095 represents the gallon per capita per day (gpcd) demand average for the Los Angeles Basin region, which remains static at the 2040 gpcd average (123 gpcd). The medium demand bar reflects a 100 gpcd water use target for the Los Angeles Basin region. The low demand bar represents a 64 gpcd target.

Figure 4.3: Existing and Projected Supplies and Demands for the Los Angeles Basin Area (adapted from LA Basin Study, 2015)



Source: Building Water Resilience in Los Angeles County, Draft Report

Existing Strategies to Mitigate the Impact of Climate Change on Imported Water Supplies

Increasing Storage and Regulation

Imported water management in Los Angeles County is heavily influenced by MWD's water management strategies, particularly MWD's Water Surplus and Drought Management (WSDM) Plan.[82] The guiding principle of the WSDM Plan is that MWD will encourage storage of water during periods of surplus and work jointly with its member agencies to minimize the impacts of water shortages on the region's retail consumers and economy during periods of shortage. When forecasts of supplies and demands predict pressure on storage reserves, MWD can trigger the Water Supply Allocation Plan[83]. This Plan aims to distribute a limited amount of water supply during drought periods according to local conditions and needs of the region's retail water consumers. [84] MWD's Integrated Water Resources Plan[85] is used to assess and adapt to changing conditions facing southern California and increase the reliability of the region's water supply regardless of the challenges that emerge. MWD has shown an increasingly diversified water supply portfolio for southern California as more local agencies increase their local supplies and decrease dependence on imported water served by MWD.

Increasing Local Water Supply

Developing local supplies to decrease dependence on imported water will help increase the availability and reliability of both local and regional supply in the face of ongoing population growth and climate change. Even agencies that cannot readily use local supplies are supporting their development as a method of increasing imported water sustainability. MWD funds the Local Resources Program to provide funding to South Bay water agencies including LADWP, City of Torrance, and WBMWD to develop local supplies for the benefit of the region. As a result, studies and strategies have been developed to unlock the potential of surface, stormwater, and recycled water.

a. *Surface Water:* Direct diversion and use of local surface water is not a major supply source for the South Bay sub-region. The Los Angeles River is the major river system in the sub-region. The Los Angeles River flows 51 miles from the union of Bell Creek and Arroyo Calabasas in the San Fernando Valley, then southeast through the City of Burbank and eventually southward to Long Beach. Originally, the Los Angeles River was the primary water source for the City of Los Angeles. Following several catastrophic floods, the United States Army Corps of Engineers (USACE) encased most of the riverbed and banks in concrete, effectively eliminating interaction between groundwater and surface water in certain areas. Today, the river is primarily fed from stormwater, effluent from wastewater treatment plants, urban runoff, base flow from the Santa Monica and San Gabriel Mountains, and groundwater inflow in the Glendale Narrows.

Source: David McNew/Getty Images

There is little potential for the sub-region to increase its surface water supply to meet increases in demand due to population growth and drought.

b. *Stormwater runoff and capture:* As shown in **Figure 4.3**, the greatest opportunity for future increases in local supply lies with stormwater capture through both distributed and centralized projects. The capture and use of stormwater runoff (runoff from urban areas that has not yet reached streams and rivers) is a source of supply that is currently underutilized. Projects and programs that capture stormwater are particularly valuable for building water resilience because they can provide a suite of benefits beyond additional water supply. Local stormwater capture decreases dependence on imported water sources, helps improve water quality, provides some flood protection, reduces peak flows that impact the region's waterways, and often involves development of new greenspace for habitat restoration and community recreation. Through these benefits, effective stormwater management contributes to developing a resilient watershed that can withstand the threat of climate change and increased needs presented by a growing population.

As a requirement of Los Angeles County's Municipal Separate Storm Sewer System (MS4) Permit requirements, South Bay cities[w] have developed Low Impact Development (LID) Ordinances that mandate the inclusion of distributed stormwater capture projects in new development and significant redevelopment projects. Additionally, the Permit calls for increased local stormwater capture through regional infiltration projects and green streets policies.

Additional studies have focused on the future of stormwater capture, investigating new opportunities and promising innovations. In 2015, LADWP completed its Stormwater Capture Master Plan[86] that evaluated the potential for stormwater capture in the City of Los Angeles. This plan outlines LADWP's strategies over the next 20 years to implement related projects and programs and to cooperate with other agencies in the City that will contribute to more reliable and sustainable local water supplies. Through this effort,

[w] The City of Rolling Hills is not an MS4 Permittee and does not have a LID Ordinance

LADWP identified several potential stormwater capture opportunities within the City of Los Angeles.

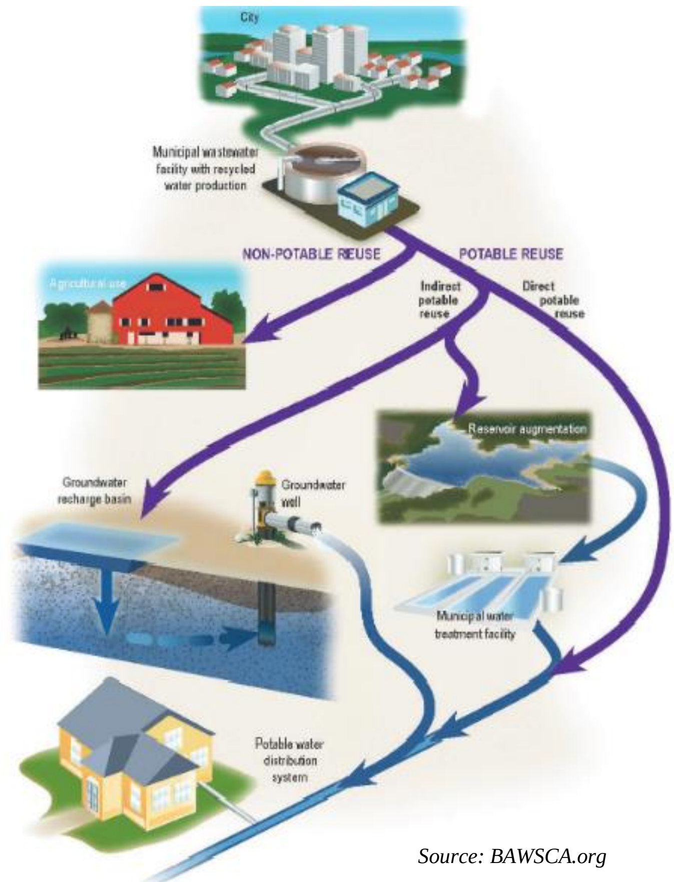
LACFCD and USBR developed the Los Angeles Basin Stormwater Conservation Study (2016)[87] to assess the Los Angeles Basin's current and projected water supplies and demands, identify any gaps, and develop adaptation strategies to address impacts from climate change and population growth. As part of the study, the group developed project concept alternatives and conducted a tradeoff analysis to evaluate the benefits and costs of stormwater concepts for the region. Results of the analysis showed that LACFCD Dam projects, local solutions, regional impact programs, and green infrastructure programs had benefits with the most value and should be considered for feasibility in the future.

The City of Los Angeles recently released its One Water LA Plan that provides an integrated approach for water supply, wastewater treatment, and stormwater management in the City of Los Angeles.[88] One Water LA is a component of the City of Los Angeles Sustainability Plan and involves multiple agencies and stakeholders working on the City's water issues. The collaborative effort aims to address long-term supplies for the City of Los Angeles in addition to enhancing resilience to drought conditions and climate change.

As an example of stormwater capture efforts being implemented in the South Bay, the SBCCOG partners with WBMWD to implement a rain barrel program to help increase localized stormwater capture for direct use by ratepayers. These programs provide some water supply to the user and are key components of rain garden and conservation programs.

c. *Recycled Water:* Partnerships between wastewater and water agencies have resulted in several ongoing recycled water programs and are now focused on expanding their recycled water systems to offset potable demands and increase the resilience of supply during periods of drought.

Within the Los Angeles Basin metropolitan area, LA County Sanitation District (LACSD) maintains a regional interconnected system of facilities called the Joint Outfall System. The Joint Outfall System employs two types of treatment plants: 1) upstream water reclamation plants that capture low salinity, high quality wastewater and treat it to disinfected tertiary recycled water; and 2) a downstream Joint Water Pollution Control Plant (JWPCP) that captures and treats the higher salinity wastewater along with the solids removed from the upstream plants. Due to the quality of the wastewater at the Joint Water Pollution Control Plant, reclaimed water from the plant requires additional treatment before it can be recycled and reused.[89]



Source: BAWSCA.org

Agencies are beginning to research the feasibility of implementing direct potable reuse projects to increase local supply. Direct potable reuse projects involve introducing advanced treated recycled water directly into the public water system, into a reservoir upstream of a water treatment plant, or injected into a groundwater basin. The main difference between “indirect” and “direct” potable reuse is that there is less residence time before use. Agencies such as LADWP are investigating the feasibility of utilizing direct potable reuse as a supply but are not able to do so until water quality regulations are released for this type of supply.

LACSD has also entered into a partnership with Metropolitan to explore the development of a large regional recycled water project to reuse water currently discharged to the ocean from the Joint Water Pollution Control Plant. This potential supply has been previously untapped due to its high salinity content. The project would provide advanced treatment to the high salinity effluent to create a new source of water to recharge several groundwater basins in Los Angeles and Orange Counties. If the project is approved, Metropolitan would build a new purification plant, distribution pipelines, and facilities to infiltrate or inject the water into the groundwater basins. A demonstration-scale recycled water treatment plant (500,000 gallons/day), called the Regional Recycled Water Advanced Purification Center will be placed into service at the JPCWP this summer (2019). The full-scale facility will take 16 years to design and build, once approved, and will cost $3.4 billion, or $129 million annually.

d. *Desalination:* Although not yet implemented within the South Bay or LA County, it is worth noting that desalination is under consideration. West Basin Municipal Water District (WBMWD) developed an Ocean Water Desalination Program Master Plan (2013) to define the overall desalination program scope and the key project components. WBMWD conducted an eight-year ocean water desalination pilot testing at the El Segundo Power Generating Station to assess the feasibility of turning ocean water into drinking water. As a result of the pilot study, WBMWD concluded that ocean water desalination could be a viable alternative water supply and is currently assessing the critical components of a full-scale ocean water desalination program.

   The planned ocean desalination facility will be owned and operated by WBMWD. In addition to WBMWD's role, several federal, State, and local regulatory agencies are involved in the oversight of this project. Numerous permits, in addition to thorough California Environmental Quality Act (CEQA) analyses are required before the ocean desalination facility can be built. West Basin is implementing on-going consultation and coordination with agencies such as U.S. Fish and Wildlife Service, the National Marine Fisheries Service, USACE, the Regional Board, the California State Lands Commission, the California Department of Fish and Wildlife, the California Coastal Commission, the California Department of Public Health, the California Department of Parks and Recreation, the California Department of Transportation, the South Coast Air Quality Management District, Metropolitan Water District, and multiple cities that surround the area where the facility will be built.

As part of the assessment and design of the ocean desalination facility, WBMWD is planning against future challenges that could reduce use of ocean desalination as a local supply source. Potential sea level rise impacts are being incorporated into planning of the desalination facility and environmental impacts are being considered and addressed. In its *Technical Memorandum: Coastal Hazards Analysis of the WBMWD Ocean Water Desalination Project for Sea Levels at Year 2100*, West Basin states, "all the beach front facilities for the Desalination Project (which are at minimum elevations of +23ft. NAVD) are safe from flooding or inundation by extreme event waves that are concurrent with extreme ocean water levels as the low range projection of sea level rise for 2100. At the high range, there is a 0.04% chance that the maximum total water level events reach 26.02 ft for the eroded beach conditions and 23.93 ft. for the accreted beach conditions."[90]

As of February 2019, WBMWD has been reviewing and commenting on the Environmental Impact Report (a draft EIR was submitted in March 2018) for the ocean desalination facility in which they are quantifying potential impacts in compliance with CEQA requirements. In May 2019, they received over one million dollars in grant funding from the Department of Water Resources to provide a new well at the existing groundwater desalination facility and to continue to advance the EIR for the ocean desalination plant. The key project components include a screened ocean intake, a concentrate discharge system, and a desalinated water conveyance system. Potential environmental concerns associated with ocean desalination programs include marine impacts from intake structures, marine impacts from brine discharge, and the high-energy usage of such facilities. WBMWD has been dedicated to investigating and researching new and emerging technologies which may mitigate negative environmental impacts.

e. *Conservation:* Conservation can be considered a type of supply in that it offsets the use of potable water to meet the same need through increasing water use efficiency. In 2010 Urban Water Management Plans (UWMP), urban water suppliers were required to comply with conservation targets laid out in the Water Conservation bill of 2009 (SBx7-7) which sets targets for 2015 and 2020 to support an overall State goal of reducing urban potable per capita water use by 20% by 2020. The 2015 UWMPs included updates to the progress toward reaching the 20% demand reductions and status on demand management measures. In 2015, as a result of the ongoing drought, Governor Brown issued an executive order directing the State Water Resources Control Board (SWRCB) to impose a state-wide 25% water use reduction. The SWRCB's mandatory water use reduction drove water agencies to increase focus on water conservation programs in their district.

<u>Vulnerability of Groundwater Supplies</u>

The South Bay relies on groundwater for its water supply, particularly during drought. Climate change is increasing drought intensity, making groundwater—with its immense potential for low-cost storage—an even more important water source.

The Water Replenishment District (WRD) of Southern California is the groundwater management agency responsible for safe and reliable groundwater in the Central Basin (CB) and West Coast Basin (WCB) in southern coastal Los Angeles County.

Source: wrd.org

Recent droughts have resulted in insufficient local rainfall and natural infiltration to maintain current groundwater basin production within the region. Climate change will contribute to inconsistent annual rainfall by changing precipitation patterns and result in fewer, yet more intense rain events that deliver increased flows over shorter periods.[91] With natural recharge supplies available only during shorter periods of time, the ability to capture, retain and recharge will be diminished. Therefore, agencies are considering ways to mitigate a potential decrease in local natural (and imported) recharge supply, including supplementing with recycled water.[92]

Projected water supply (**Figure 4.4 & Figure 4.5**) for WCB and CB were prepared using Urban Water Management Plans' projections as well through a discussion with the pumpers and purveyors.

Figure 4.4: West Coast Basin Water Current Supply by Source Type[93]

Wholesale: Water Supplies — Actual				
Water Supply	Additional Detail on Water Supply	2015		
		Actual Volume	Water Quality	Total Right or Safe Yield *(optional)*
Desalinated Water	Brackish groundwater	690	Drinking Water	
Purchased or Imported Water	Direct Use and Replenishment	105,569	Drinking Water	
Recycled Water	Delivery for the West Basin service area only	29,110	Recycled Water	
	Total	**135,369**	**-**	**-**

Source: UWMP 2015

Figure 4.5: West Coast Basin Projected Supply 2010-2030[94]

Wholesale: Water Supplies — Projected						
Water Supply	Additional Detail on Water Supply	**Projected Water Supply** *Report To the Extent Practicable*				
		2020	**2025**	**2030**	**2035**	**2040** *(opt)*
		Reasonably Available Volume	Reasonably Available Volume	Reasonably Available Volume	Reasonably Available Volume	Reasonably Available Volume
Desalinated Water	Brackish groundwater	1,000	1,000	1,000	1,000	1,000
Desalinated Water	Ocean Water	0	21,500	21,500	21,500	21,500
Purchased or Imported Water	Direct Use and Replenishment	98,426	77,654	77,673	77,913	77,491
Recycled Water	Delivery for the West Basin service area only	38,894	44,135	44,135	44,135	44,135
	Total	**138,320**	**144,289**	**144,308**	**144,548**	**144,126**

Source: UWMP 2015

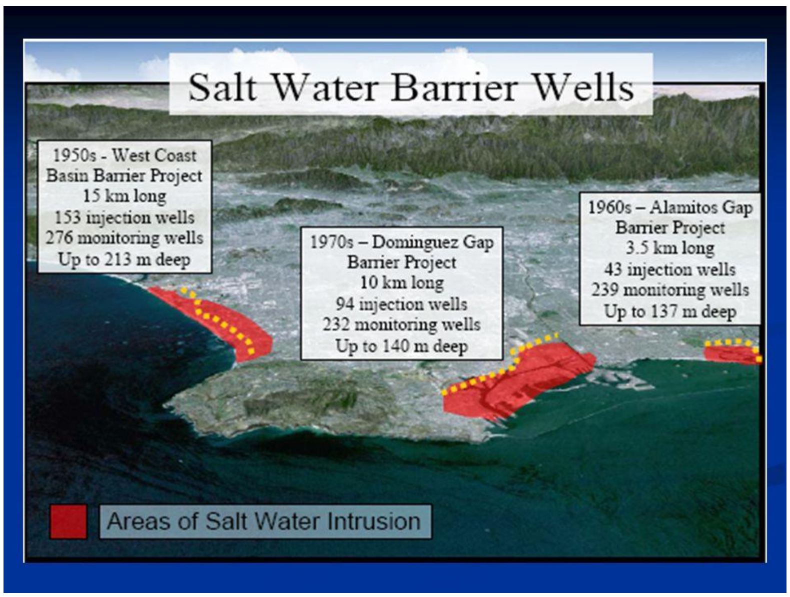
In addition to potential decreases in precipitation, sea level rise poses a significant threat to the region's groundwater supply. Most of the groundwater in the WCB remains at an elevation below sea level due to historic over-pumping. Seawater has the potential to seep into the aquifers and mix with groundwater. Without treatment, this groundwater does not conform to drinking water or agricultural standards.[95]

Existing Strategies to Mitigate the Impact of Climate Change on Groundwater

Saltwater Intrusion Barriers

To prevent seawater intrusion into the WCB and CB, three seawater intrusion barriers, the Alamitos, Dominguez Gap and WCB Barriers are maintained by injecting imported water and recycled water.

As a result of developing the barriers, the saline influence was confined to a single plume now trapped inland of the WCB Barrier. The saline plume continues to impact pumping capacity in the WCB and results in one-third of the pumping rights in the basin going unused. WRD and WBMD both have implemented desalters in the basin to pump and treat some of the saline water for use.[96]



Source: wrd.org

WRD also coordinates regularly with Los Angeles County Flood Control District (LACFCD), which manages the spreading grounds that recharge groundwater basins and the injection wells that maintain the seawater barrier, and West Basin MWD, which sells WRD the recycled water used for the seawater barriers.

Policy & Regulation

In 2014, the State of California adopted the Sustainable Groundwater Management Act (SGMA) in response to over-pumping and a lack of groundwater recharge in some areas of the state. SGMA requires the formation of locally controlled groundwater sustainability agencies (GSAs) which are responsible for developing and implementing a groundwater sustainability plan (GSP).

The West Coast Basin already has these structures in place through WRD and is meeting SGMA requirements.[97]

According to the authors of California's 4th Assessment reports, a major issue of the SGMA is that it does not require restoration of groundwater basins to pre-2015 conditions. This issue could be a problem in basins with already significant overdraft and drying up of shallow wells, as well as other pre-2015 undesirable effects.

Overdraft occurs when, over a period of years, more water is pumped from a groundwater basin than is replaced from all sources – such as rainfall, irrigation water, and streams fed by mountain runoff.

The lack of specific requirements or incentives to address accumulated overdraft and concomitant reduced storage could increase drought vulnerability.[98]

Integrated Water Management-- Storage Capacity and Interconnections

WRD is increasing their ability to fund, import, access, and store large amounts of water whenever it is available to protect against reduced supply during dry years through sharing and coordinating supply – otherwise known as Integrated Water Management. Recent amendments to the WCB and CB Judgements allow for more flexibility in the use of these basins' storage capacity, including coordinated use of the groundwater basins. These Judgement amendments allow for increased optimization of the WCB and CB operations and provide for a more reliable and cost-effective water supply for the region. Judgement amendments provide for water to be stored in the basins, allow inter-basin transfers of storage rights between the WCB and CB, and permit pumping beyond adjudicated rights through water augmentation projects.[99]

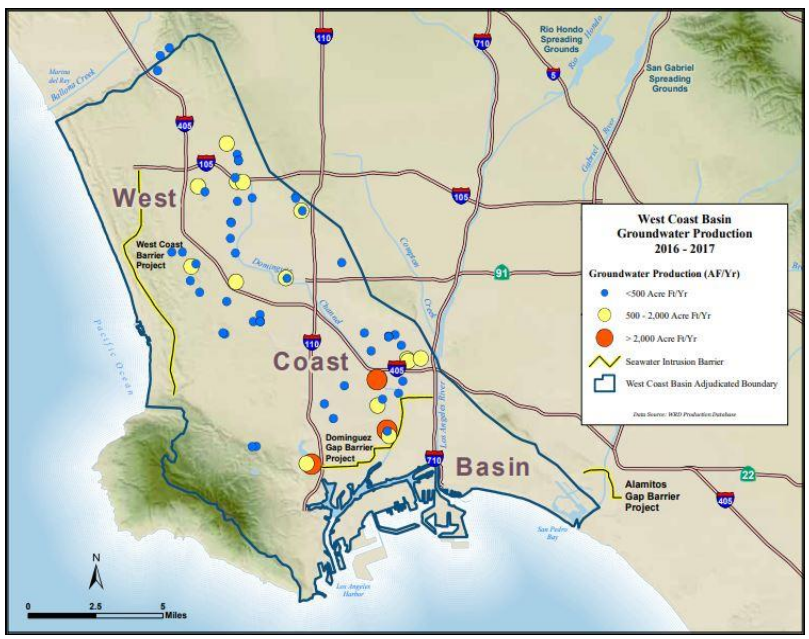
*The West Coast Basin Judgment limits the amount of groundwater each party may extract annually from the Basin. This limit, referred to as the "**adjudicated right**" is shown in **Table 4.1** for each municipal-serving party in the South Bay.*

Table 4.1: West Coast Basin Adjudicated Rights for South Bay Municipal-Serving Parties

South Bay Municipal Party	AR[x] 2016-2017	Allowable Extraction[y]	Amount Pumped	Balance[z]
El Segundo	953	953	0	953
Hawthorne	1,882.00	0	0	0
Cal Water--Hawthorne Lease	0	2,357.79	1,095.45	1,262.34
Inglewood	4,449.89	8,846.78	2,482.57	6,364.21
Lomita	1,352.00	1,872.70	448.93	1,423.77
Manhattan	1,131.20	3,365.44	318.16	3,047.28
Torrance	5,638.86	11,277.72	932.51	10,345.21
Golden State Water Company	7,502.24	10,008.81	3,172.45	6,836.36
Cal Water (Dominguez)	10,417.45	20,834.90	3,636.31	17,198.59
Cal Water Service	4,070.00	8,140.00	1,396.51	6,743.49
Total	**37,396.64**	**67,657.14**	**13,482.89**	**54,174.25**

Source: West Coast Basin Watermaster Report 2016

As a result of drought and the varied geometry of the groundwater basins, some areas have experienced wells going dry while others have not. In these basins, an important component of ensuring supply reliability is maintaining interconnections and in-lieu agreements between pumpers to allow for water transfers via the "Exchange Pool". An interconnected system, or Exchange Pool, allows agencies to share water with neighboring pumpers when certain portions of the basin are experiencing water quality issues or agencies need additional water to meet demand. To provide this flexibility, the Judgment contains provisions, such as "Carryover," to allow each party to carry over into the succeeding administrative year its unused adjudicated rights.



Source: West Coast Basin Watermaster, 2018

[xx] AR- Adjudicated Rights

[y] Allowable Extraction = Adjudicated Rights + Net Carryover + Leases + Storage

[z] Balance = Allowable Extraction – Amount Pumped

Many South Bay cities do not currently have the pumping capacity[aa] to extract the entirety of their pumping rights out of the WCB. There are a variety of reasons cities or water agencies don't pump their full water rights worth of groundwater, including water quality issues and other technological and financial constraints. Municipalities might consider strategies that increase their capacity to extract the entirety of their allotted groundwater. For example, water augmentation projects, wherein recharge and extraction volumes are matched within an established timeframe, offer additional opportunities beyond existing pumping and storage rights to store and extract water.

Recharge—water added to the basin
Extraction—water taken, or removed, from the basin

Water augmentation projects provide additional opportunities to increase the conjunctive use of these basins by providing an avenue to establish partnerships with potentially all other rightsholders in the groundwater basins. Identifying projects that would facilitate working with other jurisdictions increases the overall water available to the region by up to 26,000 acre-feet per year.[100] Partnerships are critical to implementing these multi-benefit projects so that both the costs and benefits can be shared among parties.

Water augmentation projects are large recharge and recovery projects that exceed the allowab' volumes under current adjudication. Thes envisioned to increase yields from the basins by matching recharge and extraction volumes on a regular basis (1 to 3 years). This type of project represents the largest potential for maximizing the reuse of recycled water.

Source: wrd.org

One of the key management strategies described in the Groundwater Basins Master Plan to facilitate the extraction of the full volume of adjudicated rights in WCB involves a shift in industrial groundwater use, particularly from oil refineries.[101] This strategy could be an opportunity for municipalities with recycled water supplies to increase their pumping in WCB. For example, the South Bay municipalities could offer recycled water to industrial users in exchange for a lease on their groundwater pumping rights and thus increase their groundwater pumping for potable use. There are at least 6 industrial parties (with over 1,000 AR) utilizing an estimated 24K (**Table 4.2**) of industrial pumping rights, which could be redistributed to municipal pumpers upon supply of re-cycled water to the industrial rightsholders.

[aa] Industrial contamination issues are the principle reason for restricted use of local groundwater pumping by the City of LA. Much of LADWP's pumping capacity has been impaired by contaminants.

Table 4.2: West Coast Basin Select Industrial Parties Adjudicated Rights (>1,000 AR)

South Bay Industrial Party (over 1,000 AR)	AR 2016-2017
Chevron USA Inc	4,601.30
Conoco Phillips Co.	6,170.00
Shell Oil Company	1019.00
Tesoro Refining and Marketing	8,741.00
Torrance Refining Co.	2,596.40
Total	**23,127.70**

Source: West Coast Basin Watermaster Report 2016

Decrease Imported Water Use

For the West Coast and Central basins, WRD is expanding its use of recycled water for replenishment and injection at the barriers through its "Water Independence Now" initiative, which seeks to eliminate the use of imported water for replenishment of the Central and West Coast groundwater basins, and Groundwater Reliability Improvement Program, a major initiative being implemented to offset water replenishment with recycled water supplies. As part of the effort to increase recycled water use in the County, West Basin MWD is planning a fifth expansion of its Edward C. Little Water Recycling Facility that will double the plant's production of recycled water. As part of the Phase V Expansion Project, West Basin MWD's facility will implement ultraviolet and advanced oxidation processes to provide up to one additional MGD (million gallons per day) of water to the Dominguez Gap seawater barrier.

Improving Emergency Response for Water Management Agencies (Groundwater & Imported)

In addition to cyclical and long-term resilience efforts, water management agencies have emergency response plans and mechanisms in place to ensure they have prepared, appropriate responses during emergency or disaster events such as system failures, water quality exceedances or other disturbances.

Maintaining emergency storage is a standard practice in water management around the County, however the amount and accessibility of storage varies. Some agencies argue that the capacity of storage is not as important as the distribution throughout the system given that a break on the only line to access the water renders it useless.

Metropolitan (MWD) maintains a 6-month supply of emergency storage south of the fault lines to ensure demands can be met if an earthquake interrupts supplies from the Bay-Delta, Colorado Aqueduct, and Los Angeles Aqueduct. Additionally, MWD has emergency storage at its reservoirs (Diamond Valley Lake, Lake Mathews, and Lake Skinner), at the SWP terminal reservoirs (including Castaic Lake in Los Angeles County), and in its groundwater conjunctive use storage accounts. While most of this storage is located outside of Los Angeles County, MWD, with few exceptions, can deliver this emergency supply throughout its service area via gravity, thereby eliminating dependence on power sources that may be unavailable or inoperative after a disruptive hazard. This emergency supply is maintained as a baseline and is not used to mitigate drought conditions. MWD member agencies are required to have 1-week of local supply available in case of an emergency disruption to MWD's facilities.

When an emergency occurs, a common response is reliance on interconnections and agreements with neighboring agencies unaffected by the disruption. This mechanism is considered an important method of ensuring access to supply and uninterrupted service by water managers. Interconnections can be particularly important in cases where the agency is entirely dependent on one source of potable supply and is less critical for nonemergency services like wastewater collection or groundwater recharge. The substantial network of imported water distribution systems within Los Angeles County provides an interconnection framework that allows for imported water users to work collaboratively to route and transfer water around and through nearly all areas of the region.

Agencies focus on ensuring there are redundancies in their system to prepare for emergency situations. Pump stations are a key component for moving flows through a system. Having redundant facilities and equipment (e.g. generators) in case one pump malfunctions and portable generators to manage a power outage are crucial elements for ensuring a resilient water delivery system. In addition, smaller components of the system, such as valves, are also extremely useful pieces of infrastructure during an emergency. Valves are used by agencies to isolate the area of their distribution system experiencing failure. By isolating the impacted areas, agencies are also able to save and contain in-system wastewater and water flows during emergencies.

Most agencies have individual Emergency Response Plans that contain information such as lists of contractors' phone numbers, resources, and other pertinent information to guide activity during emergencies. Some smaller agencies do not have sufficient Emergency Response Plans (if at all), which puts them at risk during emergency situations. Being linked to an Emergency Operations Center is another mechanism for managing emergency situations. Many agencies in the County have an Emergency Operations Center in place or are in the process of linking into one.

To better prepare for emergencies that threaten their infrastructure, WRD is participating with the USEPA on a Climate Resilience Evaluation and Awareness Tool (CREAT) to be the case study for identifying infrastructural vulnerabilities within their agency. CREAT is a risk assessment application that helps utilities adapt to extreme weather events by better understanding current and long-term climate conditions.

Sector 2: Energy Management

For the energy sector of the vulnerability assessment, the SBCCOG summarized the findings of external reports conducted by or on behalf of utilities that service the South Bay subregion. These reports assess the potential risk of climate change impacts on energy infrastructure capacity, as well as identify adaptation strategies to mitigate identified risk. The energy sector analysis is composed of three sub-sections:

1. **Background** on the regulatory and legislative status of climate adaptation in the energy sector
2. **Detailed Summary of SoCal Gas** and **Southern California Edison's** efforts to assess and mitigate risk of climate change impacts
3. **Summary of South Bay's grid vulnerability to extreme heat**, extrapolated from the *4th Assessment Report: Grid Vulnerability in LA County*

Background

In 2012, Lawrence Berkeley National Lab (LBNL) issued a report entitled, *Estimating Risk to California Energy Infrastructure from Projected Climate Change*. The report identified types of energy assets that could be affected, how they might be affected, under what conditions they might be affected, and potential consequences of those effects. LBNL's model shows higher temperatures may require up to a 38% increase of generation capacity and a corresponding increase of up to 31% additional transmission capacity by the end of the century. These increases are due to the compromising effects of higher temperatures on power plants, transformers, and substation capacity and transmission and distribution line losses, coupled with higher peak electricity demand.

In April 2015, Governor Brown signed Executive Order B-30-15 that called for an adaptation implementation plan for each sector of the economy. To address the energy sector, the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) held a joint workshop in July 2015 to better understand the adaptation efforts at the large investor-owned utilities. From this workshop, several energy agencies formed a working group on climate adaptation to support electric utilities on the development of vulnerability assessments and resilience plans. This work was completed through the Department of Energy's Partnership for Energy Sector Climate Resilience. As an electric investor owned utility, Southern California Edison participates in this DOE Partnership. The Partnership continues to work with utilities on planning and climate vulnerability studies.

***Order Instituting Rulemaking (OIR) -** is an investigatory proceeding opened by the CPUC to consider the creation or revision of rules or guidelines in a matter affecting more than one utility or a broad sector of the industry.*

Comments and proposals are submitted in written form to the CPUC. Oral arguments or presentations are sometimes allowed. The CPUC's decision is often implemented in a General Order.

In May 2018, the CPUC issued an Order Instituting Rulemaking (OIR) to consider strategies to integrate climate change adaptation planning in relevant Commission proceedings and other activities. Southern California Edison and SoCalGas, among many others, filed written comments in response to the OIR.[102] Phase 1[bb] of this Rulemaking, currently underway, will broadly consider how best to integrate climate change adaptation into the larger investor-owned electric and gas utilities' planning and operations to ensure safety and reliability of utility service. This phase focuses on addressing five key topics, described below:

1. Definition of climate adaptation for utilities
2. Appropriate data sources, models, and tools for climate adaptation decision-making
3. Guidelines for utility climate adaptation assessment and planning

[bb] The entities filing as the California Association of Small Multi-Jurisdictional Utilities and Independent Storage Providers will be Respondents in Phase 2 of the proceeding and are/were not required to participate in Phase 1.

4. Identification and prioritization of actions to address the climate change related needs of vulnerable and disadvantaged communities
5. Framework for climate-related decision-making and accountability

The working group tasked to address these topics will complete reports in the summer of 2019, with a CPUC decision expected in September 2019. The working group focusing on the definition of climate adaptation completed its report[103] in January 2019.

SoCal Gas

In SoCalGas' 2016 Risk Assessment Mitigation Phase (RAMP), a chapter was dedicated to a vulnerability assessment and adaptation plan for safety-related threats to gas infrastructure posed by climate change. SoCalGas identified potential regional risks to gas infrastructure also due to climate change -- primarily the transmission pipelines. The transmission pipelines, which operate at a high pressure, were the initial target for assessment because failure or rupture may potentially result in a catastrophic event compared to a failure on medium-pressure pipelines.

In the chapter, SoCalGas identified the following threats to their infrastructure and operations (summarized in **Table 5.1**):

Table 5.1: Threat, Events and Potential Consequences

Threat	Events	Potential Consequences
Increased Frequency and Severity of Storm Events	Storm Surge (El Niño events), Flooding, high winds, and heavy snow.	1. Increased frequency of emergency response from Gas Emergency Centers (GECs) and SoCalGas crews. 2. Levee erosion or failure causing asset repair, replacement or relocation to low-lying above and below ground gas assets. 3. Exposure of underground pipelines.
Change in Precipitation Patterns and Droughts	Subsidence, Landslides, Mudslides, weakened soil structure, drought induced vegetation loss.	1. Horizontal subsidence cause compressive stresses resulting in buckling of gas pipelines.[14] 2. Exposure of underground pipelines. 3. Reduce access to pipeline Right of Ways. 4. Effectiveness of cathodic protection system diminishes which can lead to increased corrosion. 5. Damage on pipelines in bridges or spans due to mudslides.
Sea Level Rise	Erosion, coastal inundation and flooding potential.	1. Levee erosion or failure causing asset repair, replacement or relocation to low-lying above and below ground gas assets. 2. Exposure of underground pipelines.
Change in Temperature Extremes	Increase natural gas demand for electric generation for meeting more cooling days or air conditioning (HVAC) demand. Increased ambient temperatures.	1. Increased cycling of compressor station and maintenance schedules along with design requirements for Compressor Stations to support the increased cycling. 2. Damage on pipelines in bridges or spans due to thermal expansion.
Increase Wildfire Frequency and Intensity	Wildfires, vegetation loss, weakened soil structure, and landslides.	1. Increased frequency of emergency response from GECs and SoCalGas crews including standby to prevent damages to infrastructure by third parties responding to the fires. 2. Increased customer outages. 3. Increased risk of erosion and landslides due to vegetation loss.

Source: SoCalGas 2016 RAMP

Based on SoCalGas' 2015 climate risk assessment, the utility proposed completing the following actions in its 2016 RAMP:

- Gas Infrastructure Resilience and Vulnerability Report[104]

- Geological Hazard Engineering Data Analysis and Flood Hazard Dashboard[cc]
- Strain Gauge Installation Projects[dd]
- Slope Stability and Erosion Control Projects[ee]

Specifically, for the Gas Infrastructure Resilience and Vulnerability Report, SoCalGas commissioned the completion of several case studies examining the impact of climate hazards on the natural gas system.[105] These case studies found that natural gas infrastructure and services were relatively resilient to hurricanes, wildfires, and mudslides. Most natural gas infrastructure is belowground, which is inherently less vulnerable to natural disasters than aboveground infrastructure. Unlike the electric system, that will have more regional impacts from above ground driven climate change events, natural gas systems tend to be impacted in isolated or distinct segments. There are no critical parts of SoCalGas' generation system that rely on electricity. Gas flow is driven by pressure differentials. All of SoCalGas' facilities use electric power in some form or another for operation, but all have natural gas back-up generation. The vulnerability of the natural gas system is not so much the natural gas infrastructure itself, but rather in its intersection with other sectors. For example, the loss of electricity due to damages to grid infrastructure can create "demand destruction" in areas where natural gas provides fuel to power plants. Similarly, ports closing in response to severe storms impact the ability of shippers to export their gas supplies. This dependency speaks more to market impacts than impacts on power generation. A summary of impacts on the natural gas system from specific hazards can be reviewed in the report.[106]

The lessons learned from these case studies, as well as identified adaptation strategies to be considered include:

- Natural gas infrastructure and services exhibited significant resilience to disasters due in part to existing system characteristics (e.g., underground assets).

[cc] This is an internal dashboard, the development of which is still in progress. No flood hazards were identified in the South Bay.
[dd] San Bernardino locations completed. Next locations will be in Ventura County in 2020. No project locations in the South Bay.
[ee] No projects in South Bay service territory.

- The greatest observed impact to natural gas infrastructure was due to intensive scouring of creeks during flood events and large boulders carried by subsequent mudslides.
- The most important impact to customers was due to proactive gas service shut-off during the California wildfires. While this protective measure can be put into place quickly, reversing this process is time-consuming and expensive. Loss of service in the interim can impact customers.
- Backup generation is an important component of overall resilience.
- Emergency responses are most effective when there is clear communication and coordination between utilities across sectors and with emergency personnel. Access to gas infrastructure must be carefully coordinated when conditions are unsafe, and natural gas utilities must communicate the locations of their assets and potential risks to avoid further damage during response activities.
- To build resilience, it is important to focus on response strategies such as sub-dividing the grid to improve the efficiency of service isolation and reconnection.

SoCalGas will file an updated RAMP in 2019. In the 2019 RAMP, climate change will be treated as a driver to other risks within the chapter, so content on climate change will be embedded within other risk chapters as appropriate instead of its own separate chapter.

<u>Southern California Edison (SCE)</u>

As part of its DOE Partnership, SCE released a *Climate Impact Analysis and Resilience Planning* document in 2016, which in addition to identifying key sector vulnerabilities, laid out resilience goals and an adaptation planning framework.

Vulnerabilities

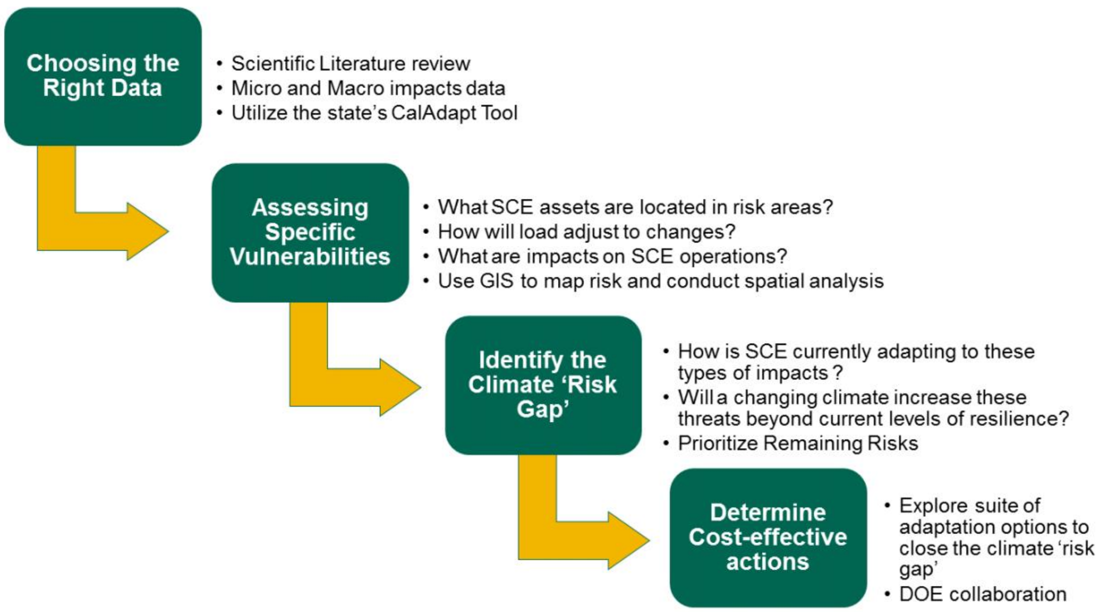
Utilizing the SCE Adaptation Planning tool - developed to assess system vulnerabilities to climate hazards at the facility-level - the following long-term impacts of climate change were identified:

- Increased risk for facility inundation and flooding, especially at 18 at-risk coastal facilities
- Transmission, distribution, and generation systems will operate less efficiently under extreme heat

- Increased demand due to ongoing elevated average temperature and extreme heat days
- Disruption of service due to facility and equipment loss following flood and landslide events
- Limited generation capacity due to decreased reservoir levels
- Disruption of service due to facility and equipment loss from wildfire events
- Employee public safety, and wellbeing impacted by wildfire events
- Increased liability due to higher potential of utility caused fires

Resilience Goals and Adaptation Planning Framework

SCE's resilience plan goal is to identify strategies that can meet California's regional climate adaptation needs while continuing to ensure that electricity is safe, reliable, and affordable. In conjunction with external stakeholders, SCE created an adaptation framework that will help the organization meet its resilience goal.



Source: Climate Impact Analysis and Resilience Planning, 2016

Adaptation Measures

After a report detailing these vulnerabilities was submitted to the DOE, the SCE held a series of workshops in which key adaptation measures were considered for the development of a resilience action plan, including:

Adaptation Measure	Description	Costs	Benefits
Design new facilities and equipment utilizing future modeling instead of historical data	Current policy dictates that all new facility locations are built using historical flood projects and current 100-year flood plain maps. This policy change	Building new facilities may become more expensive due to more stringent location requirements and environmental standards.	Hardened infrastructure to increasing intense and frequent weather events. Ability to maintain reliable service through a major

	would use maps developed with future projections and computer modelling for determining optimal building locations.	More analysis required in planning phase of building new facilities. Least expensive adaptation measure.	weather event that would have been interrupted at a previous location.
Initiate facility relocation well in advance of coastal inundation at at-risk facilities	Relocate facilities located in projected 100-year flood plain locations 10 years prior to flood plain encroachment.	Decommission and demolish old facilities and re-purpose land. Cost associated with rebuilding a new facility in a potentially more costly location. New environmental and regulatory constraints.	Offers an opportunity to relocate facilities that were not in ideal locations in the first place.
Implement engineering solutions to mitigate facilities at increased risk for inundation, flooding, mudslides, and debris flows	Conduct site-specific engineering review to assess the need for engineering solutions including raising each site above flood plain levels; place critical equipment on raised or floating platforms; place flood berms around facilities and equipment; addition of seawalls in impacted communities	Construction and equipment purchase cost associated with upgrading facilities. Potential failure of certain mitigating engineering solutions resulting in facility failure and lack of reliable service	Hardened infrastructure to increasing intense and frequent weather events. Ability to maintain reliable service through a major weather event that would have been interrupted at a previous location.
Install additional equipment to decrease burden on existing equipment	As equipment becomes less efficient due to increased temperatures and increased demand, add new equipment to reduce the burden on the existing equipment.	R&D costs associated with determining appropriately engineered equipment. Cost of procuring and replacing the outdated equipment as well as siting new locations for equipment.	Increased reliability due to more contingency infrastructure in case of failure at certain points. Increase the lifespan of older, overburdened equipment.
Increase the use of distributed energy solutions to limit the burden on the transmission system	As increased demand and generation efficiency occur, focus on increasing the availability of distributed generation capacity and the ability of the grid to perform two directional flow.	R&D costs associated with determining appropriately engineered equipment; upgrading or replacing outdated equipment, and increased need for accurate localized load forecasts.	Increased grid stability and reliability; decreases likelihood of equipment failures and costs associated with repairing or replacing the impacted equipment.
Increase the capacity of the existing reservoir system through additional locations	As the frequency of rain becomes less often, but the intensity increases, the ability to capture runoff to support	Building new reservoirs as well as increasing the capacity of existing reservoirs would require significant	Enhance Edison’s ability to maintain hydro generation during periods of extended drought as well as

and a more robust catchment system	hydrological generation will decrease. By adding additional reservoir locations and increasing capacity, additional rain can be captured during high intensity periods of rain.	construction spending. Optimizing reservoirs would require climatological analysis, downstream water user, and environmental studies.	optimizing the system for the anticipated changes in precipitation patterns.
Mandate all new facilities in at-risk location for wildfires have 2 independent evacuation routes	Implement a policy change that requires all SCE facilities to have two geographically independent evacuation routes for every Southern California Edison (SCE) facility.	Extremely costly in remote areas to develop a secondary evacuation route if none exists. In some areas, the secondary evacuation route may be as vulnerable to fire as the primary evacuation route.	Allows Edison employees to work more safely and confidently in areas of high fire risk. Could potentially be lifesaving if fire conditions do threaten the facility.

Key Challenges

One of the major challenges SCE faces is aligning its adaptation strategies with the long-term planning of local communities. Before moving substations that may be inundated due to sea level rise, SCE must first consider how affected communities will choose to adapt. For example, if a community decides to build a sea wall that protects the community from inundation, SCE may not need to relocate the potentially at-risk substation. Alternatively, if a community decides to relocate, SCE will have to relocate its critical infrastructure to service that community in another location. Another significant challenge is understanding the costs and creating mechanisms to fund adaptation measures. Edison believes that the complexity of analyzing financial impacts over the next 100 years will require the creation of a standardized model for all utilities.

Findings

Upon their preliminary assessment, SCE believes their system is resilient to the majority of projected near-term (now through 2030) impacts of climate change. Due to careful investments in energy infrastructure, adaptive capacity is built into many of SCE's assets and operational processes. (Ex. SCE's transmission lines have a wind and temperature rating high enough to ensure service through many of the scenarios predicted into mid-century.)

Next Steps

SCE plans to continue active participation in the DOE efforts, and work with state regulators to:

- Broaden the definition of assets

- Assess the system as a sum of its assets
- Assess future system assets
- Assess emergency management procedures
- Assess the vulnerability of customers
- Assess internal and operational vulnerabilities
- Monitor, evaluate, and reassess best available climate projections
- Evaluate and prioritize resilience measures
- Develop a resilience action plan

Grid Vulnerability to Extreme Heat: Findings of the 4th Assessment Report

As part of California's Fourth Climate Change Assessment, the California Energy Commission sponsored researchers at UCLA and Arizona State University (ASU) to develop a report that identified the vulnerability of energy infrastructure to rising temperatures. The report, *Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat*, analyzed infrastructure vulnerabilities for power generation plants, transmission lines, and substations for the effects of higher ambient air temperatures.

Rising air temperatures can affect electricity infrastructure in two ways:

1) A direct reduction in the components' (generator, transmission line, or substation) safe operating capacities. Since electric power flow creates heat, and components can only tolerate so much before protection gear trips or internal parts physically break, their capacity to support power flow generally decreases as ambient air temperatures rise.[107]

2) An increase in the load on those components due to increased demand (air conditioning use, for example).

The SBCCOG utilized the data from the 4th Assessment Report to extrapolate the neighborhood-level grid vulnerabilities within the South Bay service territory. To better inform long-term capital investment and policy decisions regarding climate change and electricity infrastructure systems, the methods of the 4th assessment report were replicated to answer the following questions:

- How much could capacity be reduced at generator plants, transmission lines, and substations by 2060 due to heat waves?

- What cities or neighborhoods within the South Bay service territory have the highest risk of shortages in delivery infrastructure capacity, and should therefore be prioritized for capital investments and/or demand side management programs?

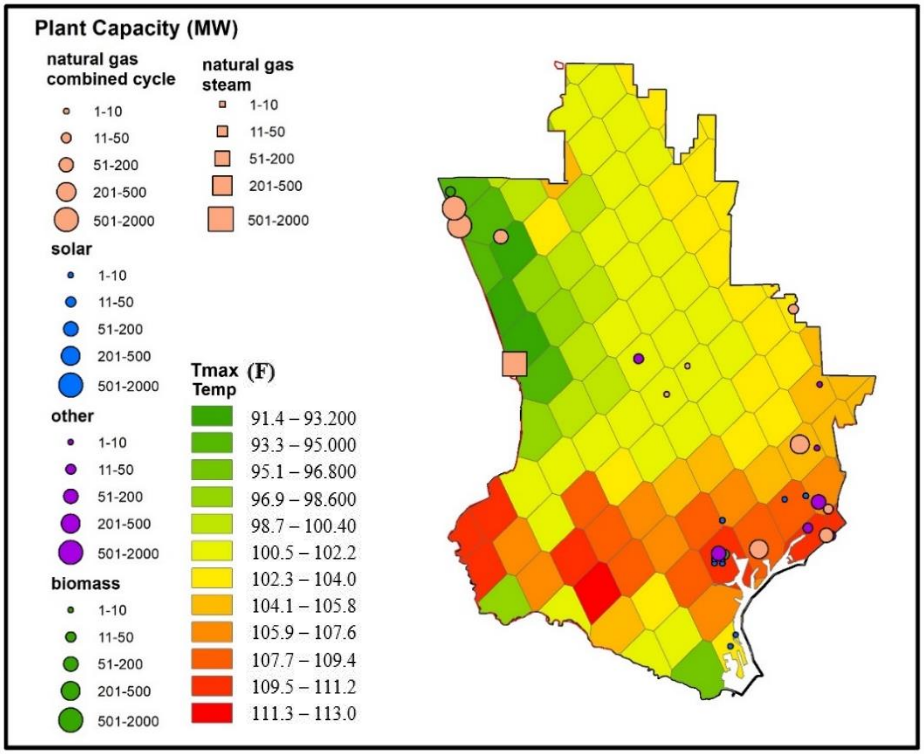
Temperature Projections

Temperature projections were used to assess the potential capacity loss of power generation, substations, and transmission lines. The Assessment quantified extreme heat and rising air temperatures due to climate change based on a 2x2km grid cell map resolution indicating the projection of the daily maximum air temperatures for a base period of 1981-2000; and two future periods, 2021-2040 and 2041-2060 for the "mitigating" (RCP 4.5) and "business as usual" (RCP 8.5) scenarios. In this SBCCOG's report, only two temperature scenarios are included: 1) historic hottest day (June 3rd, 1985) from 1981-2000 and 2) the composite temperature projection for 2041-2060 under RCP 8.5 (worst-case scenario). Composite temperatures represent the highest projected temperature in each 2x2km grid cell for the given scenario.

Power Generation

Supply vulnerabilities were assessed as potential loss, or *derating*, in megawatts for generation capacity (MW) due to rising air temperatures in generation plants. Power plant data from the Assessment Report were obtained from the US Energy Information Administration (EIA)[108], including plant type, capacity, and geospatial location, as shown in **Figure 5.1**.

Figure 5.1: Map of Power Plants by Type and Capacity Overlaid to Historical Hottest Day



A ***Combined-Cycle*** *power plant uses both a gas and a steam turbine together to produce up to 50% more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is outed to the nearby steam turbine, which generates extra power.*

Derating *is a loss in electricity capacity and can be driven by increases in temperature.*

De-rated Load Factor *is proportional to substation heat stress and risk of outage. The higher the load factor, the higher the risk of outage.*

Generation plants sensitive to high ambient air temperatures include dry-cooled natural gas plants, the dry-cooled portion of combined cycle natural gas plants, and solar PV plants with quantities and derating factors as listed in **Table 5.2**.

Table 5.2: Power Plant Capacities by Type and High Air Temperature Derating Factors

Generation Type	Count	Total MW	Derating Factor	Estimated MW Lost[ff] at 2060 RCP 8.5 (worst case)
Natural Gas (combined cycle)	10	2490.6	.003 +/- .001	28.59
Natural Gas (steam)	1	1310	--	0
Solar PV	9	16.3	.0035 +/- .0025	0.57
Biomass	2	53.4	--	0
Other*	7	235.7	--	0
Total	**29**	**4106**	**--**	**29.16**

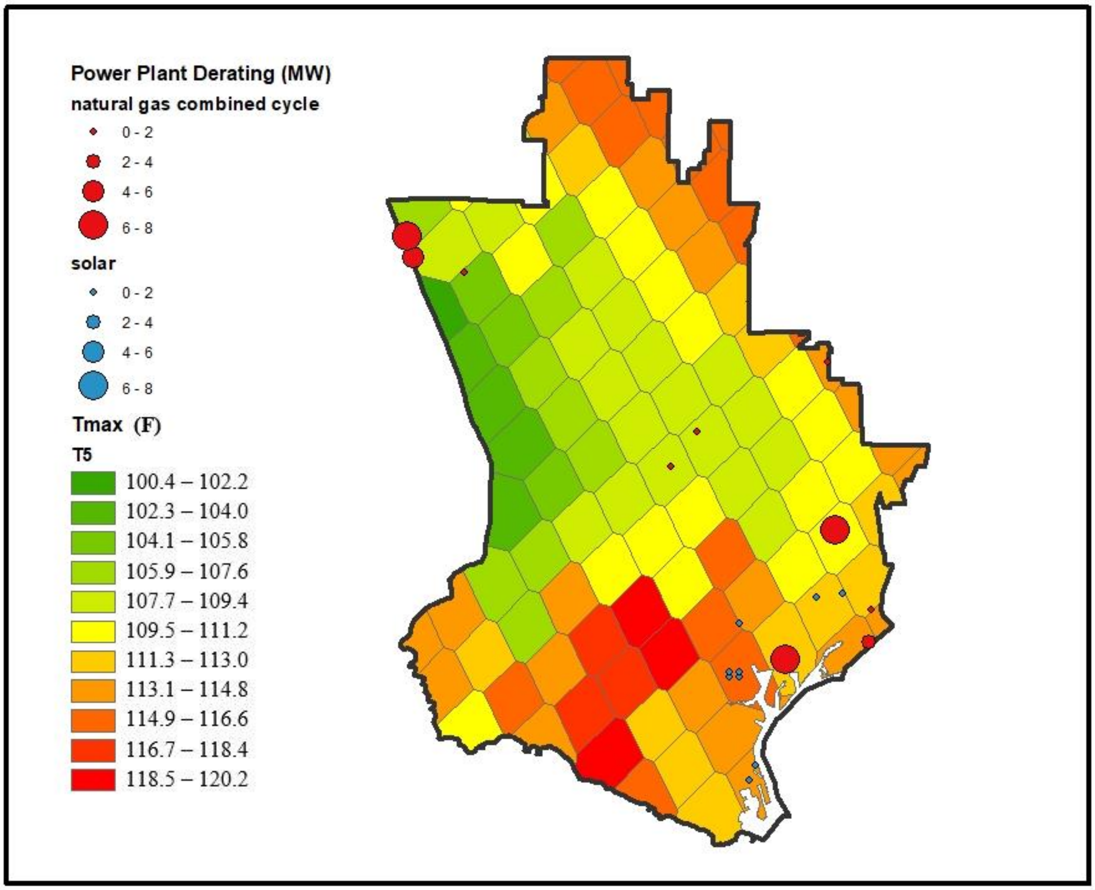
*Includes biomass generation

[ff] Calculated using derating factor plus positive error. Formula: (TotalMW)*(DeratingFactor + error) *(Degrees above 40 C)

The power generation facilities in the South Bay account for approximately 30% megawatt (MW) of all generation capacity in Los Angeles county. As shown in **Figure 5.2**, for worst-case 2060 temperature projections under RCP 8.5, the natural gas combined cycle plants including the Scattergood Plant in Playa Del Rey; the Watson Plant in Carson; and the Harbor Plant in Wilmington. They represent the most vulnerable generation capacity. Of the South Bay's 4.1 gigawatt (GW) of local power generation, approximately 2,507 MW are potentially vulnerable to increases in air temperature. An estimated 29 MW will be lost for the projected worst-case[gg] temperatures in 2060 under a "business as usual" (RCP 8.5) scenario: less than 1% of total generation capacity. Note, the figure is shown in units of MW, not percentages; derating values are a function of both temperature change and type of plant. Heat wave temperatures affecting natural gas plants ranged from 39-46 C (102-114 F) in this scenario (RCP 8.5, 2060). Maximum temperatures at solar PV plants ranged from 44-47 C (111-117 F).

[gg] Highest projected Tmax in each 2km^2 grid cell

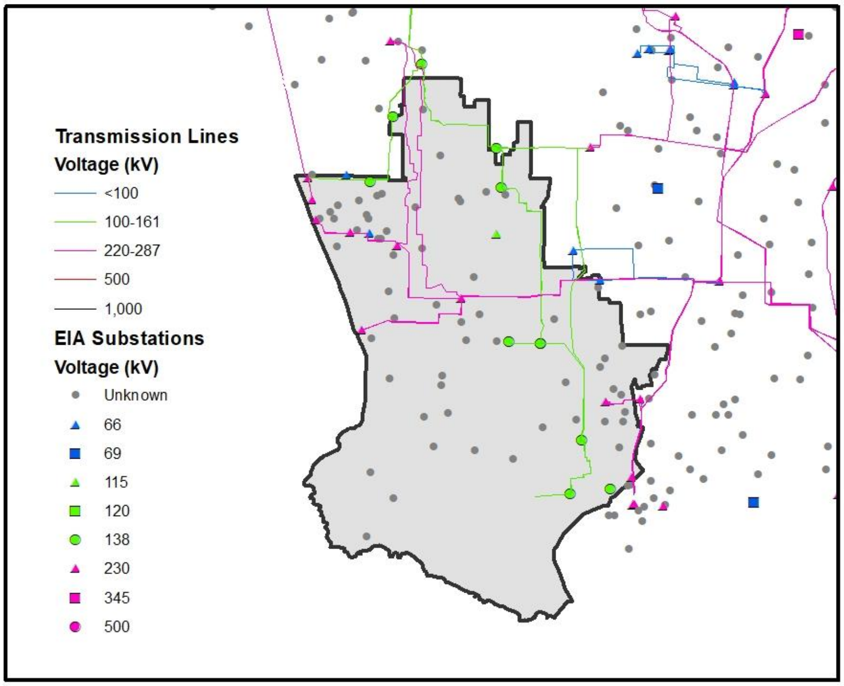
Figure 5.2: Map of Worst-Case Losses in Plant Capacity in 2060 (Composite temp. RCP 8.5)



Substations

Supply vulnerabilities were assessed by risk of substation overload based on projected future conditions. Substation data were obtained from the US Department of Homeland Security[109] and included 77 substations total in the South Bay. 20 were labeled as having maximum voltage ratings, as shown in **Figure 5.3**, 11 were labeled high (66k to 138kV), 9 labeled medium (230kV), and 57 were labeled unknown and assumed to be low (<69 kV).

Figure 5.3: Substations and transmission lines in and around the South Bay



De-rated Load Factor is proportional to substation heat stress and risk of outage. The higher the load factor, the higher the risk of outage.

***DERiM** allows developers to connect with SCE system data to enable strategic distributed energy resource siting.*

***Distributed Energy Resources** are small-scale units of local generation connected to the grid at distribution levels.*

Risk of overloading was estimated at SCEs substations for current and future projected conditions. Only SCE substations overload was estimated, as those were the only substations where both load and capacity data were available to estimate load factor or utilization. The base peak load factors on SCE substations were estimated using the SCE Distributed Energy Resource Interconnection Map (DERiM) data and values were assumed at 40 C (104 F). *De-rated load factors*[hh] were then estimated for present day circumstances using the composite maximum temperature projection images for the recent historical period, and derating substations by any amount above 40 C. **Table 5.3** provides risk level analysis of different load factors.

Table 5.3: Substation De-rated Load Factor Risk Metrics[110]

Load Factor	Risk Level	Reference	Description
n/a	Unknown	n/a	Substations exist in this space according to DHS database[111], but not SCE DERiM[112], so loading data were unavailable.
0.01-0.5	Very Safe	Assumption	Negligible thermal wear, probably n-2 reliable if in parallel/redundant configuration.
Load Factor	**Risk Level**	**Reference**	**Description**

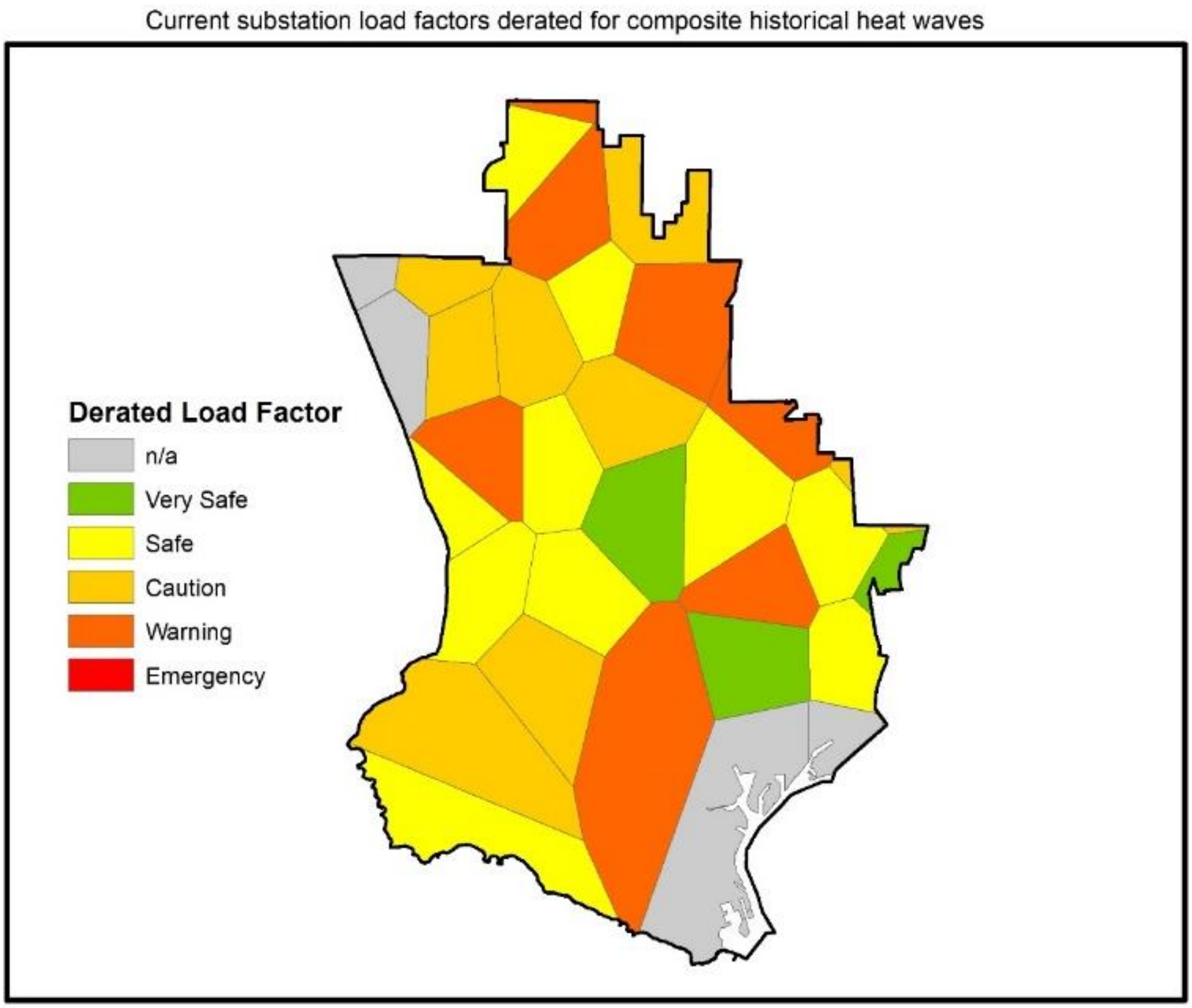
[hh] Substation load, capacity, and load factor estimates were developed from the published DERiM data, and ranges allocated to the remaining substations in the LAC infrastructure. For more information, see Appendix D3 of 4th Assessment Report.

0.51-0.85	Safe	15% rule	Very low thermal wear, probably only n-1 reliable if in parallel/redundant configuration.
0.86-1.00	Caution	15% rule	Non-negligible thermal wear, probably not n-1 reliable.
1.01-1.20	Warning	[[113]], [[114]]	Thermal wear, component overloaded, automatic switching may occur in 24 hours to 30 days if loading continues at this level, or sooner with sub-hourly spike, depending upon switch gear settings.
1.21-2.00	Emergency	[iv], [v]	Significant thermal wear, component very overloaded, automatic switching will occur in 30 min, or sooner with sub-hourly spike, depending upon switch gear settings.
>2	Outage	[v]	Extreme thermal wear, switchgear will automatically trip to prevent hardware damage and failure.

As indicated below, most areas throughout the South Bay, based on data availability, have substations that are projected to operate at a weather de-rated load factor of 0.72 for the hottest historical heat wave temperatures, which is considered a "safe" risk level. Importantly, at least five areas [115] within the South Bay are projected to have substations operating at a weather de-rated factor of 1 to 1.2 for the hottest historical heat wave temperatures (**Figure 5.4**). Components are technically overloaded at this point and automatic outage switching may occur within 24 hours to 30 days if loading continues at this level (depending upon switchgear settings). Due to high operating temperatures, substation mineral oil may experience accelerated thermal wear, and depending upon system redundancies, neighborhoods may not be in a secure state (or n-1 reliable) in this condition.

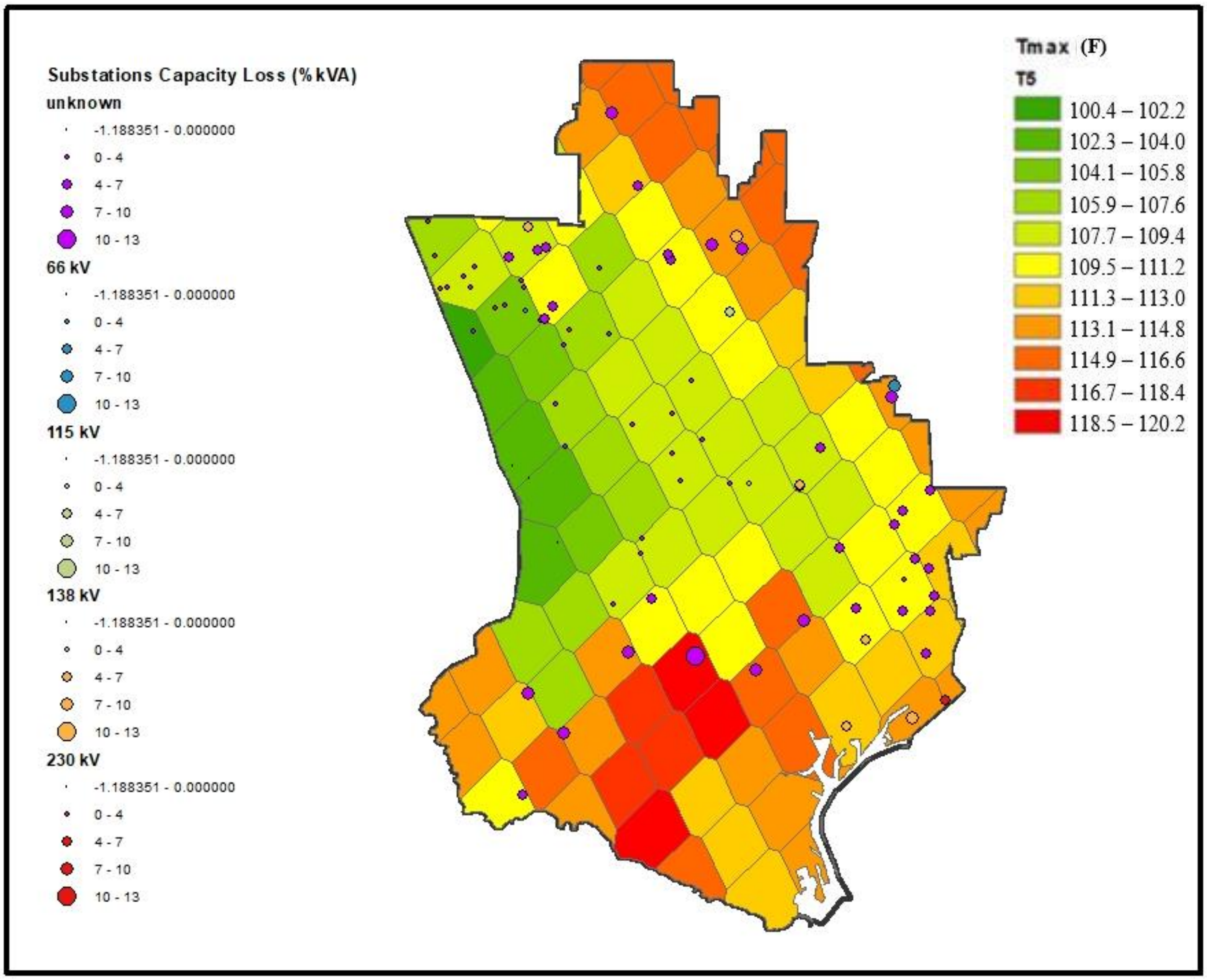
N-1 *means that there is a power backup in place should a single system component fail. The "N" stands for the number of components necessary to run the system. The "1" means there is one independent backup should a component of the system fail.*

Figure 5.4: Map of today's low-voltage substation risks.



Risk of component overload was also estimated at SCE's substations for future scenarios. As shown in **Figure 5.5** for temperature projections in 2060 under the "business as usual" scenario (RCP 8.5), seven unknown substations (presumably low voltage connective air cooled); two 138kV; and one 66kV substation could experience temperatures up to 46-49 C (114-120 F). Most substations were projected to experience average capacity losses of 4.5% with a maximum of 12.6% under this scenario.

Figure 5.5: Worst-case losses of substation capacity for composite temperatures (2060, RCP 8.5)



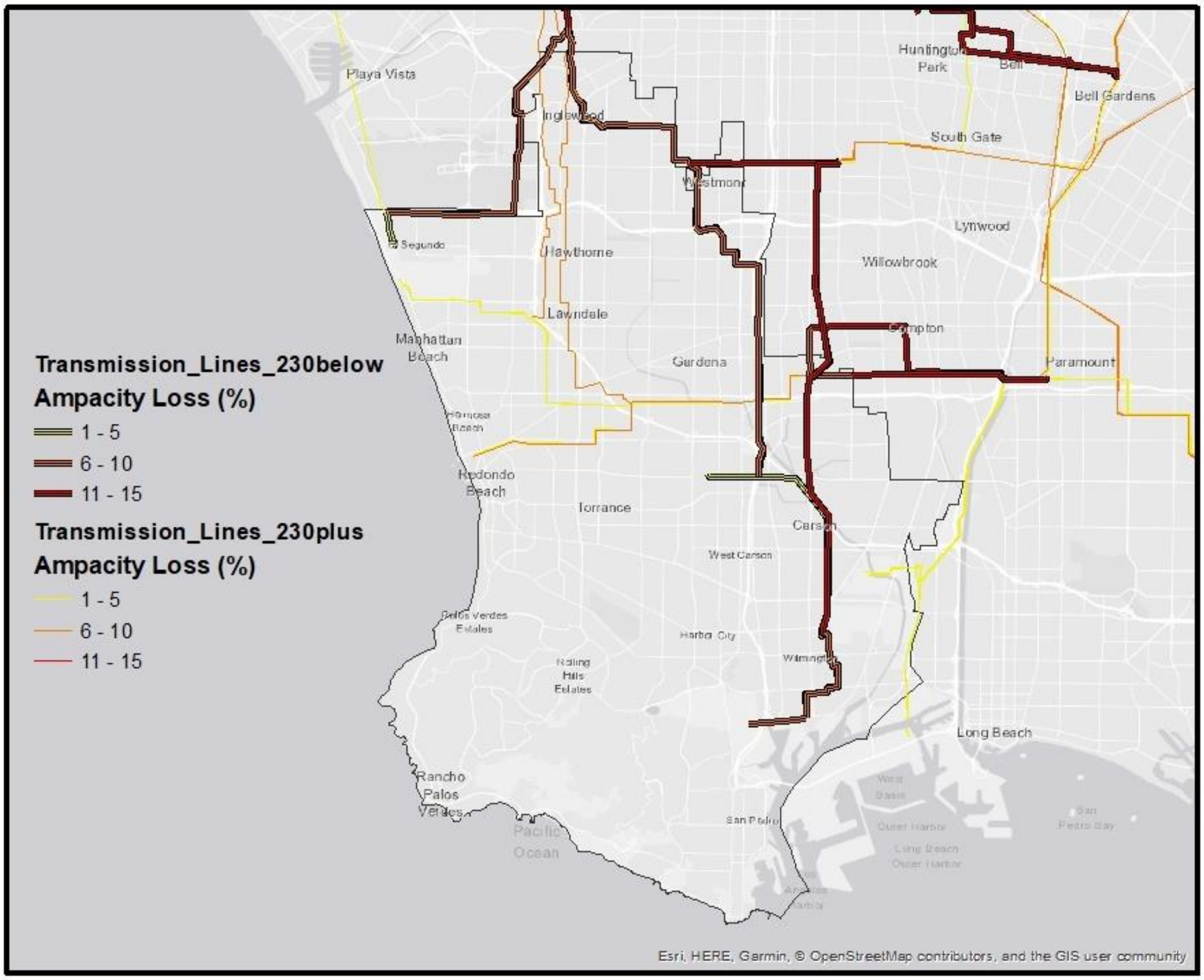
Transmission Lines

Of the total transmission lines running through the South Bay, 224,739 meters (140 miles) are high voltage (230 kV or above) and could experience temperatures up to 42-47 C (107.6-116.6 F). On average, these high voltage lines are projected to experience 3.46%, plus or minus 50% ampacity loss (1.73-5.19% ampacity loss). Of the 154,640 meters (96 miles) of low voltage (230 kV or below) transmission lines in the South Bay, the average projected ampacity loss is 8.4% (plus or

***Ampacity** is the maximum current (measured in electric units called amperes) that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.*

minus 33%). As shown in **Figure 5.6**, the low voltage transmission lines that are most vulnerable to heat waves track from North to South Carson, with projected air temperatures up to 43.7 C (110.6 F) and corresponding reductions in ampacity of 10.8% plus or minus 33% (or 7.2-14.4%).

Figure 5.6: Worst-Case Transmission Line Ampacity Loss



Results:

- Of the South Bay's 4.1 GW of local power generation, approximately 29.16 MW (0.7%) of energy generation capacity could be lost due to temperature increases over 40 degrees Celsius under the worst-case scenario (2060, RCP 8.5). The South Bay's power generation is therefore at minimal risk to projected temperature increases.
- The maximum projected substation capacity loss is 12.6%. Approximately 37 square miles within the South Bay (26%) are within a substation area projected to have

substations operating at a weather-de-rated factor of 1-1.2. This de-rated load factor corresponds to a "warning" risk level.

- Approximately 16.8% of the sub-region live within a "warning" designated risk level substation area
- High voltage transmission lines are projected to experience on average ampacity loss of 3.46%; low transmission lines are projected an average ampacity loss of 8.4%.
- Transmission lines are most vulnerable between North and South Carson

Sector 3: Biodiversity

Climate change has the potential to stress native biodiversity and alter the conditions in existing ecosystems. Temperature and precipitation changes, drought timing and frequency, as well as beach and cliff erosion, can result in habitat loss, species loss, alteration of the range and distribution of species, increased competition with non-native species, and disruption of ecosystem interactions. Building off the City of L.A.'s Biodiversity Index[116] and the indicators selected for UCLA Sustainable LA Grand Challenge's 2015 Environmental Report Card,[117] the SBCCOG assessed the potential climate impacts on habitats and biodiversity in the sub-region. In this section, the SBCCOG provides: 1) a summary of habitat vulnerability; 2) further examination of the potential impacts of specific climate stressors on species and habitats; and 3) consideration of several secondary impacts of climate change on biological systems.

***Biodiversity** is the variety of life found in the world or in a particular habitat or ecosystem.*

I. Vulnerability of South Bay Habitats

The South Bay and greater Los Angeles region is home to diverse micro-climates and eco-regions, which are key drivers of urban biodiversity, ecosystem function, and landscape character. The United States Department of Agriculture's Forest Service characterizes the greater Los Angeles region as a mix between Coastal Chaparral Forest and Sage Scrub ecological composition.[118] The SBCCOG also assessed coastal dune habitats, an ecosystem classification that characterizes several of our beach cities.

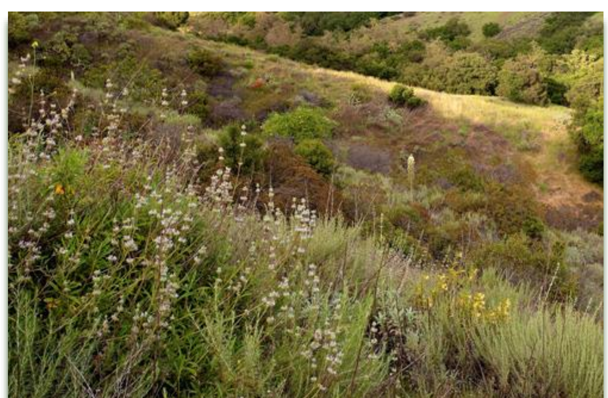
> ***Micro-climates*** *are very small or restricted areas of atmospheric conditions that differ from those in the surrounding areas.*
>
> ***Eco-region*** *is an area defined by its environmental conditions such as climate, landforms, and soil characteristics.*

Although the sub-region is highly developed, characteristics of the region's native ecology are primarily evident on the Palos Verdes Peninsula. The Palos Verdes Nature Preserve encompasses approximately 1,400 acres comprised of eleven Reserves.[119] The Preserve is owned by the City of Rancho Palos Verdes and is co-managed by the Palos Verdes Peninsula Land Conservancy for ecological values and habitat restoration.

The following analysis of Southern California Chaparral and Coastal Sage Scrub Habitats summarizes the findings of EcoAdapt's Vulnerability Assessments[120] [121] of South Bay habitats based on expert input and existing information. Vulnerability rankings were determined through habitat expert vulnerability assessment survey results and comments, peer-review comments and revisions, and relevant references from the literature.

Sage Scrub Habitat Vulnerability

The relative vulnerability of sage scrub habitats in southern California was evaluated to be *moderate* by habitat experts based on the following classifications: *moderate sensitivity* to climate and non-climate stressors, *moderate exposure* to projected future climate changes, and *moderate adaptive capacity* classification.



Source: ca.audobon.org

Sage scrub habitat distribution and composition is largely determined by precipitation and temperature. [122] Warming temperatures and shifts in rainfall and drought timing and severity will affect sage scrub germination and overall species composition. Although sage scrub habitats are adapted to wildfire, increasing fire frequencies prevent sage scrub recovery and seedbank regeneration, creating conditions favorable for invasive species and potential vegetation conversion to exotic annual grassland.[123] Type conversion results in a loss of native diversity and the change from deeply rooted shrubs to shallow rooted grasses and forbs further increases fire frequency and reduces carbon storage.[ii]

***Nitrogen deposition** describes the input of reactive nitrogen from the atmosphere to the biosphere. Enhanced nitrogen deposition is a consequence of global emissions of oxidized nitrogen from fossil fuel combustion.*

Sage scrub habitats are also drought-adapted and able to recover from disturbance, but non-climate stressors such as invasive species and nitrogen deposition undermine the natural resilience of this habitat. Sage scrub habitats exhibit moderate-high diversity and provide a variety of ecosystem services including native habitat, protection from erosion, recreation, and carbon sequestration.

Chaparral Habitat Vulnerability

Source: californiachaparral.com

The relative vulnerability of chaparral habitats in southern California was evaluated to be *low-moderate* by habitat experts based on the following classifications: *low-moderate sensitivity* to climate and non-climate stressors, *low-moderate exposure* to projected future climate changes, and *moderate adaptive capacity*. Drought is the key climate driver affecting chaparral habitats.[124]

Chaparral habitats are adapted to seasonal drought, but prolonged and/or more frequent drought or shifts in the onset of seasonal drought may contribute to plant dieback, shrub mortality, and/or altered community composition. These conditions lead to increase in fine fuels such as grass and leaves that ignite readily and can contribute to more frequent large fire events in the future. Many chaparral species are fire-adapted but increasing fire frequencies, linked with more human

[ii] Mature semiarid chaparral ecosystems can be a significant sink for atmospheric carbon dioxide

ignitions, and increased drought can inhibit chaparral regeneration and facilitate conversion to exotic grassland and degraded shrubland communities.

Chaparral habitats have experienced significant fragmentation; current and future habitat continuity and extent are threatened by development and land use conversions and a variety of other landscape barriers, such as transportation corridors, agricultural and grazing lands, and fuel clearance/vegetation treatments. Interacting climate and non-climate stressors may reduce the inherent resilience of chaparral habitats, but moderate species diversity may bolster habitat adaptive capacity in the face of climate change. Chaparral habitats provide a variety of ecosystem services including biodiversity, recreation, and carbon sequestration.

Beaches and Coastal Dunes Habitat Vulnerability

Beach and dune systems are formed from unconsolidated sand from coastal bluffs and watersheds. They are shaped by a myriad of marine and terrestrial processes and provide habitat for a variety of species, including pinnipeds and sea and shorebirds, as well as unique vegetation.

The vulnerability of beach and dune habitats in southern California was evaluated to be *moderate-high* by habitat experts based on the following classifications: *moderate-high sensitivity* to climate and non-climate stressors, *high exposure* to projected future climate changes, and *moderate adaptive capacity* classification.

Coastal dune habitats are highly sensitive to sea level rise, coastal erosion, wave action, and sediment supply and movement. Beaches and dunes are also sensitive to precipitation and pH, but to a lesser extent than the aforementioned factors. Beach and dune habitats are transcontinental in geographic extent, have moderate habitat connectivity, and moderate structural and functional integrity due to impacts from coastal, inland, and watershed development. Overall, beach and dune habitats are highly valued and can recover quickly if they have space to migrate or have enough sediment supply to keep up with sea level rise and erosion.

II. Vulnerable Species

The Chaparral and coastal sage scrub habitats host a wide variety of species, many of which are increasingly threatened as habitats become stressed by development and climate related pressures. This section identifies climate stressors that may impact species health and distribution throughout the South Bay. **Figure 6.1** shows the distribution of endangered or threatened species utilizing 2013 data from the California Natural Diversity Database. Endangered or threatened species in the South Bay include:

- Palos Verdes blue butterfly

Source: en.widkepedia.org

- Pacific pocket mouse

Source: patch.com

- Lyon's pentachaeta

Source: smmflowers.org

- El Segundo blue butterfly

Source: lataco.com

- Coastal dunes milk-vetch

Source: coastal webweaver.com

- Coastal California gnatcatcher

Source: audobon.org

- Brand's star phacelia

Source: lnaturalist.org

Figure 6.1 Endangered and Threatened Species Distribution

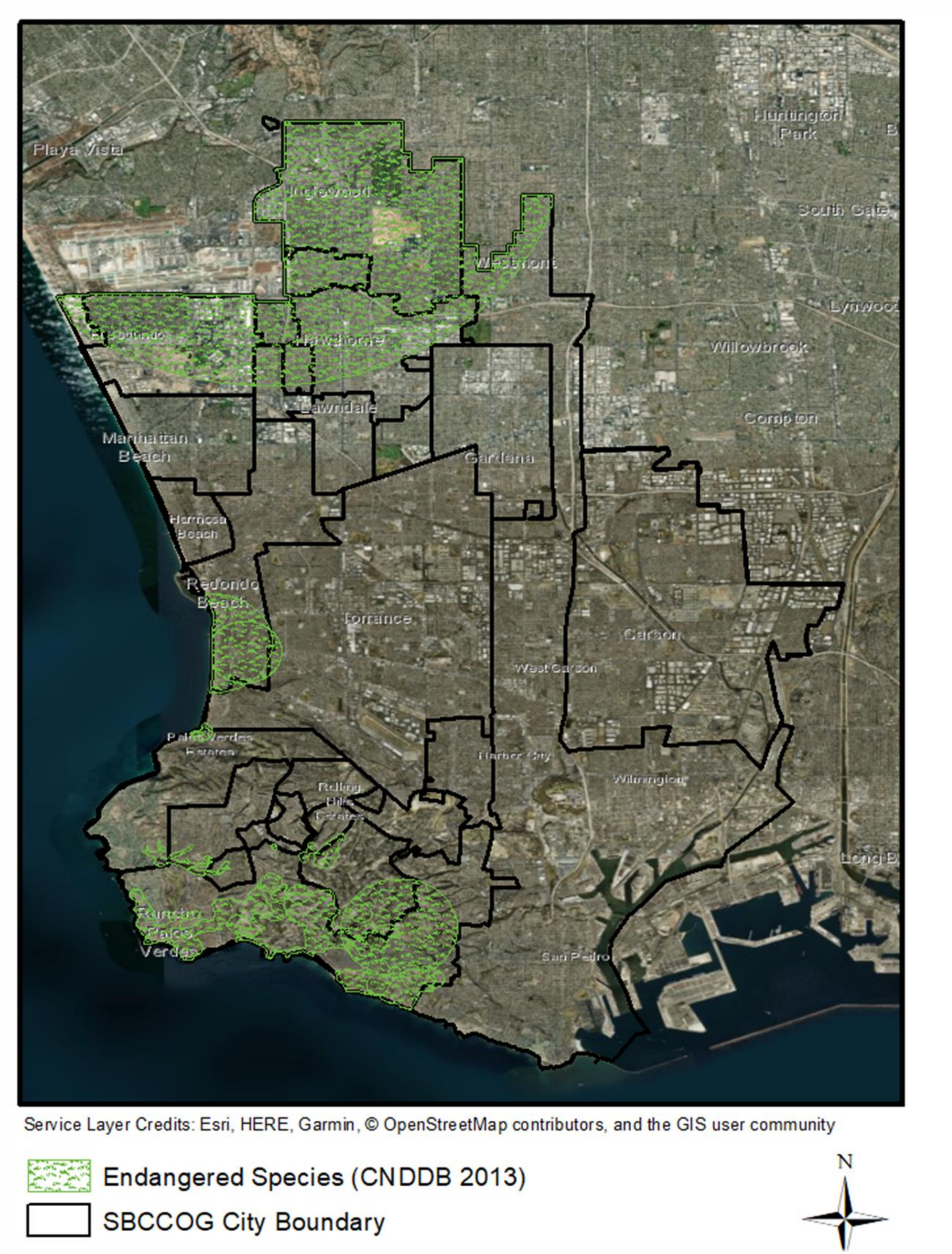
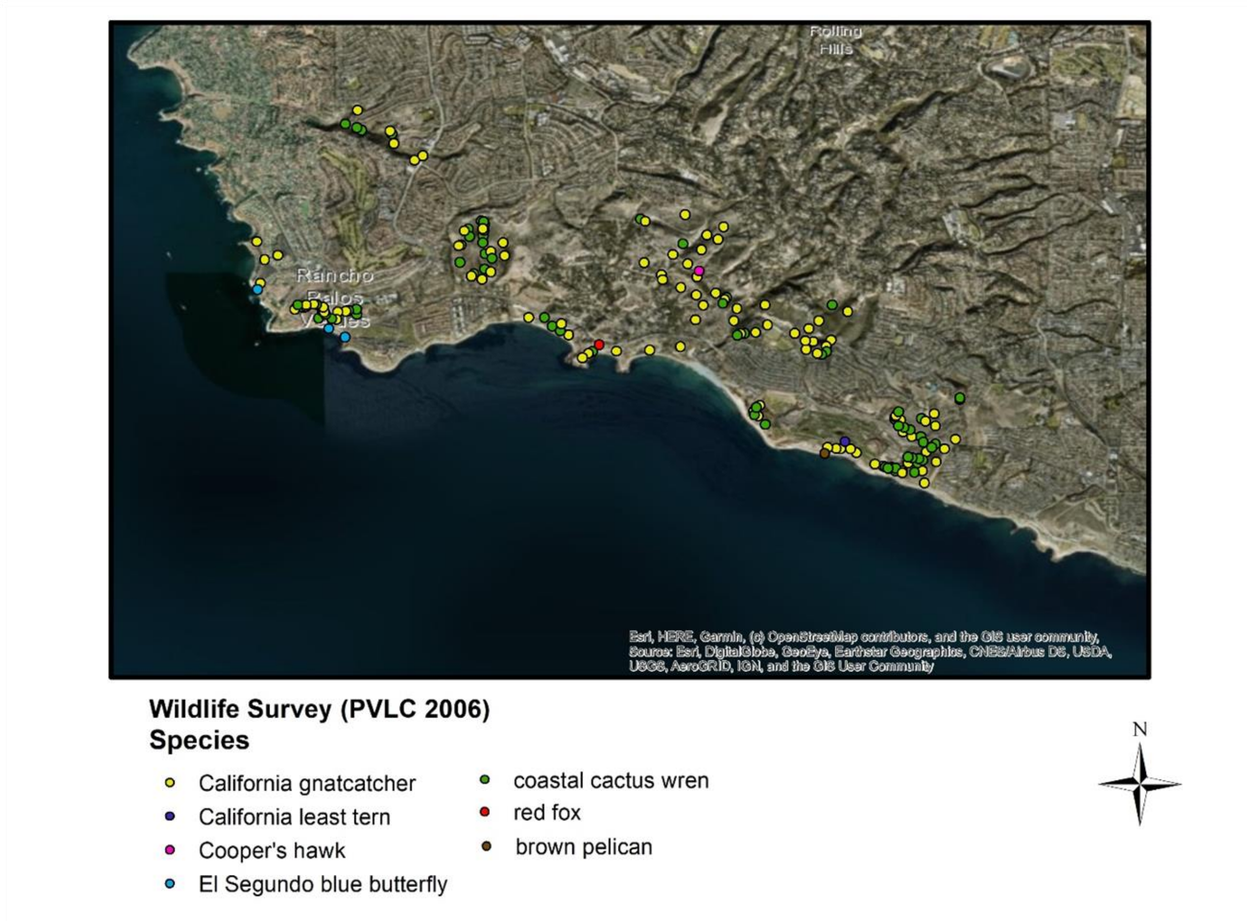


Figure 6.2 provides a closer examination of species distribution on the Palos Verdes Peninsula, with species observations from the Palos Verdes Land Conservancy.

<u>Figure 6.2 Species Distribution on the Palos Verdes Peninsula</u>



The Palos Verdes Land Conservancy (PVLC) last surveyed the wildlife on the Peninsula in 2006. They observed species including:

- California gnatcatcher
- El Segundo blue butterfly
- Western rattlesnake
- Cooper's hawk
- Red fox
- Rufous-crowned sparrow
- California least tern
- And the Brown Pelican
- Cactus Wren

Some studies have attempted to classify and rank the vulnerability of specific species to determine how susceptible they are to the negative impacts of climate change. In 2012, Point Blue Conservation Science published a paper assessing and ranking the vulnerability of

California birds to climate change related impacts such as sea level rise and vegetation change.[125] Vulnerability scores were calculated by first ranking each of the following sensitivity and exposure criteria on a scale of 1 to 3: changes in habitat suitability, changes in food availability, changes in extreme weather, habitat specialization, physiological tolerances, migratory status, and dispersal ability.[126] Then the sum of the exposure scores were multiplied by the sum of the sensitivity scores, generating a climate vulnerability index with scores ranging from 12 to 72, with a median score of 24 (higher index indicates greater vulnerability). **Figure 6.3** and **Table 6.1** includes species present in the South Bay that were ranked in this assessment.

Figure 6.3 Vulnerable Bird Species Distribution

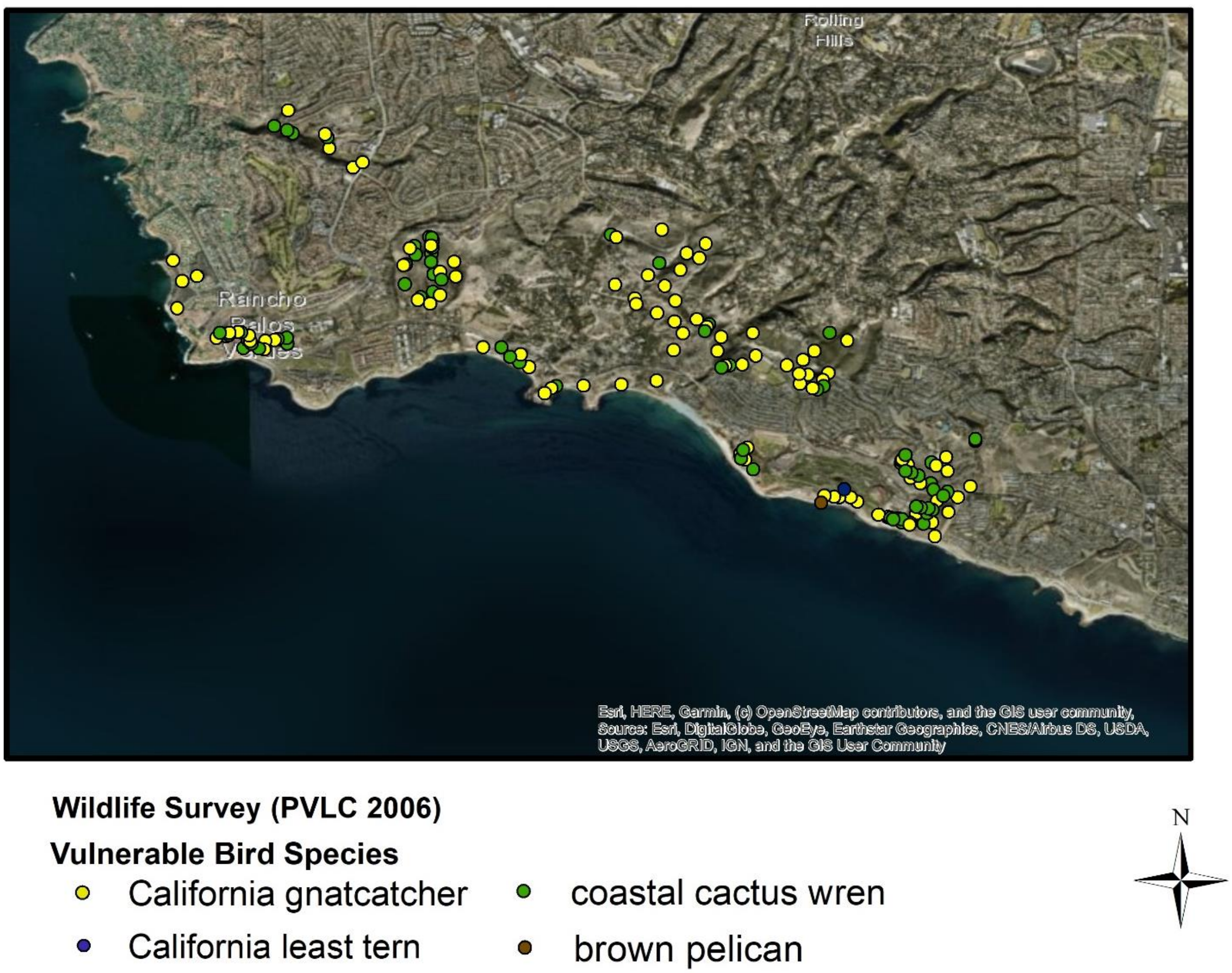


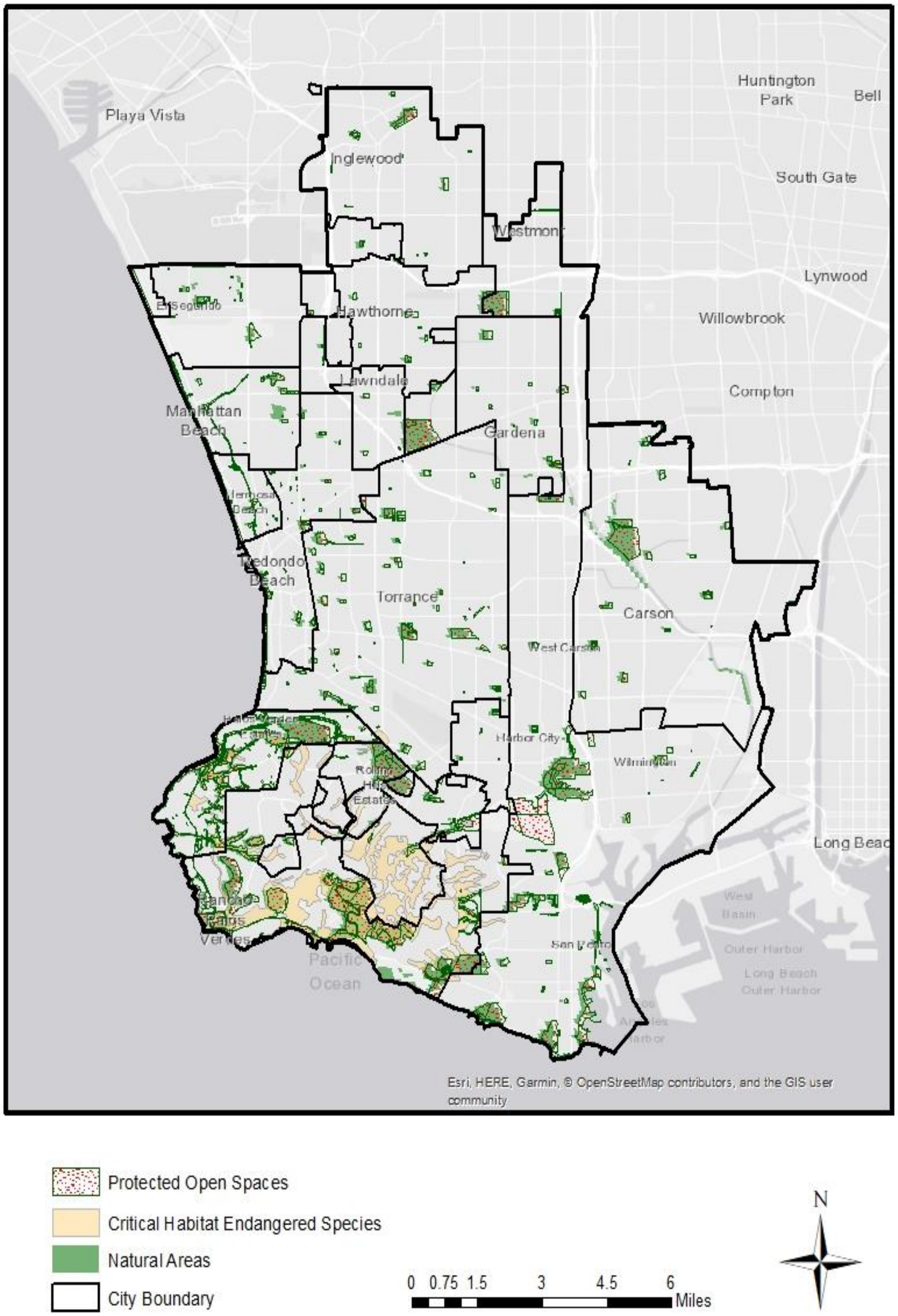
Table 6.1 Bird Vulnerability in the South Bay

Species	Vulnerability Score	Climate Priority	Endangered Species Listing Status
Least Tern	63	1	Endangered
Brown Pelican	42	2	Not Listed
Cactus Wren	36	3	Not Listed
Coastal Gnatcatcher	32	3	Threatened

A more in-depth analysis would need to be conducted to evaluate the vulnerability of all other species in the South Bay sub-region.

Few species can adapt to changes without shifting location, particularly those native to California which are well-adapted to a specific microclimate. Species that experience stress due to climate change may migrate (shift their range) to more suitable conditions. Migration assumes a level of habitat accessibility and species mobility that may not be present. If migration is not possible, species risk extinction.[127] **Figure 6.4** shows critical habitat areas (areas where endangered species reside) and natural areas that threatened species could potentially migrate to.

<u>Figure 6.4 Critical Habitat and Habitat Connectivity Zones in the South Bay</u>



34.5% of Critical Habitat and 58.2% of Natural Areas lie within Protected Areas, lands that are owned and protected for open space purposes by public and nonprofit agencies.

Temperature Change

Plant and animal species have a preferred temperature range and ecological setting. Climate change results in altered seasonal temperature, which can affect the suitability of habitats for species. For example, species already surviving at the upper end of their preferred temperature range are likely to experience more frequent and prolonged thermal stress.[128] These changes not only alter the physical comfort of species, but also may alter the entire habitat type.

Phenology describes the timing of biological events in plants and animals such as flowering, leafing, hibernation, reproduction and migration.

Shifts in temperature and precipitation may affect chaparral phenology[129] and/or chaparral distribution[130 131], although sensitivity likely varies by species[132 133] and not all range shifts can be attributed to temperature and precipitation drivers.[134]

Warmer temperatures may also affect germination and abundance of some sage scrub species. Studies in the Channel Islands documented reduced germination[135] and spring population size[136] of coastal sage scrub species following rainfall events with warmer temperatures.

Wildfire Distribution and Frequency

Similar to many other Mediterranean-climate regions, wildfire is an integral component of the ecological processes. Land use practices and fire management policies have altered fire regimes, affecting ignition frequency, vegetation patterns, and ecological processes. These elements interact with each other, with natural climate variability, and with anthropogenic climate change, in a highly complex system of feedback loops and time lags.

A feedback loop is a biological occurrence wherein the output of a system amplifies the system (positive feedback) or inhibits the system (negative feedback).

Increased fire frequency in native shrublands can result in cumulative loss of dominant native shrub species, and increase of easily ignitable exotic, annual grasses and broadleaf weeds. In chaparral habitat, conversion to grassland is often precipitated by short-interval fires that specifically target non-re-sprouting seeding shrubs such as certain species of California-lilac.[137]

Subsequently, they are more susceptible to invasion by non-native herbaceous species. Fire events that occur less than six years apart have been highly detrimental to chaparral.[138] [139] Multiple fires within a six-year interval have reduced re-sprouting species, further opening the chaparral environment to invasion.[140] Researchers found that over a 76-year period, 49% of the sage scrub shrublands in parts of southern California had been replaced by annual grasses and a substantial amount of this could be attributed to fire frequency. [141]

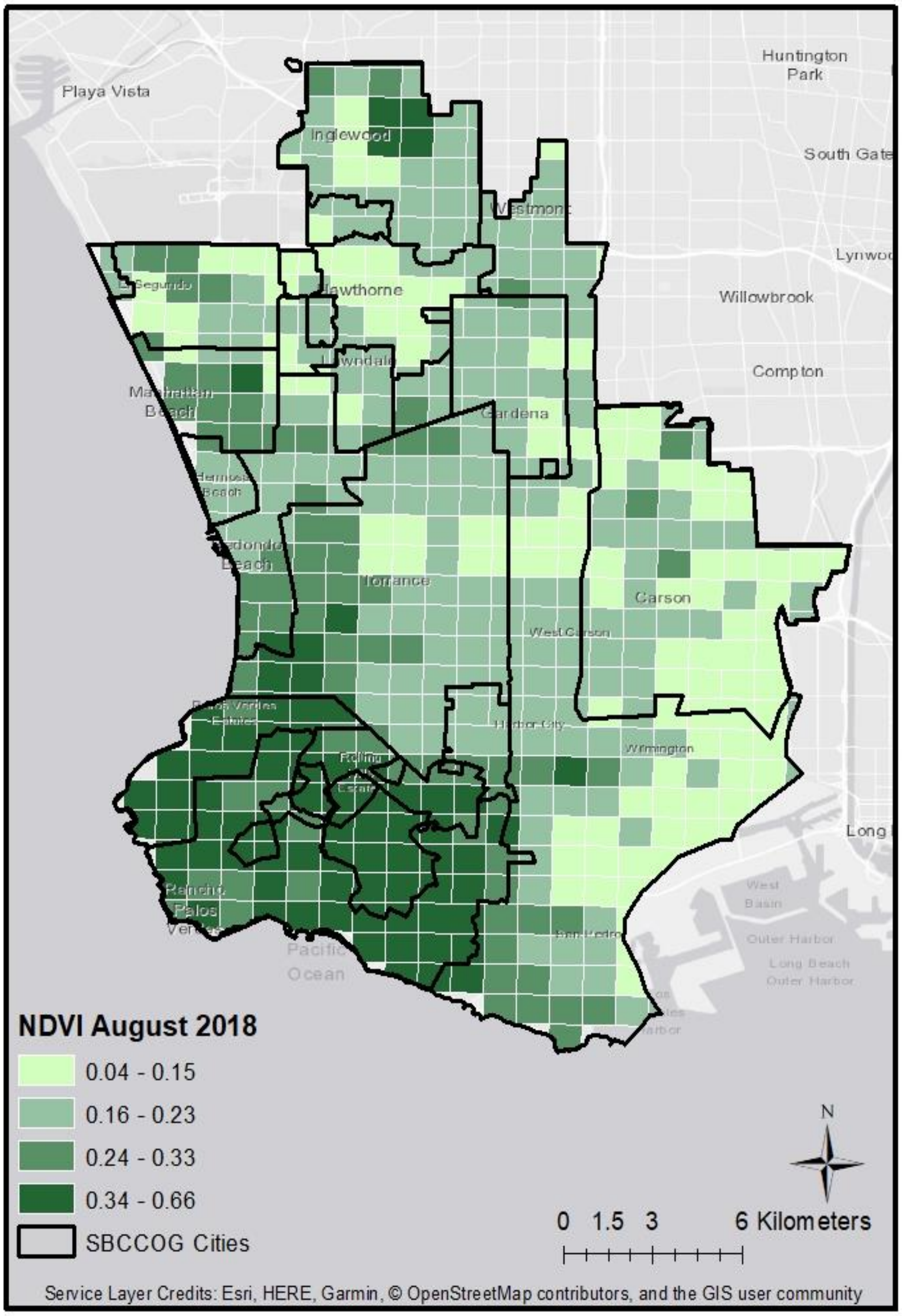
Some bird species (including the California gnatcatcher, present in the sub-region) are also threatened by overly frequent fire. Ecological studies revealed significant differences in the post-fire bird community located in the low-elevation chaparral, low-elevation coastal sage scrub, and the high-elevation grassland communities. [142] Vegetation characteristics altered by fire, such as decreases in shrub and tree cover, influenced the changes observed in the bird communities.

A significant component of firefighting is the use of prescribed burning or mechanical alteration of vegetation. In many forests, such fire hazard reduction treatments are compatible with resource protection; however, in chaparral shrublands, such treatments may cause ecosystem damage such as an increase of invasive species. [143]

Drought Stress

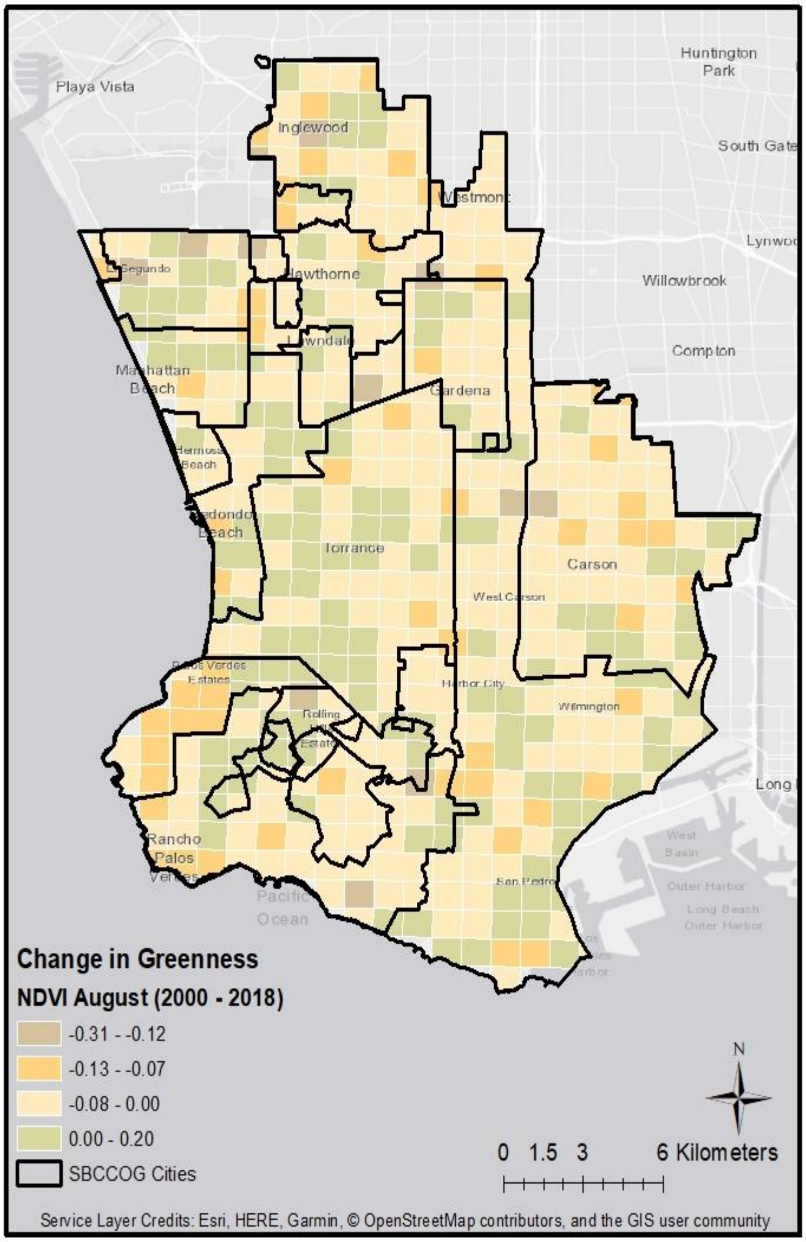
Coastal sage scrub and chaparral communities in southern California are resilient to drought conditions. Drought-deciduous shrubs (plants that drop their leaves during the dry season) utilize moisture in mind-to upper-soil levels and feature a variety of adaptations that allow them to persist during seasonal summer dry periods and in locations with low soil moisture. Although these habitats are resilient to drought, they may be sensitive to shifts in drought timing or severity. Shifts in drought that start earlier in the growth season can reduce seed production of completely drought-deciduous shrubs. Persistent dry conditions may facilitate conversion to other shrub communities. For example, field observations in eastern Riverside County have documented areas that have changed from coastal sage scrub to desert scrub species after multiple years of minimal rainfall.[144] This exemplifies a habitat shift which is less problematic than conversion to non-native species. As climate stressors become more extreme, there could be a loss of moderate temperature environments resulting in a loss of overall biodiversity -- especially in areas that traditionally had Mediterranean Climates.

Figure 6.5 NDVI August 2018



Drought stress of vegetation in Los Angeles County can be assessed by satellite imagery using a measurement called NDVI (Normalized Difference Vegetation Index), also referred to as "greenness". NDVI ranges from 1.0 to -1.0 with positive values (i.e. 0.5) representing high greenness and negative values (i.e. -0.2) representing little or no vegetation. This tool collects information the human eye cannot see. **Figure 6.5** shows August 2018's NDVI and **Figure 6.6** highlights the change in August's NDVI from 2000 to 2018.

Figure 6.6 Change in NDVI August 2000-2018



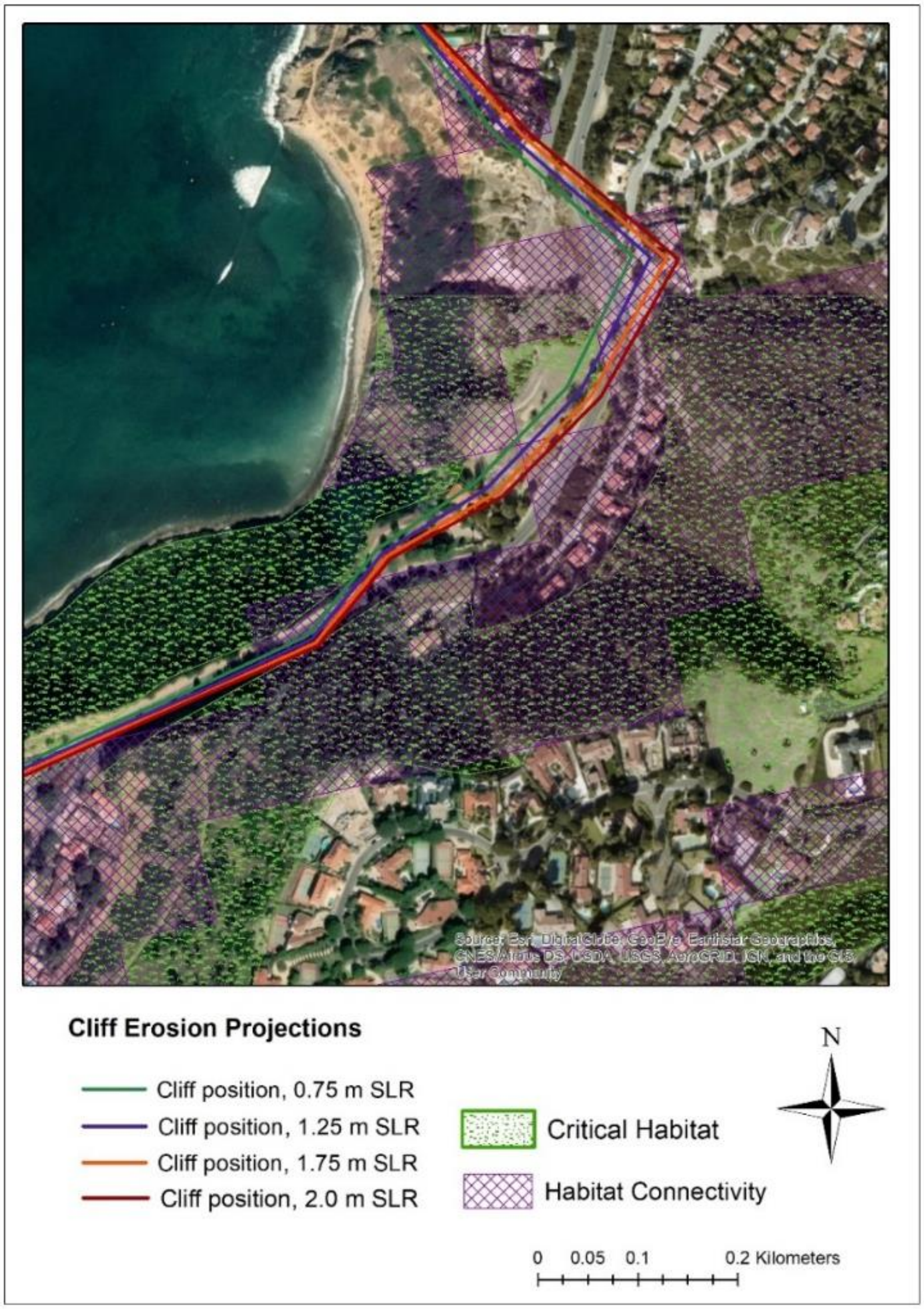
The NDVI for the South Bay decreased 2.6% between 2000 and 2018.

Critical Habitat Areas saw an NDVI reduction of 3.7% over the same time period.

Cliff Erosion

While some species are more or less sensitive to climatic shifts in temperature or wildfire, cliff erosion due to sea level rise poses a direct threat to habitat and species. Cliff erosion is a very complicated process which includes the processes of water and wind erosion, abrasion, and landslides. Approximately 150 acres of critical habitat is vulnerable to projected cliff erosion with 2 meters of sea level rise on the Palos Verdes Peninsula. **Figure 6.7** demonstrates the threat to critical biodiversity habitat that is threatened by projected cliff erosion due to sea level rise.

<u>Figure 6.7 Threat to Critical Habitat from Cliff Erosion</u>



In addition to the physical loss of habitat, indirect impacts on biodiversity are also observed due to coastal erosion. Landslides and erosion can increase long-term marine water turbidity, or cloudiness, and local eutrophication—when a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of algae. Other impacts of increased turbidity are further discussed on pg.15 of this document.

III. Secondary Climate Impacts

Invasive Species

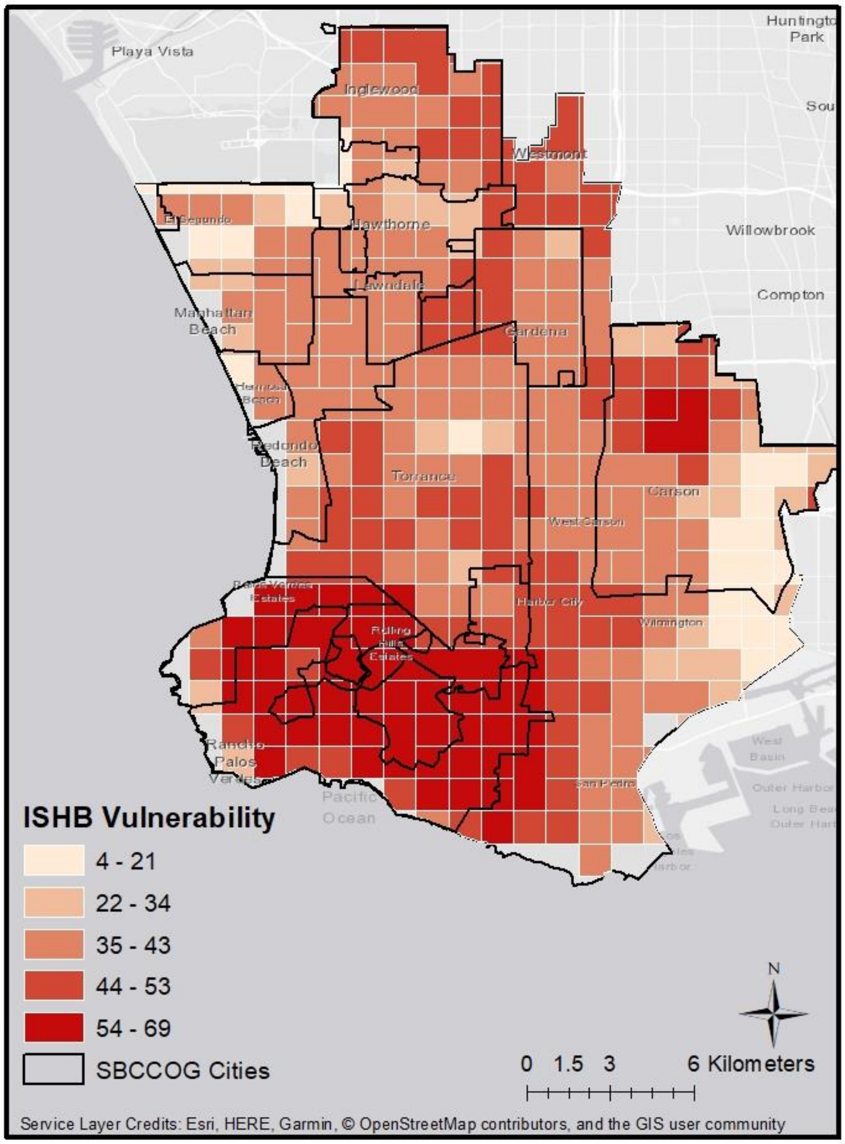
The impact of climate change on ecosystems is difficult to predict, due to both uncertainty in climate change scenarios and uncertainty in understanding how species will respond to those changes. There are, however, several reasons to expect that most climate change scenarios will increase the extent, frequency, and severity of invasive species, as well as facilitate a shift toward species, that have not historically been, becoming invasive.

Invasive species have short generation times, strong dispersal abilities, and broad environmental tolerances, which will allow them to cope with rapid changes, making them well suited to succeed in environments affected under climate change scenarios. Climate change will in many cases lead to a future of warmer temperatures with increased carbon dioxide and nitrogen from cars and agriculture. [145] This increase in resources allows species to invade arid environments such as western shrublands.[146] Research indicates that some invasive plants improve their growth rates and exhibit evolutionary developments under higher carbon dioxide concentrations in test conditions.[147] Furthermore, an increase in extreme storm events, a likely outcome of a changing climate, has the potential to disperse invasive plants and insects through air or water farther and in different patterns.[148] Extreme weather events will also lead to increased disturbance, and invasive species generally thrive in disturbed landscapes with high light availability and fragmented native communities.[149]


Source: ca.audobon.org

Scientists have modeled habitat susceptibility to an exotic beetle called the invasive shot-hole borer (ISHB), which is believed to be native to Southeast Asia. ISHB spreads a tree disease called Fusarium Dieback, and has attacked over 260 tree species in California, including native plants, urban trees, and agricultural crops like avocado.[150]

Figure 6.8 ISHB Vulnerability



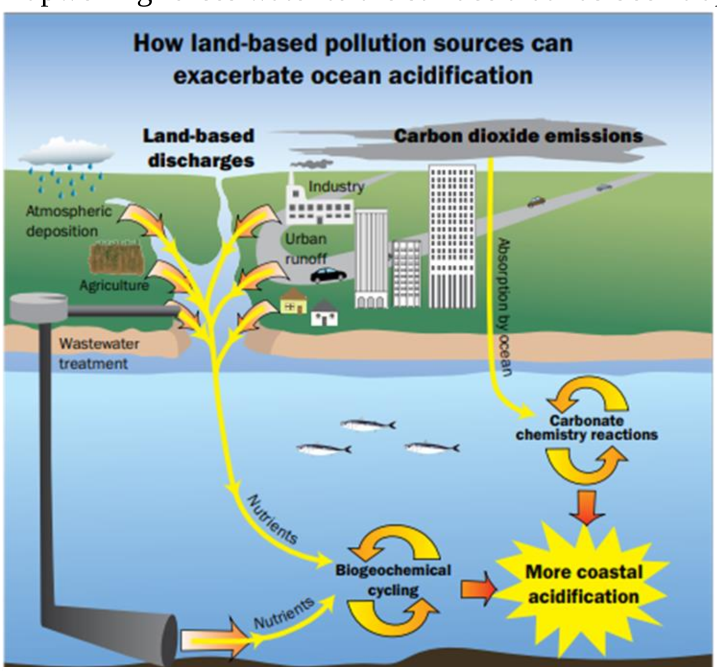
ISHB was first detected in Los Angeles in 2010. Since then, it has been linked to the deaths of hundreds of thousands of trees in Southern California. Scientists are researching the biology of the beetle and host response to treatments to better understand and manage this destructive species. **Figure 6.8** illustrates the likelihood that ISHB would occur in a given area based on the vulnerability of the environment (within that map pixel). The values in the map have been scaled so that there is a maximum vulnerability score of 100.

Ocean Acidification

Approximately one third of the carbon dioxide that humans release into the atmosphere is absorbed by the ocean, gradually moving seawater conditions toward a more acidic, corrosive state.[151] The change in water chemistry, known as ocean acidification, is making seawater a less habitable environment for organisms ranging from sea snails to crabs and fish.

The ecological consequences of ocean acidification will not be felt uniformly around the world. Unique ocean circulation patterns make the coastline of the North American West Coast among the most vulnerable ecosystems on earth. Corrosive seawater conditions are turning up in Southern California's coastal waters. The Southern California Bight 2013 Regional Monitoring Program[152] documented corrosive conditions at average depths of just 80 meters along the continental shelf during the spring season, and at 120-meter depths the rest of the year. These unfavorable conditions eventually are expected to reach the upper water column – home to abundant marine life, including tiny sea snails called pteropods that form the base of marine food webs.

The dominant force bringing corrosive conditions into shallow coastal waters is a natural phenomenon called upwelling. Triggered by seasonal winds off the coast of North America, upwelling forces water to the surface that has been trapped at the bottom of the Pacific Ocean for decades. These deep waters tend to be high in dissolved carbon dioxide and low in dissolved oxygen. When winds are particularly strong – as is common during the spring months – West Coast upwelling can bring so much carbon dioxide-rich water to the surface that seawater pH can drop as much as 90%.[153] Although West Coast marine organisms have adapted to intermittent exposure to corrosive, hypoxic seawater, these conditions are expected to become more prevalent and pervasive in response to



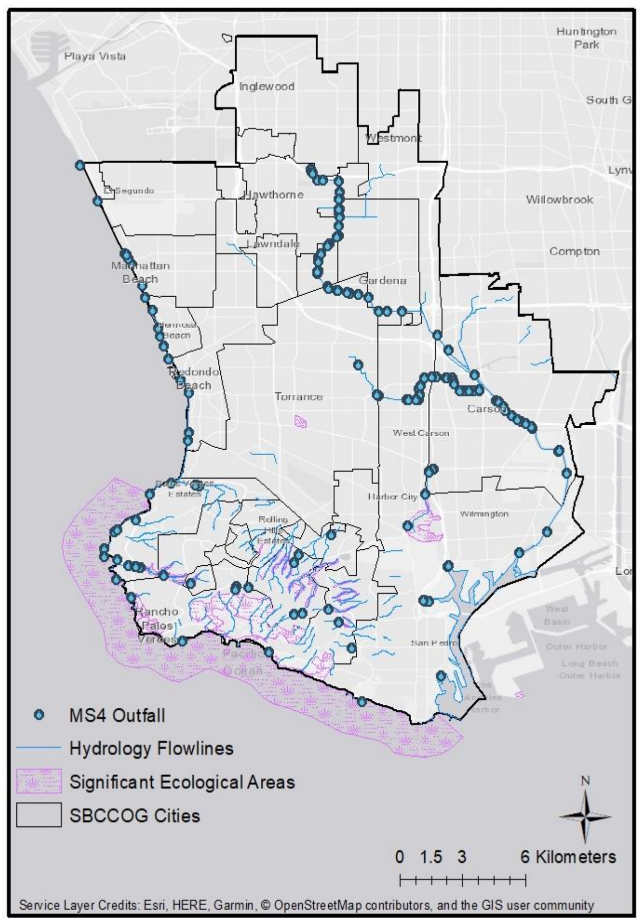
Source: SCCWRP 2017 Annual Report

global climate change. Indeed, changing weather patterns are expected to bring even stronger West Coast winds that trigger more intense upwelling events.[154]

Researchers are working with the coastal management community to determine whether local, land-based discharges are directly exacerbating acidification of coastal waters and driving down dissolved oxygen levels. For generations, coastal communities have released treated wastewater, rainfall runoff, and other discharges into coastal marine waters. These discharges typically contain high levels of nutrients – especially nitrogen and phosphorous – that can trigger complex biogeochemical cycling processes that raise dissolved carbon dioxide levels and lower dissolved oxygen levels.[155] Coastal environmental managers want to know if these nutrient discharges are making coastal waters more corrosive and hypoxic (oxygen-deprived) than they otherwise would be – and if so, when and where the ecological impacts are greatest.

In California, for example, there are just eight major wastewater outfalls – four in the San Francisco area and four in Southern California – that discharge about 50% of all the nitrogen that Californians are introducing to coastal waters.[156] Polluted stormwater runoff is commonly transported through municipal separate storm sewer systems, and then often discharged, untreated, into local water bodies. **Figure 6.9** shows the location of MS4 outfalls throughout the South Bay in relation to significant ecological areas. MS4 outfalls include discharges from pipes, ditches, swales and other points of concentrated flow.

<u>Figure 6.9 MS4 Outfall Distribution Throughout South Bay</u>



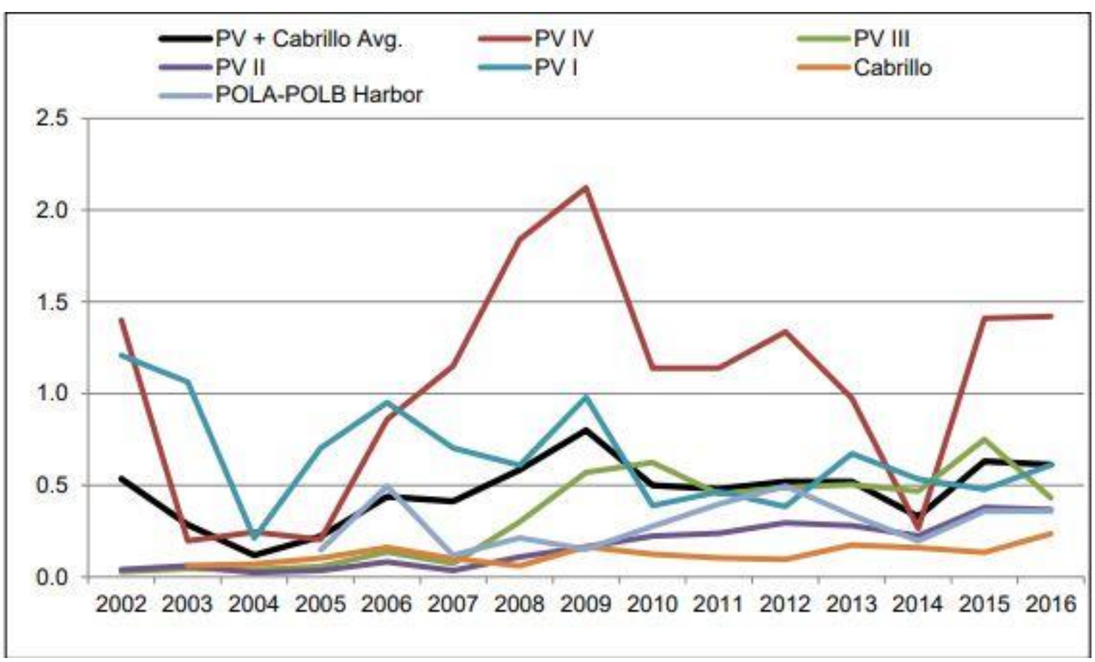
Kelp Distribution

Kelp forests provide habitat and protection for hundreds of species of fishes and invertebrates, second only to tropical reefs in the number of marine species supported. In California, kelp forests are formed by giant kelp (marocystis pyrifera). Giant kelp can reach lengths of 180 feet and typically create a dense canopy near the water's surface. The extent of giant kelp canopy is considered an important indicator of subtidal rocky reef health.

Kelp canopy is affected by a variety of factors including storm wave disturbance, density of grazers (especially sea urchins), nutrient availability, and sunlight penetration (which can be reduced by water turbidity or sediment accumulation, potentially from coastal discharges of stormwater and/or wastewater), and erosion in developed areas in the coastal zone.[157]

To evaluate the health of kelp beds off the coast of the South Bay sub-region, the SBCCOG utilized data from the Central Region Kelp Survey Consortium (CRKSC). The CRKSC was formed in late 2002 to fulfill requirements for ocean dischargers to create a regional kelp bed-monitoring program using aerial surveys. According to a report[158] on the *Status of the Kelp Beds in 2016*, the kelp canopy coverage of the Palos Verdes Peninsula has increased by 7.8% from 2002-2016.

Figure 6.10 Kelp Coverage Per Year, 2012-2016: Palos Verdes & Cabrillo Average vs Kelp Beds off Palos Verdes



Source: Status of Kelp Beds, 2016

Palos Verdes Kelp Beds

The Palos Verdes (PV) kelp beds are typically quite large and have been more accessible to researchers than other areas, resulting in many comprehensive surveys of this region. The CRKSC divides the two beds that CDFW recognizes into four distinct kelp regions. Though there has been an observable upward trend between 2002 and 2016, the beds off Palos Verdes decreased in size by 6% between 2015 and 2016. This decrease, however, was not consistent among the four beds (i.e., two of the bed sizes decreased, one bed increased, and one bed remained essentially the same size).

The Portuguese Bend landslide is an important local factor in limiting kelp forests on reefs along the southern face of Palos Verdes. It affects areas in the Palos Verdes (PV) I and PV II kelp beds. This slide, which has been active since 1956, has contributed as much as 9.4 million metric tons of sediment to the nearshore waters.[159] Besides increasing water turbidity (cloudiness) which affects sea floor light availability, sediment from the slide buried many low-lying reefs that would otherwise support kelp beds.[160] This process will likely be exacerbated by continued cliff erosion due to rising sea levels.

Source: Status of Kelp Beds, 2016

To enable the recovery of historic kelp forests, the "Kelp Project" engaged in sea urchin suppression to reduce the density of urchins on shallow rocky reefs. The Kelp Project demonstrated that reducing urchin density from as high as 100 sea urchins per square meter to less than 2 sea urchins per square meter enabled the natural development of giant kelp and other macroalgae at restoration areas in Malibu and Palos Verdes.

Restoration sites have been established at 5 locations off Palos Verdes: Honeymoon Cove, Marguerite, Underwater Arch Cove, Hawthorne, and Point Fermin. Restoration efforts at Honeymoon Cove and Underwater Arch Cove are considered complete: urchin suppression has resulted in urchin densities below the target of <2 per square meter in a total area of 8.33 acres for Honeymoon Cove and 8.37 acres for Underwater Arch Cove. Restoration efforts remain in progress at the other three restoration sites, but urchin suppression has resulted in urchin densities below the restoration target. An estimated 3,248,619 purple urchins have been suppressed over three years at these five restoration sites on the Palos Verdes Peninsula. [161] Analyses of urchin body mass, species richness of fishes, and fish biomass, as well as increased density of giant kelp, indicate preliminary results from the restoration effort were positive. [162]

Synopsis

Climate change will likely impact the biodiversity of the sub-region. Species and ecosystems react differently to varying levels of climate stress, ranging from rising temperatures, increasingly frequent drought events, and wildfire, among others. The negative impacts associated with climate change will likely be further exacerbated by increasing population density, which puts pressure on the already limited critical habitat and habitat connectivity areas. This document provides a preliminary baseline assessment of the habitats and species native to the sub-region and should be referenced in conjunction with existing habitat conservation plans to develop strategies aimed at protecting the South Bay's ecosystems and biodiversity from climate stressors.

Sector 4: Coastal Resource Management

Beaches offer natural protection against flooding, and as such, are the first line of defense to protect people and assets situated adjacent to beaches. Most of the beaches located in the South Bay are either owned or operated by the Los Angeles County Department of Beaches and Harbors (DBH) (**Table 7.1**). This section summarizes the findings applicable to the South Bay from two technical studies that identified the risk and cost of maintaining coastal assets (natural and built) as a result of sea level rise (individual city studies will be included in the city-specific vulnerability assessments):

(1) *Pathways to Resilience: Adapting to Sea Level Rise in Los Angeles (2018)*[163] - describes the potential effects of sea level rise on coastal LA County and adaptation pathways along with estimates of associated costs in order to cope with sea level rise.

(2) *Los Angeles County Public Beach Facilities Sea Level Rise Vulnerability Assessment (2016)* – provides inventories and determines levels of sea rise associated with lost assets.

By providing information on the projected extent and impact of coastal erosion due to sea level rise (SLR), South Bay elected officials and the general public will be better equipped to address the future challenges of maintaining South Bay beaches, and the importance of the continuation of beach nourishment as the primary policy for maintaining the protective strength of beaches to reduce flood risk.

Beach Erosion and Loss

Due to sea level rise, beach widths in the South Bay will gradually decrease without periodic nourishment.[164] [165] Sediment supply to LA beaches decreased by 14–66% since 1920. El Segundo and Redondo beaches are comparatively less stable than other LA County beaches, and erosion rates at Redondo Beach are relatively high, losing sediment to nearby Redondo Submarine Canyon. To address beach erosion, Redondo and El Segundo beaches were nourished in the 1960s, and since that time, have lost 50% of their width because of stabilizing measures such as jetties, offshore breakwaters, and groins[166]. **Table 7.1** shows future beach-width losses assuming different sea level rise scenarios, using CoSMoS simulations.[167] The simulations indicate future beach widths for LA County beaches, assuming a 100-year storm and sea level rise scenarios of 0, 0.5, 1, 1.5, and 2 meters (0−6.6 ft).

Table 7.1 Future Beach Width Projections

Beach	Owner	2010 Width M (ft)	CoSMoS 2100 SLR 1 m (3.3 ft) Loss %	CoSMoS 2100 SLR 2m (6.6 ft) Loss %
Dockweiler State Beach	State of CA	180 (590)	10	40
Manhattan Beach	DBH	128 (420)	25	50
Hermosa Beach	City of Hermosa	143 (470)	50	60
Redondo Beach	DBH	43 (140)	25	60
Torrance Beach	DBH	76 (250)	25	60
Whites Point/Royal Palms Beach	DBH	n/a	100	100

Source: Pathways to resilience: adapting to sea level rise in Los Angeles (2018)

Risk of Beach Erosion to South Bay

By the year 2100, some of the County's assets (built) will be vulnerable to erosion at most South Bay beaches (**Table 7.2**). Under the existing condition, it is expected that some assets will be flooded in years 2040 and 2100, unless preventive action is taken.[168] (Maps of impacted assets under different sea level rise scenarios can be found in Appendix B)

Table 7.2: Percentage of Public Beach Assets Potentially Impacted by Future Sea Level Rise (SLR)

		CoSMoS 3.0 SLR Scenario with 100-year storm				
South Beach	**Total Assets**	**0cm**	**50 cm**	**100 cm**	**150 cm**	**200 cm**
Dockweiler State Beach	27	0%	19%	56%	81%	85%
Manhattan Beach	7	0%	0%	0%	43%	86%
Hermosa Beach	5	0%	0%	20%	60%	100%
Redondo Beach	8	0%	0%	13%	88%	88%
Torrance Beach	4	0%	0%	25%	25%	25%
Royal Palms County Beach	2	50%	50%	100%	100%	100%
White Point County Beach	2	0%	0%	0%	0%	0%
Point Fermin Beach	0	--	--	--	--	--

Source: Los Angeles County Public Beaches Sea-Level Rise Vulnerability Assessment (2016)

Beach erosion also poses socio-economic costs such as loss of beach quality (area, sand quality, wave quality for surfing, etc.), associated recreational uses, loss of private property,[169] and losses within the tourism sector.[170] [171] Several studies correlate a decrease in beach width with a decline in beach attendance in order to estimate changes in economic revenue.[172] A study conducted by Wei and Chatterjee (2013) calculated economic losses for LA County from a 10-year flood event using an input-output mode.[173] While this study does not address impacts from beach erosion on tourism, it does find that business interruption losses (**Table 7.3**) could increase from $3.4 million under current conditions to $6 million in a +0.5 m (1.6 ft) sea level rise scenario, and to $9 million in the +1.4 m (4.6 ft) sea level rise scenario. For a 100-year flood event, the losses increase from $7 million under current conditions to $11 million in a 0.5 m sea level rise scenario and $22 million in a 1.4 m sea level rise scenario. The reason for the relatively low business interruption losses is that approximately 95% of the projected damaged buildings are residential.

Table 7.3: Projected Business Interruption Costs due to Sea Level Rise (SLR)

	Current Sea Level		**+0.5 m (1.6 ft) SLR**		**+ 1.4 m (4.6 ft) SLR**	
	1/10 flood [$ mln 2010]	1/100 flood [$ mln 2010]	1/10 flood [$ mln 2010]	1/100 flood [$ mln 2020]	1/10 flood [$ mln 2010]	1/100 flood [$ mln 2020]
Output losses	3	7	6	11	9	22
Income losses	2	5	4	7	6	14
Employment losses	24	52	41	74	64	158

Source: Wei and Chatterjee, 2013 [174]

Sand Replenishment

In the year 2012, LA County launched a comprehensive Coastal Regional Sediment Management Plan to prevent erosion, maintain safety, and conserve and restore sediment resources along the LA coastline. The US Army Corps of Engineers (USACE) maintains and develops beach nourishment projects, although a city can also initiate such activities. For beaches in LA County, it is estimated that over 35 million cubic yards (cy) (26.8 million m3) of sand has been placed to widen the beaches from 1930 to 2015.[175] Most sand for nourishment comes from harbor dredging programs, and for some areas from natural sediment supply by creeks.[176] In the future, however, the volumes of sand provided by rivers and dredging programs are likely to be insufficient to sustain beach nourishment. The historic sources and volumes of sand, from adjacent coastal dunes and dredging spoils of an entire marina, are not a viable option today due to the developed nature of LA's coast. Therefore, it is important to quantify the characteristics and extent of offshore sand reserves.[177]

Offshore Sand

Sand is defined as all particles between 0.062 mm and 2 mm in diameter; this grain size is characteristic of most California beaches. The CRSMP plan explicitly states that available sediment resources near the coastline (e.g. suitable for dredging) for maintaining nourishment of beaches are finite and limited, especially when facing accelerated rising sea levels. One option is to continue investigating the significant offshore sand deposits from the late Quaternary or Holocene geologic time periods. These deposits may be found offshore on the inner continental shelf. Research indicates that 325 million cy of offshore sand is available with a grain size of 0.13 mm and 198 million cy of offshore sand should be available with a coarser grain size between 0.44−0.59 mm.[178] Other research describes similar totals of 372 million cy yards of sand and gravel deposits believed to exist offshore of LA County's coast.[179] The thickness of these deposits could measure over 60 feet (18 m).

The USACE performed an assessment between 1973 and 1978 near Santa Monica and Torrance, where sand deposits were estimated at 26 million cy (19.9 million m3). Most of these sediments are in deep waters offshore, where it may not be economically feasible to excavate all these sediment deposits. One caveat for this sediment source is that it is unknown how much of this volume would consist of sand with the required grain size for beach nourishment.

More recent studies to locate suitable offshore sand closer to west Malibu have not been successful as the sediment was too finely grained for beach nourishment.[180] In addition, California's system of marine managed areas needs to be considered in the context of developing adaptation plans. Balancing environmental concerns of habitat impacts (from both extraction and placement) of dredging with maximizing the use of offshore sediment will be a continual challenge for coastal managers.

Inland Sand

Sand can also come from inland quarries. This process typically involves careful screening and mixing to ensure a grain size, color, and material suitable for the specific beach. Los Angeles County operates and maintains over 160 debris basins and dams, most of them located in the San Gabriel Mountains[181]. They are designed to capture sediment and gravel flows during storm runoff, before they can clog drainage systems and cause flooding. These debris basins are regularly cleaned out to prevent buildup of sediment as well as to make room to capture new sediment flows. The Los Angeles County Department of Public Works indicates that over 18 million cy of sediment has been collected since the 1930s at an average annual total capture rate of over 300,000 cy.[182] Most of this sediment, however, is trapped in the Los Angeles and San Gabriel rivers, which do not supply sediment to LA County beaches. Trapped sediment behind dams near Ventura and Malibu may be feasible inland sources for beach nourishment -- namely, the Matilija Dam on the Ventura River and Rindge Dam on Malibu Creek. Some lessons learned can be derived from other dam removal projects on the West Coast (Elwha Dam and San Clemente Dam) that have restored habitat and sediment connectivity [183] [184]. Given the complex nature of dam removal there is much debate about how practical dam removal will be for restoring natural sediment regime.

Costs of Beach Nourishment

Between the years 1984 to 2010, more than $67 million was spent to re-nourish California beaches, according to the California Department of Boating and Waterways.[185] In addition, the Army Corps spent $48.5 million on re-nourishment projects in California between the years of 1990 to 2011, for a total volume of approximately 7.9 million cy (2011 dollars).[186] The cost of material for nourishment can vary greatly depending on its origin and associated transportation costs.[187] One study estimates a need for 248 million cy (190 million meters cubed) of sand over 100 years for Southern California.[188] Other studies estimate the average cost of nourishment is $19-$48 million/yr for the low range sea level rise scenario of 0.5m (1.6 ft) by the year 2100.[189] An offshore cost estimate of $13/cy was used in this study, which is approximately $14/cy ($10.7/m3) in 2015 values. If this number is applied to the required future sand volumes, the adaptation cost of future beach nourishment, assuming different beach shapes and sea level rise scenarios, can be estimated (**Table 7.2**). South Bay cities can use this method to estimate the cost of beach nourishment for their respective coastline by using the beach slope and berm height.

Table 7.2: Adaptation Cost of Future Beach Nourishment by Beach Slope and Berm Height

Beach Slope	*Berm Height*	*0.2 m SLR Mln $/100yr*	*0.5 m SLR Mln $/100 yr*	*1 m SLR Mln $/100 yr*	*2 m SLR Mln $/100 yr*	*3 m SLR Mln $/100 yr*
1:20 (2.86°)	8	13	32	64	127	191
1:20 (2.86°)	12	19	48	96	191	287
1:50 (1.15°)	8	32	80	159	319	478
1:50 (1.15°)	12	48	119	239	478	717
1:75 (0.74°)	8	48	119	239	478	717
1:75 (0.74°)	12	72	179	358	717	1075
1:100 (0.57°)	8	80	199	398	637	956
1:100 (0.57°)	12	96	239	478	956	1434

Source: Pathways to resilience: adapting to sea level rise in Los Angeles (2018)

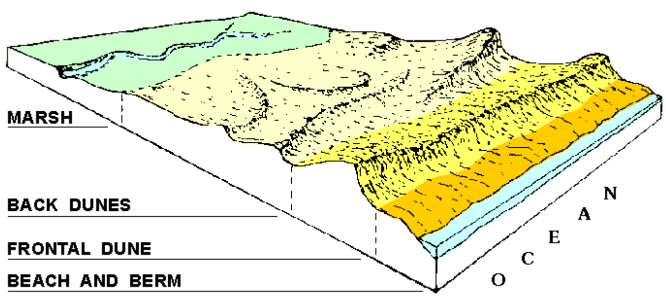
Other Adaptive Strategies

Green Infrastructure

> *Sand dune systems are sand and gravel deposits within a marine beach system, including, but not limited to beach berms, frontal dunes, dune ridges, back dunes, and other sand and gravel areas.*

Apart from beach nourishment, additional green infrastructure and nature-based adaptation measures are important to consider as flood protection measures, where appropriate. There are, for example, opportunities for the construction and maintenance of more landward dune systems. Although larger volumes of sand are required, dunes provide a natural buffer against storms and can "naturally" re-nourish beaches impacted by high storm surge.

Dunes are most practical when sufficiently wide; at least 45−60m (150−200 ft) of beach width is required to develop dunes.[190] As with sand berms, artificial dune construction involves the placement of sediment deposits, which are then reshaped into dunes using bulldozers. The volume of sand for dune restoration is expected to cost the same as beach nourishment ($14/cy, 2015 values). Additional costs are dependent on the type of vegetation used and the maintenance of the area. To make sure the sand of the newly formed dunes remains stable at its position, fences can be used on the seaward side to trap sand and help stabilize any bare sand surfaces.[191] [192]



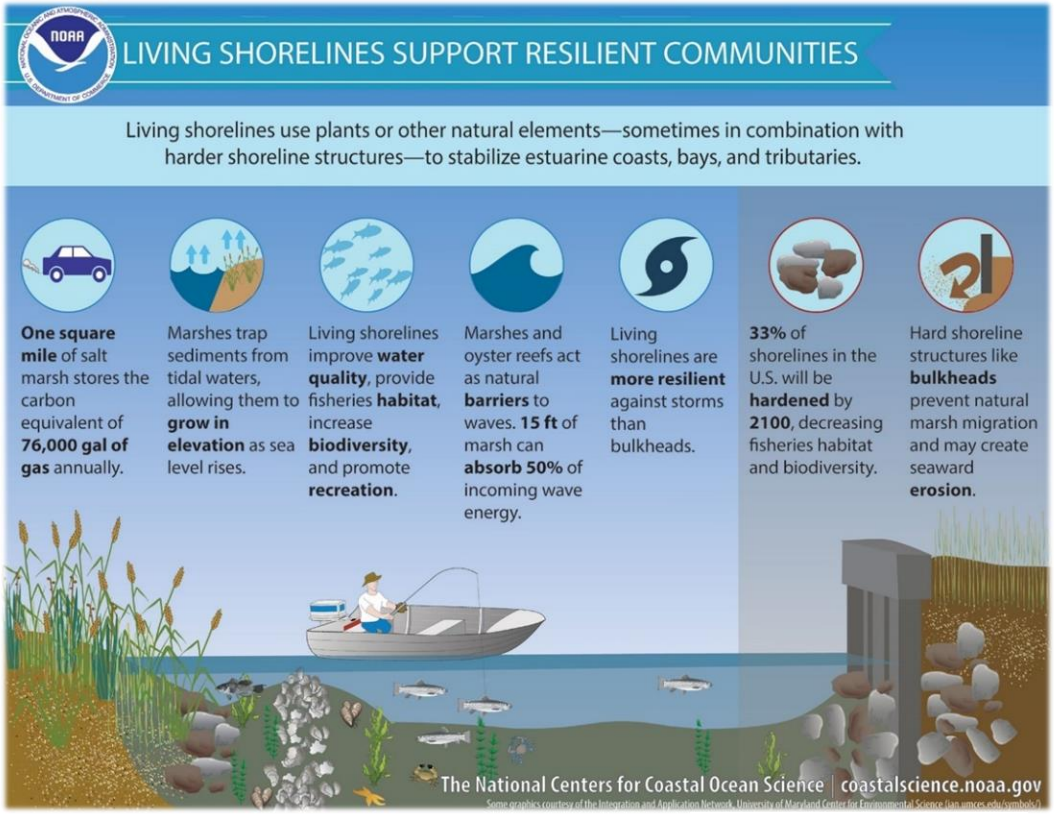
Source: main.gov


Source: coastalcare.org

Vegetation (pictured left) may be planted to stabilize natural or artificial dunes and promote the accumulation of sand from wind-blown sources.[193] In addition, dunes can provide habitat for plants, birds, and other terrestrial and beach organisms. Experimental dunes have been shown to attract endangered Least Terns (pictured


Source: audobon.org

right), once a common resident of Southern California beaches. New nests have been observed within the first year of new dune projects. Pilot studies in Los Angeles have tested the viability of dune rehabilitation on urban coastlines.[194] While dune fields may cause disturbances to nearby communities from windblown sand or hinder ocean views, adequate vegetation cover should reduce some of these effects.



Source: habitatbluepring.noaa.gov

Other approaches, such as living shorelines, have shown promise for their ability to reduce impacts and rebound following significant coastal storms [195] while promoting long-term stability.[196] For example, at San Buenaventura State Beach in Ventura County, beach grooming (removing debris and seaweed) was halted to determine whether natural dunes and vegetation would return. After four years, all four natural vegetation species returned, and after 13 years, dune hammocks measured 2−3 feet tall and demonstrated an ability to store sand, build topography, and self-repair following extreme wave erosion. [197] [198]

Hard Infrastructure

Apart from nature-based protection, there are different types of 'hard' engineered protection measures. These are often applied in high-density urban areas, since they are relatively expensive. For example, seawalls are designed to resist the forces of large coastal storm surges. They have different designs and often reinforce existing bluffs with concrete against erosion and flooding impact. Dikes and levees are embankments that protect low-lying land, and these structures are made from various materials such as concrete, clay, and boulders; with a top layer of resistant vegetation or armoring material such as asphalt.

Over ten percent of California's coast is armored, with approximately 136 miles of seawalls and levees. [199] [200] The total capital cost for these measures for all of California is estimated between $7 and $14 billion. [201] [202] A study commissioned by the State of California estimated the cost of upgrading existing levees and other defenses to meet future conditions for the whole of California (including the San Francisco Bay Delta) at more than $34 billion.[203]

Climate change and sea level rise can result in reduced stability and increased overtopping of existing protective structures. Whether these existing structures can be modified to accommodate sea level rise depends, for example, on the suitability of the foundation material to support the additional weight of the structure, and whether space is available for widening the base of the structure. [204] Further discussion of both nature-based and hard engineering adaptive measures can be found in the full technical report *Pathways to resilience: adapting to sea level rise in Los Angeles*.

Synopsis

Beach nourishment has been a widely used strategy for combating coastal erosion and sea level rise along the coast of California. The purpose of beach nourishment is to restore and maintain the width of an eroding beach on a temporary basis providing two primary benefits: increasing and maintaining an area for recreation and preserving the protective values of the coastline against storm surges.[205] Other benefits from beach nourishment include increased tourism revenues, increased public access to beaches, reduced need for hard protective structures, higher property values, and enhanced public safety. Although the placement of sediment on a beach may provide more space for potential wildlife habitat, the placement of the sand as well as the equipment used to place the sand can negatively affect biota in the region. Additionally, environmental impacts may also arise from the removal of sediment from its original location (i.e. offshore). Due to high to very high erosion rates in California, beach nourishment in Southern California has been often coupled with structures that hold sand in place (e.g., groins and jetties). LA County is in the process of implementing its Coastal Regional Sediment Management Plan, which describes several options for maintaining beaches, and addresses the importance of a long-term vision for the impacts of sea level rise. South Bay Cities should engage in the implementation process to ensure their beaches are receiving proportional and adequate nourishment relative to their risk.

Sector 5: Transportation

Overview

Climate change will challenge the ability of transportation agencies to maintain a state of good repair of transportation assets. These agencies are trying to think proactively by planning for climate impacts and designing systems to be more resilient. In this section, the SBCCOG synthesizes reports developed by the Los Angeles Metropolitan Transportation Authority (Metro) and the California Department of Transportation (Caltrans) to assess and mitigate the risk of climate change on public transit and highway transportation in the South Bay. The SBCCOG also considers the impact of climate change on active transportation. Arterials are managed at the local government level and are addressed in the city specific vulnerability assessments.

Active transportation is any self-propelled, human-powered mode of transportation, such as walking or bicycling.

I. Public Transit: Los Angeles Metropolitan Transportation Authority

Climate change will have impacts on public transportation. Subway tunnels, busways, tracks, and maintenance facilities are vulnerable to increase in flooding from more intense rainstorms, sea level rise, and storm surge. Extreme heat can cause deformities in rail tracks, at minimum resulting in speed restrictions and, at worse, causing derailments. Public transportation can also be used to provide evacuation services during extreme weather emergencies that are projected to become more common with climate change. Transit dependent populations are particularly vulnerable. Adapting transit assets to climate change impacts is critical to maintaining a state of good repair, protecting the safety of travelers, and ensuring mobility.

Across the region, service disruptions have already occurred during periods of extreme heat and heavy precipitation; these incidences are likely to increase in the future if Metro does not implement their climate adaptation plans. Identifying portions of the transit system that are already vulnerable, or that may become vulnerable, will help guide planning, and prevent disruptions in the future. Critical assets and services to be considered in climate adaptation planning include any infrastructure, equipment, and property currently owned and operated by Metro, including bus operations, light and heavy rail, and equipment yards. The agency also has several large infrastructure projects in progress which are anticipated to remain a cornerstone to their service for decades to come. Throughout the building process, Metro must continue to consider future climate impacts if they are to ensure optimal performance and safety in new and existing development.

In preparing for these climate impacts, Metro has developed the following planning documents aimed at assessing and mitigating identified risk to their assets and riders.

- **2012 Climate Action and Adaptation Plan (CAAP)**

The purpose of this document was to 1. Create a framework to evaluate and prioritize areas of opportunity for Metro to reduce GHG emissions from operations, and 2. Present an approach for responding to the likely impacts of climate change on Metro's system

- **2013 Metro Climate Change Adaptation Pilot Project Report**

This project capitalized on the agency's existing CAAP, Environmental Management System (EMS) and asset management system to integrate climate adaptation principles into ongoing conversations and implement best management practices in the areas of maintenance, preparation, scheduling, environmental compliance, and employee health and safety.[206]

- **2015: Resiliency Indicator Framework**

The purpose of this document[207] was to introduce a set of resiliency indicators developed for Metro's transit programs to help address climate change. The Framework was intended to help prioritize and evaluate climate adaptation implementation priorities to ensure infrastructure resilience and maintain a good state of repair. The indicators provided a mechanism to measure and prioritize actions to ensure assets and the organization are resilient in the face of climate change, and the resulting evolving frequency of extreme weather events. These indicators provided a method to assess the progress of Metro's climate management efforts over time and gauge the effectiveness of specific strategies.

- **2019: CAAP Update (update on CAAP)**

In July 2019 Metro released the Draft Final 2019 CAAP. This document[208] provides an update on what Metro has accomplished and how approaches to climate action have changed since its 2012 CAAP. The greenhouse gas emissions inventory builds on the methodology used in 2012 to allow direct comparison and expands on the mitigation and adaptation analysis. The Plan considers several new mitigation measures based on industry best practices and robust modeling, as well as stakeholder engagement. It evaluates risk from four additional climate hazards and emphasizes flexible adaptation pathways for evaluating and selecting appropriate adaptation strategies and actions.

'Pathways' in relation to adaptation is an approach designed to schedule adaptation decision-making: it identifies the decisions that need to be taken now and those that may be taken in the future. The pathway approach allows decision makers to plan for, prioritize and stagger investment in adaptation options. Trigger points and thresholds help identify when to revisit decisions or actions.

Climate Risks to Metro Assets

Given the mild climate of Southern California, regional transit agencies do not need to worry about extreme winter snowstorms and cold, as many others across the nation do. Agencies do, however, need to consider other types of extreme weather events throughout the year. Between the 2012 and 2019 CAAP, Metro assessed exposure of their assets to the following climate hazards: extreme heat and heavy precipitation (**Table 5.1**), sea-level rise, wind, and wildfire.

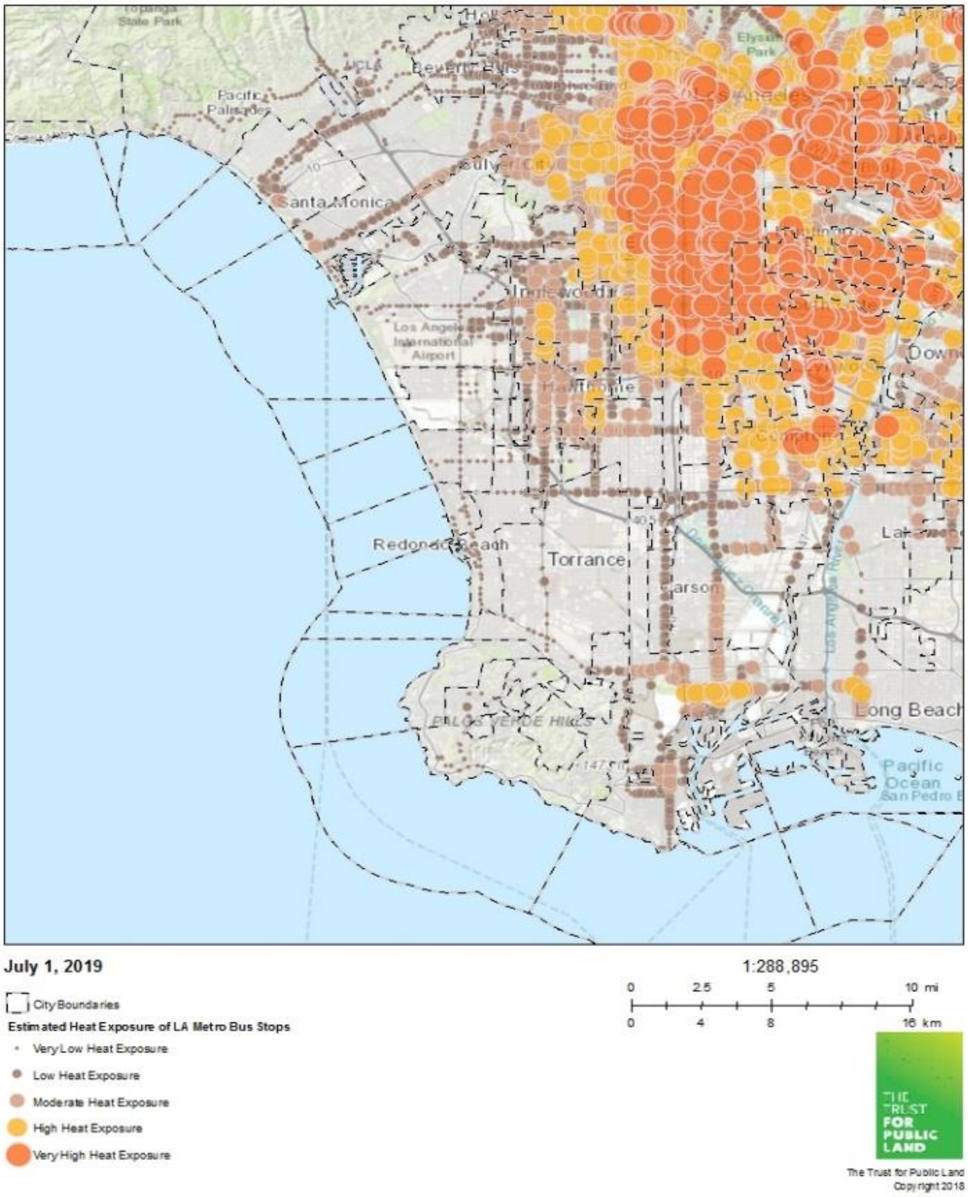
Table 5.1 Vulnerability Matrix of Critical Assets

Exposure	Critical Asset	Sensitivities	Adaptive Capacity	Vulnerable?
Extreme Heat	Bus Fleet	Equipment failure and higher frequency of breakdown	Moderate: Bus fleet is relatively large	Yes
	Light Rail (Green Line)	Rail buckling and higher risk of equipment (e.g., electrical systems, air conditioning failure)	Moderate: Operations can be modified (speed reductions), but damage to rails can still occur	Yes

	Bus Rapid Transit (BRT) right of way (Silver line)	Pavement degradation can be accelerated	Moderate: Pavement likely to be replaced relatively frequently	Possible: depending on the expected frequency of pavement replacement
	Measure R construction work	Construction speed and worker health can be compromised by extreme heat	Moderate: Construction schedules can be modified; exposure could be lowered depending on mode choices and locations	Yes
	Measure R planned assets	Above Measure R construction work sensitivities and adaptive capacity apply, depending on mode choices and locations		Possible
Extreme Precipitation	Bus Fleet	Bus services may be limited when streets flood, but buses are likely to avoid being damaged.	High: buses can be moved and re-routed to avoid flood areas	Possible: buses are unlikely to be vulnerable, but the service through flooded locations is vulnerable
	Bus Rapid Transit (BRT) right-of-way (Silver Line)	At-grade locations could experience flooding, but existing BRTs not in floodplains	Low: Right-of-ways are stationary	Possible
	Light Rail (Green Line)	Similar to BRTs, at-grade locations could experience flooding; elevated rail has lower sensitivity	Moderate: Rail is stationary	Yes
	Measure R planned assets	Above Measure R construction work sensitivities and adaptive capacity apply, depending on mode choices and locations		Possible

Source: Metro 2019 CAAP

Many bus stops in the South Bay will face increasing heat exposure, threatening ridership safety at certain locations. Without shade, riders walking to stations or waiting at bus stops could experience heat-related health impacts. **Figure 5.1** identifies bus stops projected to be exposed to extreme heat.



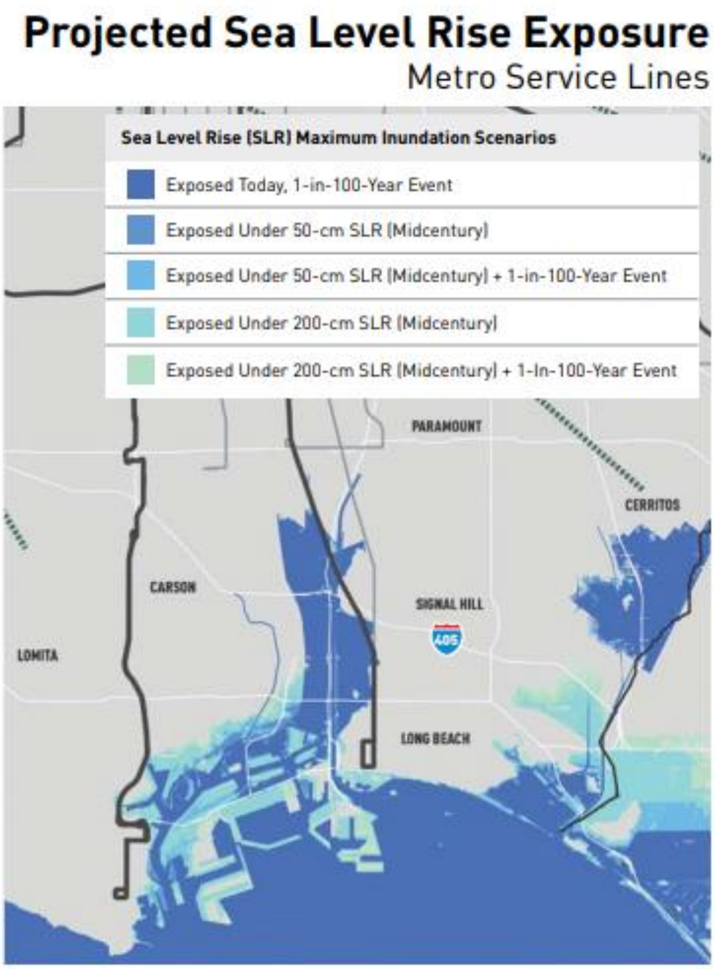
Source: Trust for Public Land, Climate Smart Cities

SOUTH BAY HIGHLIGHT

Bus stations with high heat exposure within the South Bay include:

- Hawthorne Blvd. between Lennox and Manchester Blvd.
- Crenshaw Blvd. between Imperial and Rosecrans
- Anaheim St. between Figueroa and Sanford Ave.

While sea level rise and coastal flooding could have severe long-term impacts on coastal assets, most of Metro's assets are inland, and therefore not at risk to these hazards. Assets most at risk include rail infrastructure, bus routes, and buildings. The Expo Line may become vulnerable in the future as it expands westward. One Blue Line station (located in Long Beach just adjacent to the South Bay) that serves the South Bay is expected to become vulnerable to expected sea-level rise.



Source: Metro 2019

Strong winds and wildfires also pose risks to Metro services. Santa Ana winds have indirectly threatened service via external power outages while wildfires threaten northern and eastern parts of the rail system, but these areas are not within the South Bay service territory.

In the 2019 CAAP, Metro also considered the potential exposure of its assets to electrical outages, which could occur from several hazards. Asset types including light rail, subway, bike share stops, metro bike hubs, bus divisions, rail divisions, terminals, radio repeater stations, and rail stations depend on electricity to operate, and are therefore are potentially exposed to electrical outages. As a result of their planning efforts and the identified expected impacts of climate change and extreme weather, Metro developed several strategies to mitigate its risk. In its 2019 plan, Metro is pursuing an approach called flexible adaptation pathways to address existing extreme weather impacts to the system. By relying on flexible adaptation pathways, Metro is working toward climate resilience by adopting clear objectives and gradually implementing adaptation actions to achieve such objectives as new information emerges.

To date, Metro has made progress on the implementation of its 2012 Adaptation Plan by:

a. Piloting of a new overhead catenary system to ensure high heat days do not cause slow-down of light rail trains via wire sagging.
b. Installing 10,000 square feet of permeable pavement in Downey as part of its permeable pavement pilot aimed at capturing stormwater.
c. Integrating weather information like temperature data into existing datasets to improve asset management.
d. Conducting air conditioning inspections and preventative maintenance as part of Bus Maintenance.
e. Updating the Resilience Indicator Framework to reflect lessons learned.
f. Leveraging existing communication channels to ensure staff responds efficiently to climate impacts in construction and operations.
g. Establishing resilience as a goal with Agency-wide strategies for implementation.

II. Highway Assessment: California Department of Transportation

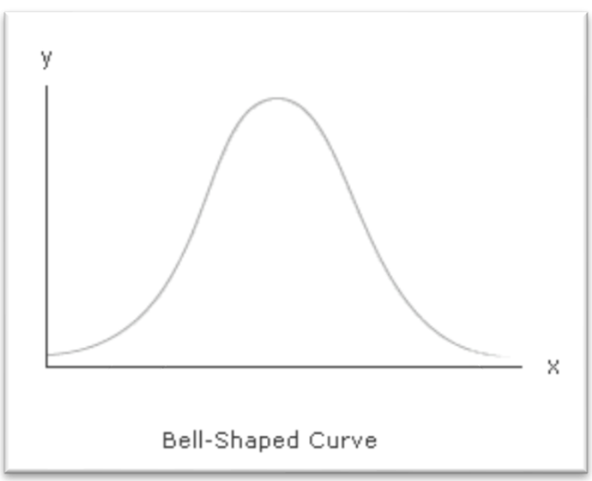
In 2013, Caltrans released "Caltrans Activities to Address Climate Change - Reducing Greenhouse Gas Emissions and Adapting to Impacts" – a report that highlights Caltrans' statewide climate change efforts. Caltrans recently completed a vulnerability assessment of District 7 (which encompasses the SBCCOG service territory). This assessment identifies sections of the highway system at highest risk to extreme weather events related to climate change. Using the results of their Climate Change Vulnerability Assessments, Caltrans will prioritize sections of the highway system for adaptation planning and strengthening. In addition, Caltrans engineers have already begun incorporating more resilient designs for long-life projects in anticipation of increased future climate stressors. These actions will help Caltrans to reduce maintenance costs and will keep the State Highway System functioning effectively and efficiently.

III. Active Transportation

In an effort to improve sustainability and reduce greenhouse gas emissions (climate mitigation), Federal, State, and Local Governments have been promoting cycling and other modes of active transportation (bicycling, walking, etc.). Evidence for this support can be found in regular investments in off-road paths and bicycle lanes. While many plans, including Metro's 2016 Active Transportation Strategic Plan, focus on the positive impact of active transportation on climate mitigation, little to no attention has been paid to how this strategy fairs in the context of climate adaptation.

Bicycle riders are directly exposed to changing weather and climate. In one study, researchers examine the results from an aggregate bicycle demand model and found that changes in weather parameters can explain nearly half of the variations in the number of bicyclist or "bicyclist volume".[209] The results reveal that around half of the variations in bicyclist volume can be explained by changes in weather. The following weather variables were found to be statistically significant for their area of study:

- Light and heavy rain
- Strong wind
- Hours of sunshine
- Temperature



The researchers found that heavy rain and strong wind produce the most noticeable reductions in ridership. Temperature affects ridership in a nonlinear way: increasing temperatures increase volume of ridership up to an optimal temperature before declining again, illustrated by a bell curve.

In addition to affecting ridership, extreme heat poses health risk to cyclists and walkers. Exercising in hot weather puts extra stress on the body. Under normal conditions, blood vessels and perspiration levels adjust to heat. These natural cooling systems may fail if exposed to high temperatures and humidity for too long, resulting in heat-related illnesses that could include heat cramps, lightheadedness or fainting, nausea and vomiting, or even a heatstroke (core temperature reaches 104 F).[210] [211] Given that governments are seeking to increase the role that cycling and walking play in reducing congestion and greenhouse gas emissions, there is a need for further study on the influence that weather, and changes in climate, have on active transportation demand and the health of active transporters. The SBCCOG acknowledges (and discusses further on p. 157) the role of neighborhood electric vehicles including e-scooters and e-bikes to mitigate greenhouse gas emissions *and* increase ridership of these modes in an increasingly hotter climate.

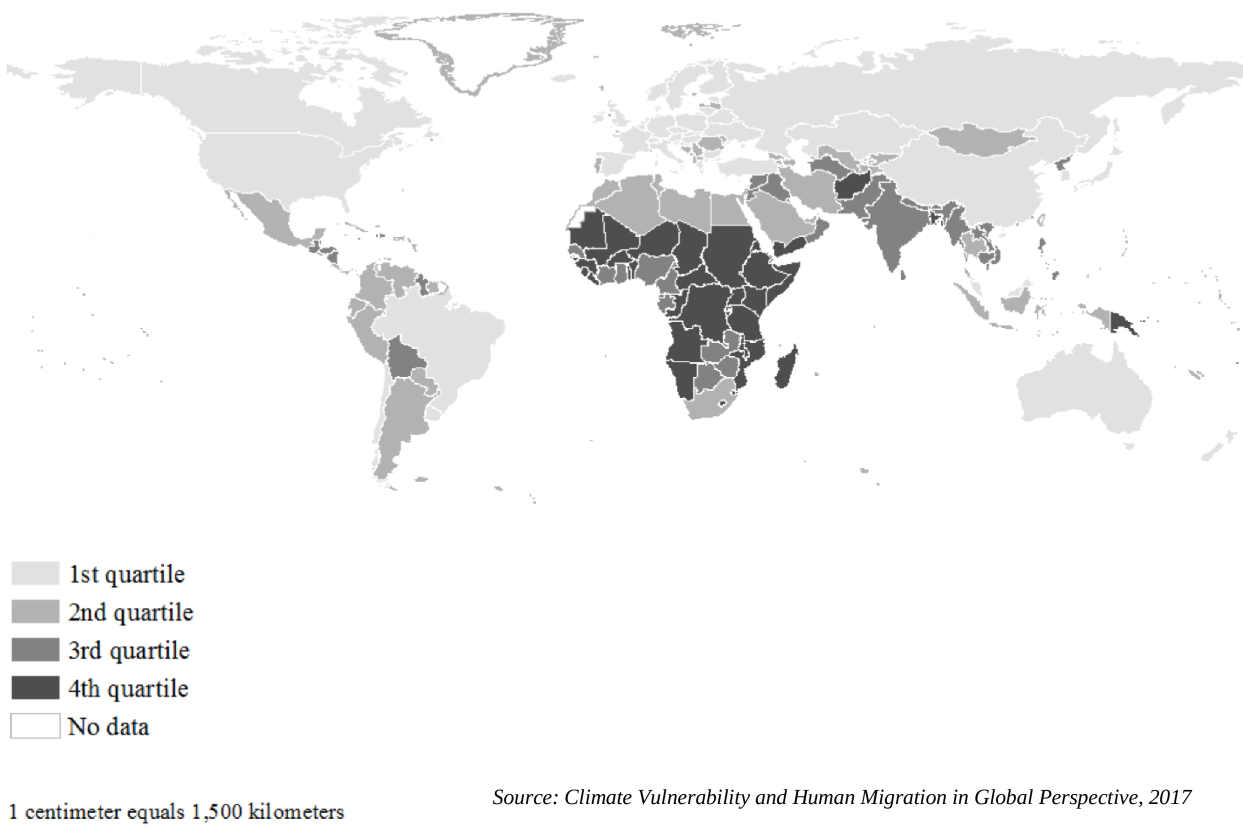
Sector 6: Climate Migration

Migration is a form of adaptation that individuals and households make when they are exposed to the stress of changing environmental conditions. Families displaced by climate disasters often migrate to cities, with their concentrated resources and economic activity. When migration occurs without a plan in place, mass migration has the potential to aggravate a city's existing stresses. From a climate change adaptation perspective; however, migration is a positive outcome because it helps to decrease the vulnerability of populations to climate change. Currently, there is no standard framework for assessing the direction or extent of climate migration; however, it is understood that people generally move from areas of higher to lower risk. Through this lens, the SBCCOG assesses the potential for migration into the sub-region from the global, national and regional level.

Global migration

It is important to understand the effect of climate change on global migration to determine the potential for increased immigration into the United States. In 2015 alone, extreme weather events displaced 19.2 million people in 113 countries.[212] The worsening of climate change ensures this pattern will continue, and very likely grow more significant. While the expected increase in global migration is widely accepted, the direction, timing, and magnitude of population flows make it difficult for local authorities to make accurate predictions, develop long-term plans, and allocate resources accordingly.

Utilizing the Notre Dame Global Adaptation Initiative's (ND-GAIN) Country Index, an established index of climate vulnerability for 179 countries, researchers found that people, on average, move from countries of higher vulnerability to less vulnerable ones.[213] Utilizing the index scores, countries were grouped into quartiles, with the 1st quartile representing countries least vulnerable to climate change (North America, Europe, and Eastern Asia), and the 4th quartile representing countries most vulnerable (Sub-Saharan Africa, South America, Southeastern Asia, and Melanesia).



Source: Climate Vulnerability and Human Migration in Global Perspective, 2017

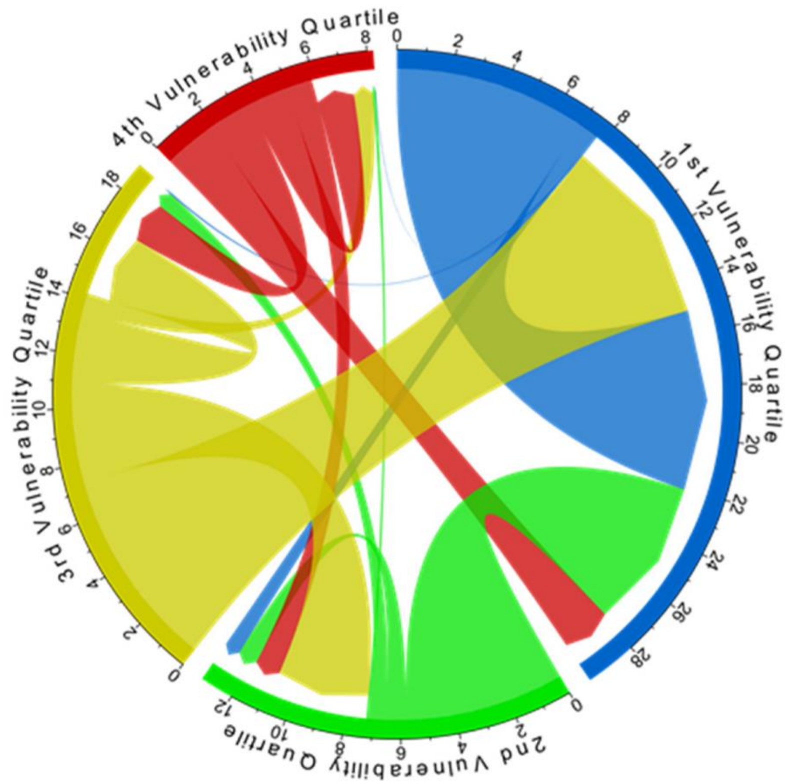
Focusing on bilateral migration flows, researchers found there was a clear vulnerability gradient. Of the estimated 14.2 million persons who migrated from countries in the third climate quartile between 2010 and 2015, 18% migrated to another

A gradient is an increase or decrease in the magnitude of a variable observed in passing from one point to another.

country in the same quartile, 25% migrated to a country in the second quartile, and 52% migrated to a country in the first quartile—resulting in a global risk reduction of 15%, but also a significant inflow of persons into the United States. The most climate vulnerable countries (fourth quartile); however, are not characterized by pronounced migration—since for many of their residents, migration may not a viable option ("trapped populations") due to financial and/or physical constraints.

National Migration

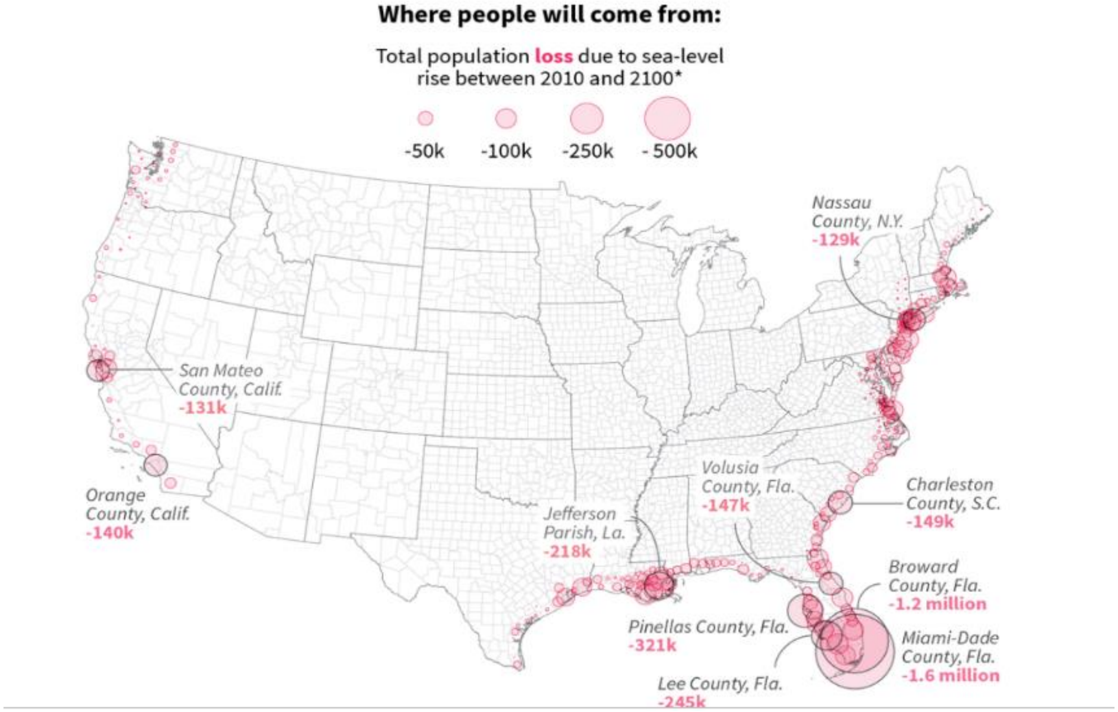
Despite the difficulty in modeling human behavior in extreme and historically unprecedented circumstances, demographers and geographers do expect nearly every city in the U.S to be profoundly impacted by migration. In the aftermath of Hurricane Katrina in 2005, researchers found that families displaced by the hurricane moved to major cities like Houston, Baton Rouge, Dallas, and Atlanta. More recently, more than 135,000 Puerto Ricans have relocated to the US mainland since Hurricane Maria hit in September 2017.



Source: Climate Vulnerability and Human Migration in Global Perspective, 2017

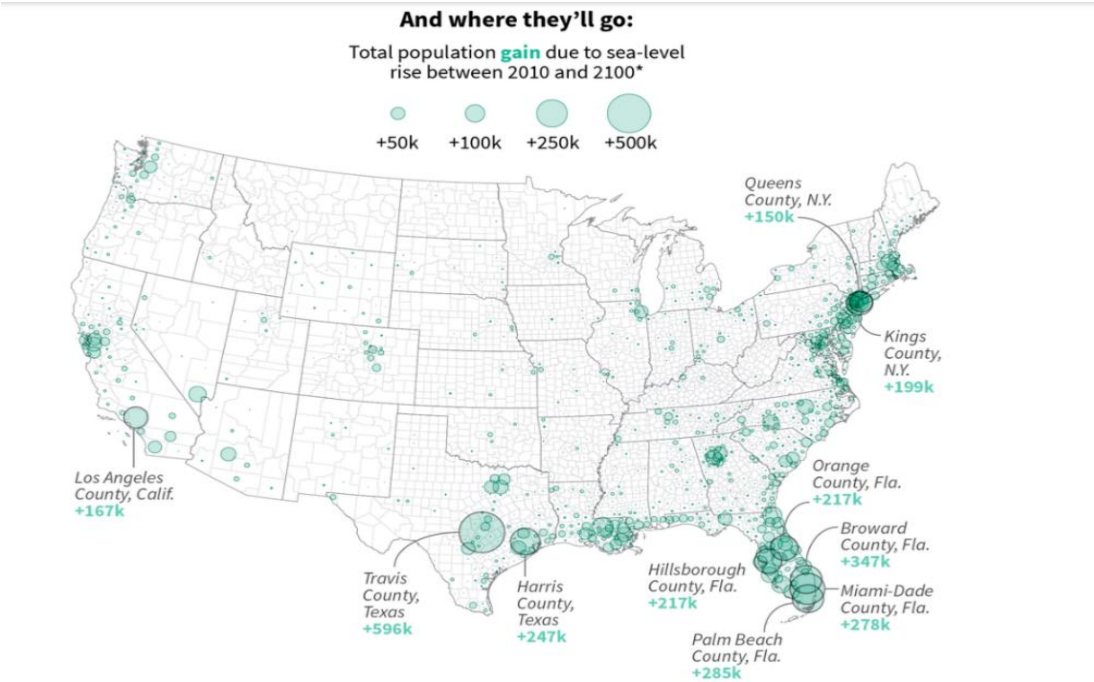
According to a popular national sea level rise migration study, 86% of areas with an urban center of 10,000+ people are projected to be affected in some way by net migration from sea level rise that could displace 13 million people nationally by the end of this century.[214] The study forecasted that LA County may see population increases upwards of 167,000. The study acknowledges, however, that the effects of climate change on migration are largely uncertain because it is driven by complex multi-causal processes, which also include social, economic, political, and demographic dimensions. Furthermore, whether, where, and when people choose to relocate is also dependent on a community's ability and willingness to adapt to climate change early on. The results of the study are summarized below in **Figures 7.1 and 7.2.**

Figure 7.1: Out-Migration due to Sea Level Rise



Source: ME Hauer, 2017

Figure 7.2: In-Migration due to Sea Level Rise



Source: ME Hauer, 2017

Regional Migration

In addition to international and national-level migration, inter-state and inter-county migration can also be expected. Under the assumption that people migrate from higher to lower risk areas, the SBCCOG compared place-based vulnerability of the South Bay to other areas of LA County to assess the potential for a population influx into the region.

The South Bay sub-region is comparably less vulnerable than many parts of LA County. Its proximity to the coast will keep it relatively cooler than inland areas of LA that are projected to experience more intense extreme heat events. Downtown Los Angeles could see an average of 45 days of extreme heat—days in which the high temperature exceeds 95 degrees—by the end of the century under a *business as usual* (RCP 8.5) scenario. The San Gabriel Valley could see up to 74 extreme heat days per year.[215] Thus, the South Bay may experience population pressure from inland Los Angeles as residents move toward the coast to escape rising temperatures.

Compared to other coastal cities, South Bay beach cities are also relatively less vulnerable to sea level rise impacts. The City of Long Beach, for example, is projected to have over 15,000 residents living in a hazard zone when sea levels rise 150 cm. (about 60 inches). In comparison, only 854 residents in the South Bay are expected to live in a flood or inundation zone when faced with the same sea level rise extent. **Figure 7.4** summarizes the number of residents per city in LA County that may be impacted by 150 cm of sea level rise (SLR).

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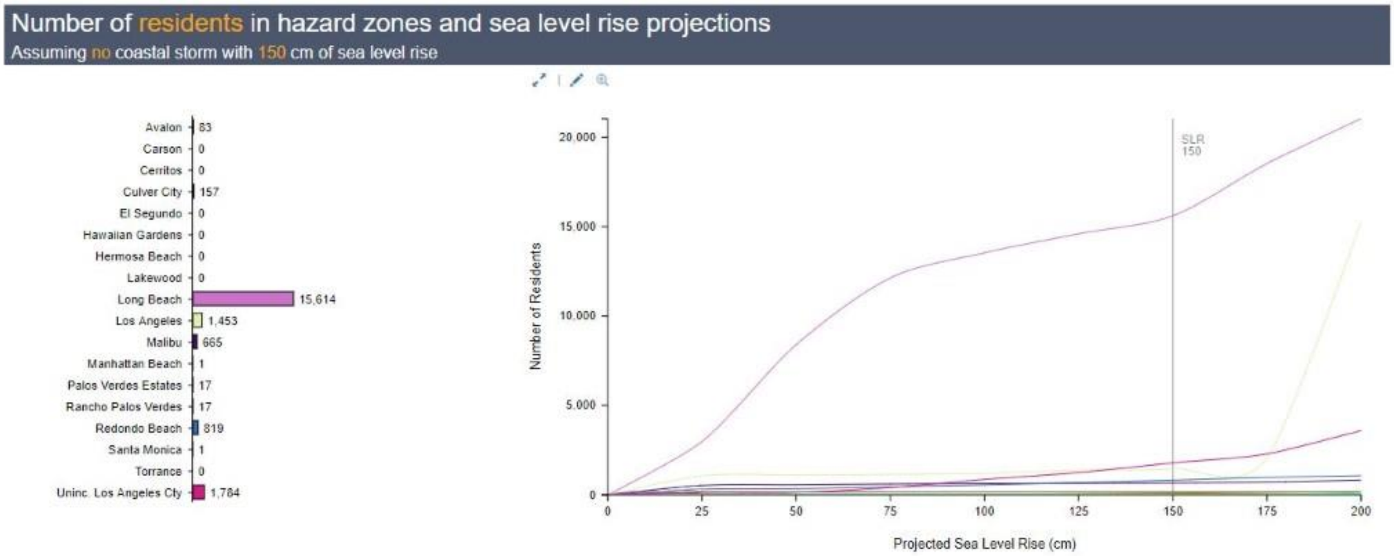
Figure 7.4: Number of Residents per City in LA County that live in SLR hazard zone



Source: HERA, 2017

Synopsis

In addition to the direct climate stressors the South Bay will experience due to global warming, it is important to understand, assess, and plan for the potential for large influxes into the region — which may exacerbate stress on already limited resources (housing, education, infrastructure, roadways, etc.) — based on comparatively lower levels of climate risk globally, nationally and regionally.

Part 2: Adaptation and Resiliency Strategies

The next decade will bring more frequent extreme heat days and wildfires, rising seas, less potable water, and more extreme weather and flooding. By conducting a robust vulnerability assessment (Part 1), the SBCCOG identified how important structures, populations, and sectors in the subregion would be affected by climate change. Priority sectors identified in the vulnerability assessment that adaptation strategies should target include:

1. Planning, Education, and Outreach
2. Water Management
3. Energy Management
4. Coastal Management
5. Transportation
6. Biodiversity
7. Migration

All strategies discussed in this section could be implemented by the SBCCOG within a short-term (1-2 years), mid-term (3-5 years), long-term (5+ years), or on-going timeframe. However, strategies cannot be implemented unless funding resources are identified. Each strategy lists a potential funding source. Additionally, economic, social and environmental benefits that can be realized with the implementation of these measures are listed as co-benefits. These include six areas where gains may be accrued beyond reducing climate risk:

1. Climate Action Plan (CAP) strategy support
2. Community Engagement
3. Economy
4. Public Health
5. Resource Conservation
6. Safe Streets

There are many strategies in the sub-regional Climate Action Plan, and through state programs, that increase resilience in the subregion. The strategies in this document; therefore, are designed to remain consistent with these existing strategies without duplicating them. Furthermore, many adaptation strategies, including those being considered or implemented by specific jurisdictions or other agencies are not listed in this document.

Strategies for Planning, Education, and Outreach

The sub-regional vulnerability assessment aims to educate South Bay elected officials, city staff, and the general public on climate impacts the region will face, and efforts underway currently by different agencies to mitigate the impacts of climate change within their respective sectors. To ensure this body of work can be continued by individual cities and communicated to the public, it is imperative that the SBCCOG work with the member cities to adopt strategies aimed at integrating adaptation planning into city planning and communicating the findings of the vulnerability assessment to the public.

Strategy 1.1: Educate and engage elected officials and city staff on the climate risks in the South Bay

Timeframe: on-going

Potential Funding: fellow/intern programs[jj]

Description: The sub-regional vulnerability assessment is over 150 pages and includes some highly technical information. To ensure the key climate risks are communicated effectively to elected officials and city staff, who ultimately have the power to make adaptation a priority and ensure our communities are protected in the face of climate change, the SBCCOG will present findings of the sub-regional vulnerability assessment to the SBCCOG board and to city staff and commissioners.

Strategy 1.2: Educate and engage South Bay residents and the general public on the climate risks in the South Bay

Timeframe: on-going

Potential Funding: fellow/intern

Co-benefit: community engagement

Description: The sub-regional vulnerability assessment is over 150 pages and includes some highly technical information. To ensure the key climate risks are communicated effectively to South Bay residents and the general public, who may need to take individual action to protect

[jj] This funding source encompasses match contributions to fellowship programs such as CivicSpark or Climate Corps, as well as SBCCOG interns and volunteers.

themselves and their property, the SBCCOG will create a story map to present the findings of the sub-regional vulnerability assessment in an easily accessible and interactive format.

Strategy 1.3: Ensure information provided in the sub-regional vulnerability assessment is accessible to diverse audiences.

Timeframe: short-term

Potential Funding: fellow/intern programs

Co-benefit: community engagement

Description: Approximately 30% of South Bay residents speak Spanish at home as their primary language.[216] To ensure all residents have access to the information presented in the sub-regional vulnerability assessment, the South Bay will translate a summary sheet of the report into Spanish which will be made available on the SBCCOG website.

Strategy 1.4: Present climate risks identified in sub-regional assessment to service providers of at-risk populations.

Timeframe: short-term

Potential Funding: SBCCOG general funds

Co-benefit: public health

Description: The SBCCOG Senior Services Working Group and Homeless Services Task Force represent a collaborative effort of bringing together the various service providers to address issues that impact these two at-risk populations. Elderly persons and those experiencing homelessness are more likely to experience negative health outcomes as a result of extreme heat, flooding, wildfire and other climate hazards. The SBCCOG will host a speaker and distribute materials to each working group to educate service providers of the climate risks and steps they can take (as well as ongoing efforts throughout the region) to better serve and protect these climate-sensitive groups.

Strategy 1.5: Provide education and outreach to businesses on climate impacts that may affect their operations

Timeframe: mid-term

Potential Funding: Green Business Program

Co-Benefit: economy

Description: Small businesses are essential to the South Bay's local economy and community vitality. Small to medium businesses need to understand how climate change might impact their business operations and how they can better prepare or adapt. The SBCCOG will provide information and resources to help South Bay businesses prepare for future impacts of climate change by engaging with the SBCCOG business network and chambers to build knowledge of risk, and planning efforts.

Strategy 1.6: Support South Bay cities in integrating information provided in city-specific vulnerability assessments into relevant local planning documents.

Timeframe: short-term

Potential Funding: fellow/intern program; SoCal Gas Adaptation & Resiliency Planning Grant

Description: City specific assessments include information from the Cal-adapt tool on climate projections, as well as a structural and social vulnerability analysis that helps determine facilities, buildings, and populations most at risk from climate change. These assessments can be used to identify areas within the city that deserve further examination of risk or should be prioritized when developing adaptation strategies. Activities may include the SBCCOG presenting city assessments at city councils or commissions to help incorporate information into relevant planning documents such as the local hazard mitigation plan, safety element of general plan, or as a stand-alone document.

Strategy 1.7: Support South Bay cities through the adaptation strategy development process

Timeframe: short-term

Potential Funding: fellow/intern programs

Description: The city-specific assessments developed in 2019 only satisfy half of the requirements of SB 379. In addition to updating the safety element of their general plan to include the risks that climate change poses and the geographic areas at risk, SB 379 also requires each city to adopt a set of adaptation and resilience goals, policies, and objectives based on the information provided in the vulnerability assessments as well as a set of feasible implementation measures. The SBCCOG will research strategies, programs, and policies and present them to individual cities for selection. The SBCCOG will help cities add an adaptation strategy chapter to their city vulnerability assessments, ultimately providing cities with a complete adaptation plan in compliance with SB 379.

Strategy 1.8: Track and publicize grant opportunities that would allow cities to further assess risk of specific areas or begin implementing adaptation/resiliency strategies

Timeframe: on-going

Potential Funding: not yet identified

Description: The SBCCOG recognizes that the city specific vulnerability assessments do not provide a highly technical analysis of some climate risks that may be required, especially in evaluating sea level rise impacts on coastal communities. Rather, city assessments were meant to provide a preliminary evaluation that identified areas that deserve further attention, either through further assessment or through adaptation action. Therefore, the SBCCOG is committed to providing cities with information on grant opportunities relevant to advancing adaptation planning or implementation in the sub-region.

Strategy 1.9: Integrate results of 2020 census into adaptation plans

Timeframe: mid-term

Potential Funding: fellow/intern programs

Description: The social vulnerability analysis provided in both the sub-regional vulnerability assessment as well as the city-specific assessments rely on 2017 5-year estimates of American Community Survey data, with the original data collected in 2010. The social vulnerability analysis maps areas have the highest percent of at-risk, or sensitive populations to climate impacts within the sub-region/cities, which inform what areas should be prioritized in adaptation funding and implementation. Therefore, upon the results of the 2020 census data release, it is important that these maps be updated to reflect the best available data. The SBCCOG will update the social vulnerability maps in the sub-regional vulnerability assessment, and, upon request by cities, update city maps with the 2020 census data.

Strategy 1.10: Update adaptation plan every 5 years

Timeframe: long-term

Potential Funding: not yet identified

Description: Adaptation planning occurs in a setting that is continually changing. Climate science is uncertain and evolving with new reports and updates being released regularly. Local conditions also evolve over time. Therefore, the climate adaptation plan should be updated, at least, every 5 years as conditions and projections change.

Water Management

Climate change is already impacting water and other resources in California and will continue to do so as California's population and demand for water increases. Increases in temperature are already causing decreases in snowpack. The mountain snowpack provides as much as a third of California's water supply by accumulating snow during our wet winters and releasing it slowly during our dry springs and summers. Warmer temperatures will melt the snow faster and earlier, making it more difficult to store and use throughout the dry season. By the end of this century, California's Sierra Nevada snowpack is projected to experience a 48-65% loss from the historical April 1 average. This significant decrease in snowpack has a direct impact on water supply for Californians. The operations and infrastructure of drinking water, wastewater, and stormwater utilities can be threatened by more frequent and intense storms that can lead to flooding. Operations and infrastructure can also be adversely affected by more frequent and intense drought, more rapid sea-level rise, and saltwater intrusion.

Strategy 2.1: Continue to promote water conservation through rain barrel distribution events and drought-tolerant landscaping classes throughout the region.

Timeframe: short-term

Potential Funding: partner funding

Co-benefits: resource conservation

Description: Rain barrels are storage units that capture runoff water from a catchment area such as a rooftop. Rain barrels help residents reduce potable water demand, ease drought impacts, and help prevent pollution in the storm drain system. Drought-tolerant landscapes provide numerous benefits for the environment including reduced water, fertilizer, and pesticide demand. The SBCCOG will continue to partner with West Basin Municipal Water District to provide water conservation services throughout the South Bay.

Strategy 2.2: Explore a multi-jurisdictional approach to planning for green infrastructure

Timeframe: short-term, mid-term

Potential Funding: not yet identified; partner funding

Description: Stormwater management is increasingly becoming a major expense for local governments addressing persistent flooding or responding to legal and regulatory mandates, such as combined sewer overflow consent decrees or municipal separate storm sewer system (MS4) permits. Communities are increasingly turning to green infrastructure as a vital tool to help manage stormwater and improve climate resilience as well as provide opportunities for improvements in air quality, public health, community recreation and enhanced aesthetics. The SBCCOG has helped cities locate priority areas for green infrastructure implementation in their city-specific vulnerability assessments using the Trust for Public Land Climate Smart Cities tool. Building on this previous work, the SBCCOG will explore potential partnerships with West Basin, Water Replenishment District, and/or the Los Angeles County Sanitation Districts to provide expertise and resources to local jurisdictions on opportunities for green infrastructure planning and implementation. These agencies, along with municipalities including Carson and Torrance, and the Peninsula and Beach Cities Watershed Management Groups are participating in the Safe Clean Water Regional Program, which will develop an annual Stormwater Investment Plan to program Regional Funds (50% of Measure W funds) into the infrastructure, technical resources, and scientific studies programs. The SBCCOG will monitor the outcomes of this group and report out to the SBCCOG Infrastructure Working Group, which focuses on transportation, storm water, and funding for infrastructure projects.

Strategy 2.3: Support cities in assessing site-specific vulnerabilities of existing wastewater and stormwater infrastructure to climate hazards.

Timeframe: short-term

Potential Funding: funding not required

Description: To better prepare for emergencies that threaten their infrastructure, the USEPA offers a free Water/Wastewater Utility All-Hazards Bootcamp training through their Creating Resilient Water Utilities initiative. The training course is designed for water and wastewater employees responsible for emergency response and recovery activities. It also explains why and how to implement an all-hazards program. The SBCCOG will promote this training course to help utilities prepare for extreme weather events.

Strategy 2.4: Encourage all South Bay cities to have residential and municipal water metering programs

Timeframe: mid-term

Potential Funding: not yet identified

Description: In response to increasingly frequent and intense drought events, water metering is a method that can be used to effectively monitor and manage water consumption. Water metering helps users to account for water consumption rates that are often coupled with pricing charges per unit consumed. Most multi-family units have a single meter for all units. Studies show that metering, when coupled with effective pricing structures, reduces water use by 15% to 20%. Additional water savings are possible through improved management of the water system, particularly the identification and repair of leaks in the distribution system. Water savings from metering all connections in California can produce considerable water savings at the local level, reducing vulnerability to drought and other water supply constraints. The SBCCOG will work with water utilities to identify opportunities to expand water metering programs.

Strategy 2.5: Inform cities of opportunities to leverage GIS technology to effectively track and report local drainage needs and flood incidents so that they may be evaluated, prioritized, and resolved.

Timeframe: short-term

Potential Funding: not yet identified

Co-benefit: community engagement, safe streets

Description: With increasing frequency of flash floods or extreme precipitation events, it is important for cities to collect data on areas susceptible to sewer overflows and flooding. The City of San Francisco, for example, analyzed 311 calls from the 10 rainiest days between 2009 and 2014 to determine locations with the highest propensity to have precipitation-related flood inundation. Community engagement tools such as ESRI's Citizen Problem Reporter application, allows the general public to submit non-emergency problems (ex: pothole, flooding) in their community from a smartphone, tablet, or desktop computer. This tool is typically used by planning departments, public works agencies, and other local government organizations to deliver a web-based service request application. The SBCCOG, by leveraging the GIS working group and GIS service providers, will inform relevant city staff on benefits of employing a community engagement tool to effectively track, manage, and resolve non-emergency community issues, including sewer overflow events.

Energy Management

The sub-regional vulnerability assessment found that the electrical grid can be less efficient and more prone to breaking down during periods of high temperatures. The US Department of Energy estimates that for a 9 degree increase in temperature, transmission line capacity falls by 7-8% and substation capacity falls by 2-4%.[217] These problems are compounded when electricity demand spikes during a heat wave, primarily due to increased air conditioning loads. In turn, the result can cause health and safety problems when power losses shut down critical equipment.

Because electricity is more expensive during summer afternoons and early evening, the increased need for air conditioning may also create economic hardships for low-income households. Approximately 71% of housing units in the South Bay were built before 1980. These homes are more likely to be energy inefficient, making them less able to retain cool temperatures in the event of a power outage. Furthermore, according to the 2009 California Residential Appliance Saturation Study, less than 50% percent of homes in the South Bay have central or in-room air conditioning. Residents, businesses and government operations in the subregion can reduce their dependence on the electricity grid by promoting energy efficiency and supporting decentralized, back-up generation.

Strategy 3.1: Track and support the development of clean energy micro-grid networks

Timeframe: mid-term/long-term

Potential Funding: not yet identified

Co-benefit: CAP strategy support

Description: Micro-grids enable a facility or group of facilities to operate autonomously when the main grid is disrupted. They enhance the stability of the local grid. They also can be powered by clean energy sources, such as solar and backup batteries, as well as can be used to reduce facilities' electricity consumption during periods of peak demand when energy prices are at their highest. The SBCCOG will track the micro-grid projects in the sub-region and work with cities to help develop a "best practices" or "lessons learned" report that will serve as a template for other jurisdictions to develop their own micro-grid projects.

Strategy 3.2: Continue to educate local governments and residents of energy efficiency programs and incentives.

Timeframe: on-going

Potential Funding: partner funding

Co-benefit: CAP strategy support, resource conservation

Description: Energy efficiency is one of the most important tools for avoiding climate change by reducing use of fossil fuels. Energy efficiency and related demand management measures also can address some of the energy sector's vulnerabilities to climate change impacts:

- Deploying energy efficient technologies in end-use facilities and in power generation, transmission and distribution can help counteract the increased demand on and decreased output of power plants due to higher temperatures;
- Demand response programs and efficiency programs aimed at peak loads can help counteract the increase in peak demand due to increased use of air conditioning and address the uncertainties in generation and consumption due to extreme weather, and thus help avoid the need for additional power plants;
- Builders can "future proof" buildings against predicted changes in weather patterns by ensuring long-lived characteristics such as orientation, insulation, and windows appropriate for expected climate conditions;
- Cities can reduce ambient temperatures, and make buildings more efficient, with cool or green roofs;
- Constructing distributed generation, especially efficient combined heat and power (CHP) plants, can provide secure electricity for large energy consumers or microgrids that are less subject to grid outages due to extreme weather.

Through existing partnerships with energy utilities, the SBCCOG will continue to advocate for and educate residents, businesses, and cities on the benefits and opportunities of energy efficiency implementation.

Strategy 3.3: Explore the feasibility of expanding and/or promoting energy efficient, weatherization programs to elderly and low-income residents

Timeframe: mid-term

Potential Funding: partner funding

Co-benefit: public health, resource conservation

Description: Extreme heat kills more Americans each year than hurricanes, lightning, tornadoes and floods combined. Everyone is at risk when temperatures rise above 90 degrees, but older persons are among the most susceptible to heat-related illness and deaths. Air conditioning is the number one protective factor against heat related illness and death. Low income residents who struggle to pay their electric bills are likely to go without air conditioning during the summer. In 2019, the California Energy Commission is surveying the state to determine what percent of households have air conditioning units. The SBCCOG will use the results of this survey, combined with the heat vulnerability index developed in the sub-regional vulnerability assessment, to explore agency partners and weatherization programs which would provide energy efficient air conditioning units to low income and elderly residents in the South Bay.

Biodiversity

Biological communities in the SBCCOG subregion are highly variable and include sage scrubs, coastal chaparral forests and coastal dunes that support diverse species. These communities are vulnerable to the effects of climate change, especially wildfire, extreme heat, and cliff erosion, and some are not adapted to extreme events and may have a difficult time reestablishing following a disaster, particularly if these events occur more frequently. Climate change may threaten existing biological communities in the subregion by making the environment more suitable for invasive species, which may out-compete native species for food and other resources, and vector-borne disease.

Strategy 4.1: Educate cities, businesses, and residents on the importance of and opportunities for promoting native species that support the region's biodiversity

Timeframe: short-term

Potential Funding: SBCCOG general funds and partner funding

Co-benefits: CAP strategy support, resource conservation

Description: Native plants are those that occur naturally in a region in which they evolved. Restoring native plant habitat is vital to preserving biodiversity. The SBCCOG will support the proliferation of native plants by:

- Promoting regional seed banks—which provide communities with access to native seeds—in SBCCOG newsletter
- Providing outreach and education to businesses (through Green Business Program) on benefits of native plants
- Integrating resources and discussion of benefits of native plants via the SBESC landscape transformation classes

Strategy 4.2: Assess the potential risk of vector-borne disease and invasive species proliferation due to climate change and goods movement

Timeframe: long-term

Potential Funding: Strategic Growth Council Climate Change Research Program

Co-benefits: public health

Description: Disease vectors and pathogens are spreading across continents due to human transport, land-use change, and climate change. Experts on the Intergovernmental Panel on Climate Change concluded that climate change events (including El Niño, La Niña, heatwaves, droughts, floods, increased temperature, higher rainfall, and others) will likely expand the geographical distribution and transmission of several vector borne diseases.[218] Travel and transportation present the greatest risk of the rapid spread of infectious diseases.[219] Given the sub-region's climate projections and proximity to the Port of LA, medical and public health practitioners would benefit from a greater understanding of the potentially changing profile of infectious diseases as a result of increased population mobility, intensified trade in goods and services, and climate change. The SBCCOG will explore partnerships (with public health agencies, research institutions, and the Port of LA/Long Beach) and funding opportunities to better assess the risk of infectious disease and invasive species proliferation in the region.

Coastal Management

Planning for adaptation to sea level rise requires regional partnerships and strategies. For coastal communities to be successful in sea level rise adaptation, there must be an understanding that water knows no borders and only collaborative problem-solving approaches that cross municipal boundaries will move the region towards adaptation.

Strategy 5.1: Monitor the Coastal Regional Sediment Management Plan implementation process to ensure South Bay communities are represented proportional to their risk with respect to funds and resources for beach maintenance and restoration
Timeframe: on-going
Potential Funding: SBCCOG general funds
Description: The California Coastal Sediment Management Workgroup (CSMW) (housed within California's Division of Boating and Waterways) was established by the U.S. Army Corps of Engineers and the California Natural Resources Agency in 1999 to develop regional approaches to protecting, enhancing, and restoring California's coastal beaches and watersheds. In 2012, LA County launched a comprehensive Coastal Regional Sediment Management Plan to prevent beach erosion, maintain safety, and conserve and restore sediment resources along the LA coastline. CSMW is currently working with a consultant to help assemble an effective governance structure for the coastal area within LA County.

Strategy 5.2: Support education of planners, stormwater managers, and local government departments on coastal management best practices
Timeframe: short-term
Potential Funding: SBCCOG general fund
Description: Natural and nature-based green infrastructure practices can play a critical role in making coastal communities more resilient to natural hazards. The SBCCOG will host a NOAA

coastal management free training, “Introducing Green Infrastructure for Coastal Resilience.” In this course, participants review fundamental concepts and examine various best practices. Local speakers share their expertise and the ways these techniques have been integrated into local planning processes. Course participants from land use planning, conservation planning, hazard mitigation, stormwater management, floodplain management, and local government departments will make valuable connections with new and experienced practitioners who are moving green infrastructure projects forward in their communities.

Transportation

Climate change will likely impact roads, highways, and public transit. Specifically, climate impacts will threaten *mobility*—the ability to move goods and services--in the following ways:

- Higher temperatures can cause pavement to soften and expand, creating rutting and potholes, and cause rail tracks to expand and buckle
- Extreme weather may result in power outages potentially leaving communities without mobility through failed gasoline pumps or electric charging stations that are inoperable
- Floods and mudslides may block roads for extended periods of time which may disrupt supply chains
- Other potential impacts are described in the Transportation section of the sub-regional vulnerability assessment

Acknowledging the threats that climate change poses on *mobility*, the SBCCOG will pursue adaptive strategies aimed at increasing *accessibility* and *connectivity*—which focus on the ability and level of ease for people to access desired goods, services, activities, and destinations.

Strategy 6.1: Encourage inter-city applications of regional broadband network to improve connectivity and coordinated emergency response efforts

Timeframe: mid-term

Potential Funding: not yet identified

Description: In 2019, the SBCCOG awarded a contract to American Dark Fiber to build and provide gigabit, scalable broadband connectivity for 16 cities and the County of LA that comprise the SBCCOG and several other regional agencies. Broadband can support cities' emergency response through public safety systems and the use of reliable and secure communication networks for search and rescue and coordinated relief efforts. Therefore, the SBCCOG will encourage and assist in the development of inter-city applications of the broadband network.

Strategy 6.2: Pilot a neighborhood resiliency hub in the South Bay

Timeframe: mid-term/long-term

Potential Funding: Caltrans, Strategic Growth Council

Co-benefits: CAP strategy support, safe streets, economy, community engagement

Description: The SBCCOG's Sustainable Neighborhood Strategy (SNS)—a GHG emission reduction plan for connecting neighborhoods through a zero-emission transportation network—was adopted in 2018 as part of the sub-regional Climate Action Plan. Building on the SNS, the Neighborhood Resilience Hub will increase neighborhood-level adaptive capacity to climate impacts and enhance community resilience by increasing and safe-guarding access and connectivity to key goods, services and community functions. Components of Resilience Hubs include:

- Community Buildings/Centers
- Back-up energy system
- Critical goods and services (refrigeration, charging stations, medical supplies, etc.)
- Reliable, low-carbon transportation (local travel network)
- Broadband network

The SBCCOG will identify community partners and apply for funding to support the planning and implementation of neighborhood resiliency hubs in vulnerable communities.

Strategy 6.3: Study the impacts of extreme heat on active transportation and EV infrastructure

Timeframe: mid-term/long-term

Potential Funding: Caltrans

Co-benefits: CAP strategy support, safe streets, public health

Description: The Sustainable Neighborhood Strategy as laid out in the sub-regional Climate Action Plan is dependent on and supports the expansion of active and multi-modal transportation. In determining which modes of transportation to invest in and advocate for in South Bay communities, the SBCCOG will seek grant opportunities to commission a study on the impact of increasing temperatures on active transportation and EV infrastructure.

Climate Migration

In addition to the direct climate stressors the South Bay will experience due to global warming, it is important to understand, assess, and plan for the potential for large influxes into the region — which may exacerbate stress on already limited resources (housing, education, infrastructure, roadways, etc.) — based on comparatively lower levels of climate risk globally, nationally, and regionally.

Strategy 7.1: Continue to monitor demographic changes and migration into the sub-region and assess our infrastructural capacity to meet the needs of a growing population

Timeframe: mid-term/long-term

Potential Funding: SCAG

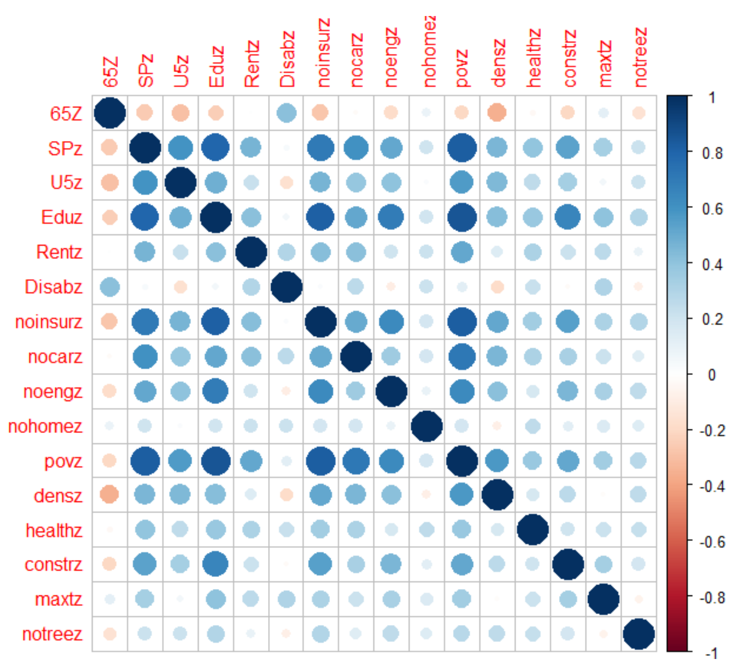
Description: In 2003, the SBCCOG developed an Infrastructure and Services Capacity Assessment to understand the impact of forecasted growth on South Bay livability. Considering the potential for climate induced migration into the region, the SBCCOG will explore funding opportunities to re-assess the demand for services and infrastructure in the community after the 2020 census to ensure critical infrastructure (water, energy, transport) and social services are available to South Bay residents.

Appendix A: Social Vulnerability Index Construction Methodology

The SBCCOG aggregated selected indicators[1] to create a heat vulnerability index. Because information on the true relationship between indicators and vulnerability is lacking, it was assumed that each indicator had a linear relationship with vulnerability and that each indicator contributes to vulnerability equally.[2]

Following the SoVI® Recipe developed by the University of South Carolina, variables were standardized by transforming the raw data values into z-scores with a variance of one and a mean of zero, such that increasing values correspond with increasing vulnerability. A correlation matrix revealed that some of the variables are correlated, in particular and unsurprisingly, many of the socioeconomic variables (**Figure 1**). To address correlation among multiple variables, a principal components analysis (PCA) of z-scores was performed, creating a composite index of components that each include a subset of heat vulnerability variables that are independent of each other (orthogonal) and thus can be added together to determine a more accurate composite heat vulnerability index.

Figure 1: Correlation Matrix



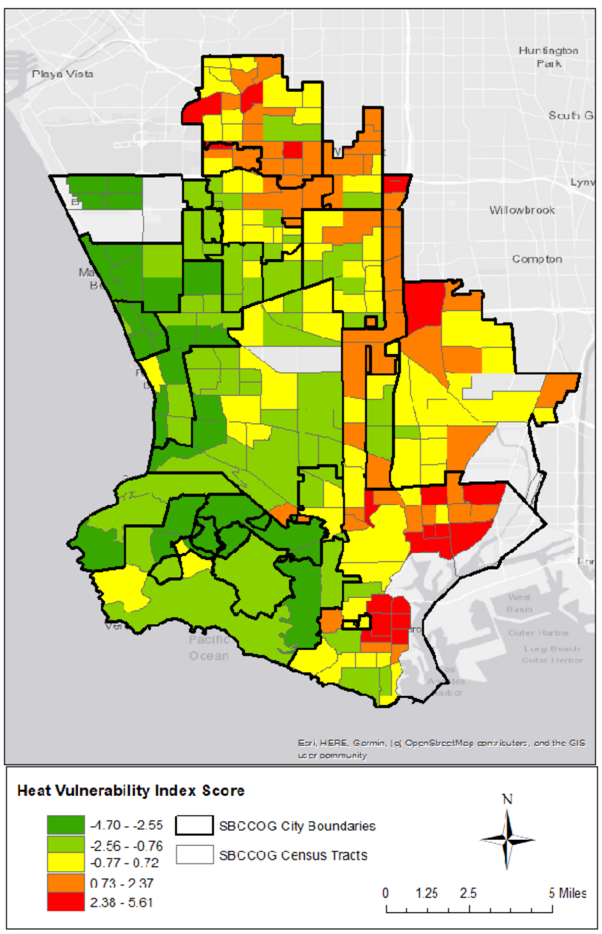
Abbreviation	Indicator
65Z	65 years or older living alone
SPz	Single parent
U5z	Under 5 years old
Eduz	Over 25 without high school degree
Rentz	Spending over 50% of income on rent
Disabz	Physical or mental disability
noinsurz	No health insurance
nocarz	No access to vehicle
noengz	No english (linguistic isolation)
nohomez	Homeless
povz	200% under the poverty level
densz	Population density
healthz	Chronic Disease
constz	Construction Workers
maxtz	Historical maximum temperature
notreez	Tree Canopy

[1] See “Dominant Variables” in Table 1 for indicators included in Principal Component Analysis

[2] Adaptive Capacity indicators (i.e. tree canopy) were reversed (subtracted from 100%) such that they contributed positively to vulnerability in the analysis.

The principal components analysis of the z-scores resulted in four categories, or components, explaining 66.48% of the variance. These components include economically stressed households, outdoor workers and heightened exposure, age/mobility, and poor health. Air conditioning did not contribute to any factor with significance[3], and therefore was not included in the index. The components that explain the other 33% were less interpretable, and therefore discarded in accordance to the SoVI® Recipe (step 5)[4]. The factor scores of the four components were summed and mapped for each census tract to create a cumulative heat vulnerability index (see **Figure 2**). Census tracts with missing or outlier data were removed prior to the analysis.[5]

Figure 2: Heat Vulnerability Index for the South Bay Sub-region



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[3] Loading for AC for any given component was below abs(0.5)

[4] Extraction criteria: Eigenvalue > 1; components with an eigenvalue of less than 1 account for less variance than did the original variable

[5] Greyed-out census tracts indicate areas with missing data or population of 0

For the sub-region as a whole, socio-economic vulnerability accounted for the most variability of all the variables (22.4%), suggesting that socioeconomic factors have the greatest effect on an individual's ability to prepare and respond to an extreme heat event. **Table 2** describes how each of the indicators and components contribute to regional heat vulnerability.

Table 2: Vulnerability Component Summary

Component	Name	% Variance Explained	Dominant Indicators	Contribution to Component (Loading)
1	**Economically Stressed Family/Household**	39.4	NOCAR	0.787
			POVERTY	0.765
			POPDENSITY	0.696
			SINGPARENT	0.678
			CHILD	0.618
			RENT50	0.549
2	**Outdoor Workers**	13.27	CONSTRUCTION	0.742
			EDU	0.739
			MAXTEMP	0.705
			NOENG	0.691
			NOINS	0.612
3	**Elderly & Disability**	7.18	DISABILITY	0.811
			ELDERLYALONE	0.673
4	**Poor Health**	6.56	HOMELESS	0.707
			NOTREES	0.683
			DISEASE	0.562
	Total Variance Explained	**66.42**		

PCA OUTPUTS FOR SOCIAL VULNERABILITY INDEX

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy. (a)		.886
Bartlett's Test of Sphericity (b)	Approx. Chi-Square	2356.536
	df	120
	Sig.	.000

(a) Kaiser-Meyer-Olkin Measure of Sampling Adequacy—This measure varies between 0 and 1, and values closer to 1 are better. A value of 0.6 is a suggested minimum.

(b) Bartlett's Test of Sphericity—This tests the null hypothesis that the correlation matrix is an identity matrix. An identity matrix is a matrix in which all the diagonal elements are 1 and all off diagonal elements are 0. You want to reject this null hypothesis.

Total Variance Explained

Component (a)	Initial Eigenvalues (b)			Extraction Sums of Squared Loadings (f)		
	Total (c)	% of Variance (d)	Cumulative % (e)	Total	% of Variance	Cumulative %
1	6.305	39.408	39.408	6.305	39.408	39.408
2	2.123	13.266	52.674	2.123	13.266	52.674
3	1.149	7.184	59.859	1.149	7.184	59.859
4	1.050	6.562	66.421	1.050	6.562	66.421
5	.811	5.066	71.487			
6	.733	4.582	76.070			
7	.657	4.106	80.176			
8	.596	3.725	83.901			
9	.564	3.525	87.426			
10	.477	2.982	90.408			

11	.423	2.641	93.049			
12	.364	2.277	95.326			
13	.324	2.026	97.352			
14	.223	1.394	98.745			
15	.124	.773	99.518			
16	.077	.482	100.000			

(a) Component—There are as many components extracted during a principal components analysis as there are variables that are put into it. In our analysis, we used 16 indicators or variables, so we have 16 components.

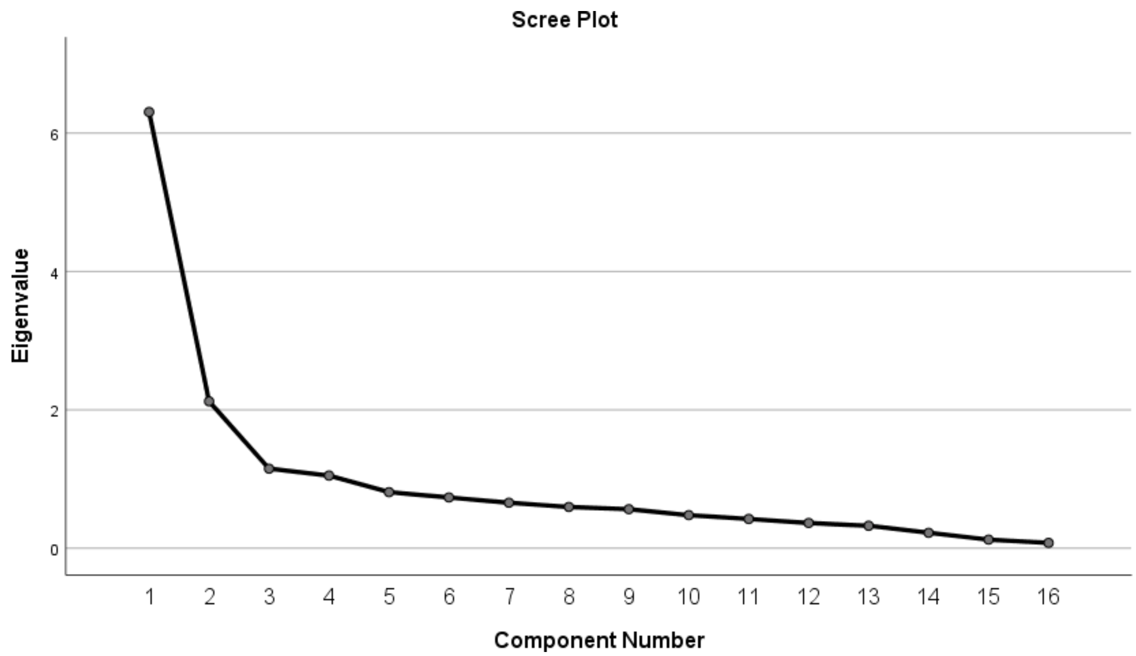
(b) Initial Eigenvalues—Eigenvalues are the variances of the principal components. Because we conducted our principal components analysis on the correlation matrix, the variables are standardized, which means that each variable has a variance of 1, and the total variance is equal to the number of variables used in the analysis, in this case 16.

(c) Total—This column contains the eigenvalues. The first component will always account for the most variance (and hence have the highest eigenvalue), and the next component will account for as much of the left-over variance as it can, and so on. Hence, each successive component will account for less and less variance.

(d) % of Variance—This column contains the percent of variance accounted for by each principal component.

(e) Cumulative %-- The column contains the cumulative percentage of variance accounted for by the current and all preceding principal components.

(f) Extraction Sums of Squared Loadings—The three columns of this half of the table exactly reproduce the values given on the same row on the left side of the table. The number of rows reproduced on the right side of the table is determined by the number of principal components whose eigenvalues are 1 or greater.



The scree plot graphs the eigenvalue against the component number. You can see these values in the first two columns of the table immediately above. From the third component on, you can see that the line is almost flat, meaning that each successive component is accounting for smaller and smaller amounts of the total variance. In general, we are interested in keeping only those principal components whose eigenvalues are greater than 1. Components with an eigenvalue of less than 1 account for less variance than did the original variable (which had a variance of 1), and so are of little use. Hence, you can see that the point of principal components analysis is to redistribute the variance in the correlation matrix (using the method of eigenvalue decomposition) to redistribute the variance to first components extracted.

Component Matrix (b)

	Component (C)			
	1	2	3	4
povz	.939	.039	-.007	-.148
Eduz	.908	.008	-.164	.140
SPz	.877	.010	-.013	-.080

noinsurz	.872	-.054	-.064	.058
noengz	.707	-.151	-.278	.183
nocarz	.689	.208	.153	-.408
constrz	.646	-.046	-.334	.290
U5z	.630	-.314	.127	-.179
densz	.592	-.433	.146	-.328
Rentz	.528	.400	.172	-.219
healthz	.472	.285	.420	.125
Disabz	.075	.808	.080	-.188
65Z	-.286	.645	-.046	-.095
maxtz	.400	.481	-.521	.182
notreez	.351	-.209	.513	.441
nohomez	.241	.422	.345	.490

Extraction Method: Principal Component Analysis.

(b) Component Matrix—This table contains component loadings, which are the correlations between the variable and the component. Because these are correlations, possible values range from -1 to +1.

(c) Component—The columns under the heading are the principal components that have been extracted. As you can see by the footnote provided by SPSS (a.), four components were extracted (the four components that had an eigenvalue greater than 1).

Rotated Component Matrix (a)

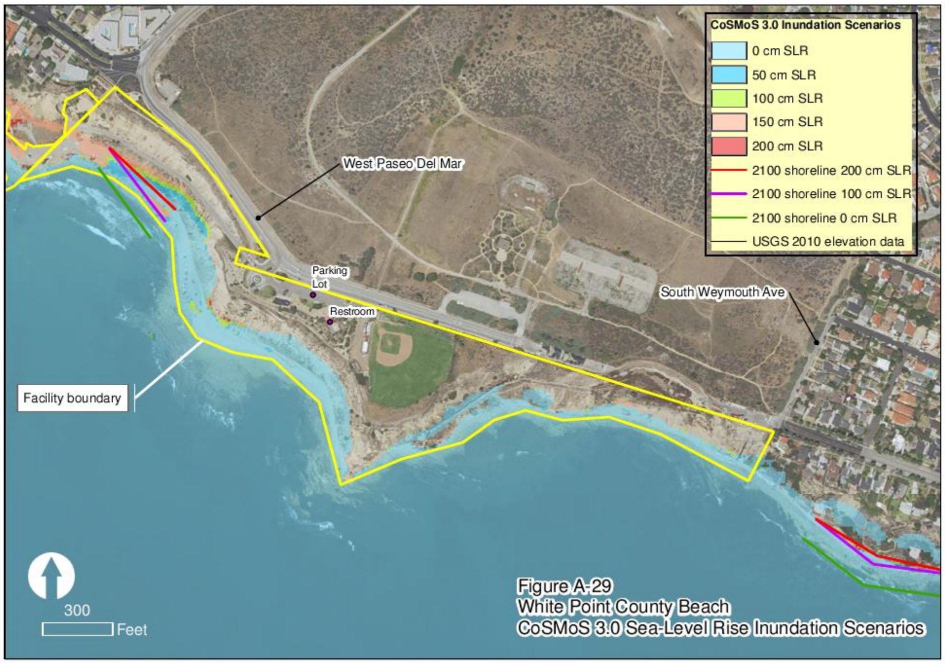
	Component				
	1	2	3		4
nocarz	.787	.184	.219		.084
povz	.765	.540	-.005		.167

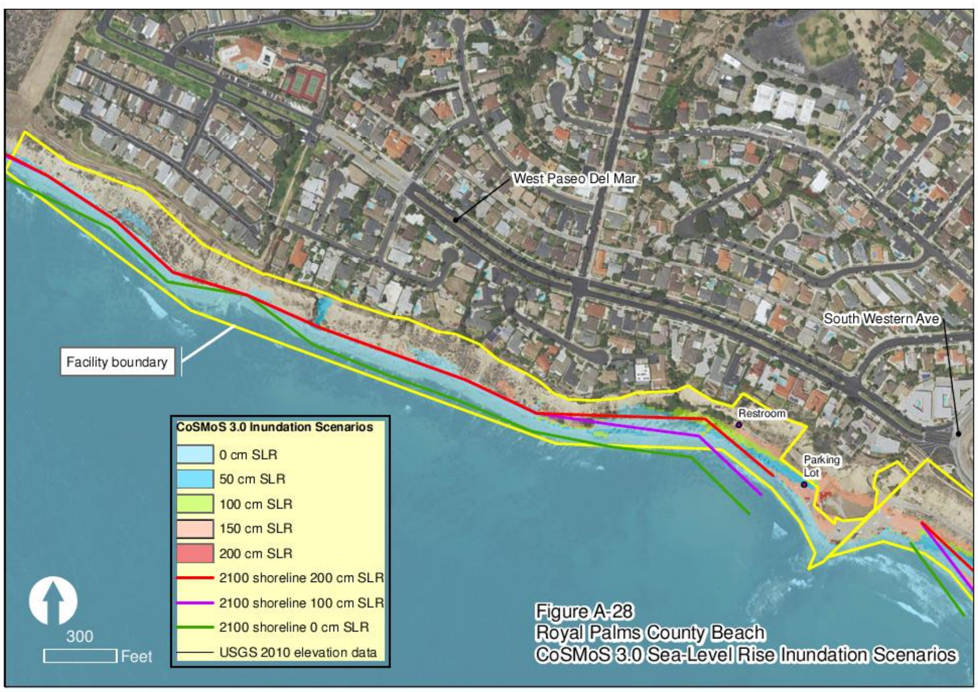
densz	.696	.109	-.412		-.039
SPz	.678	.530	-.042		.183
U5z	.618	.216	-.329		.078
Rentz	.549	.163	.377		.214
constrz	.188	.742	-.126		.117
Eduz	.519	.739	-.079		.224
maxtz	-.002	.705	.444		-.032
noengz	.320	.691	-.216		.082
noinsurz	.576	.612	-.128		.219
Disabz	.157	-.018	.811		.136
65Z	-.191	-.139	.673		-.026
nohomez	-.050	.165	.258		.707
notreez	.140	.054	-.369		.683
healthz	.374	.100	.175		.562

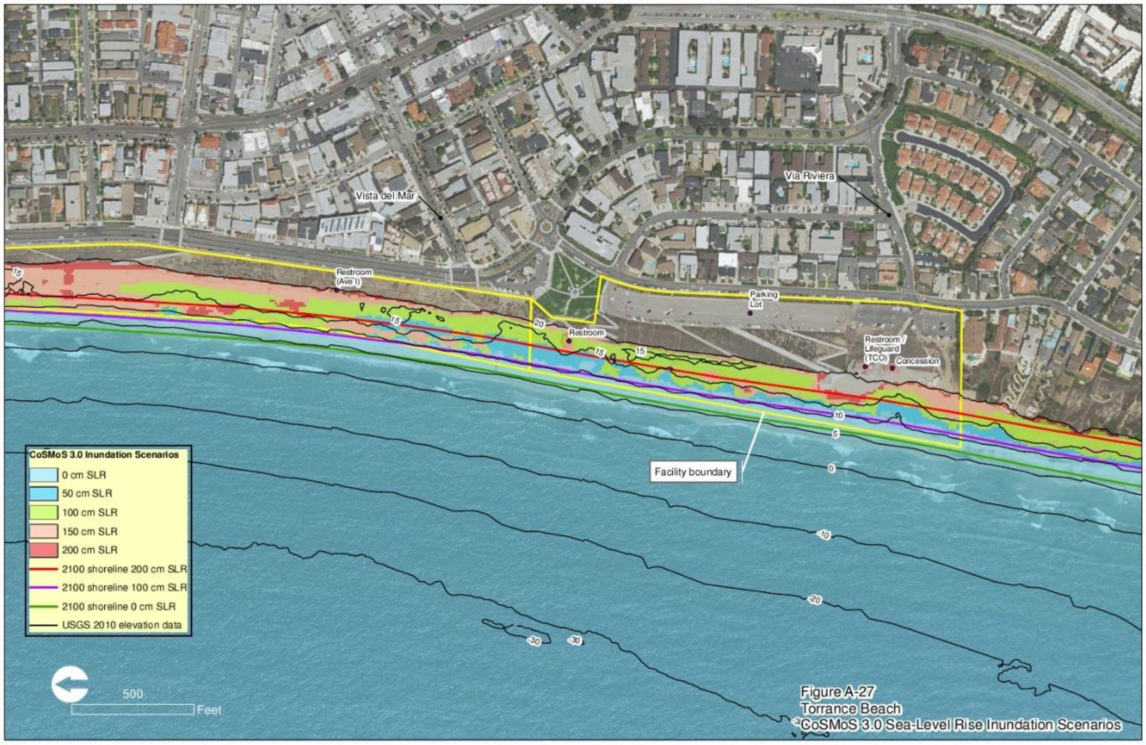
(a) Rotate Component Matrix—SPSS can rotate the factors to better fit the data. The most commonly used method is varimax. Varimax is an orthogonal rotation method that tends to produce factor loadings that are either very high or very low, making it easier to match each item with a single factor.

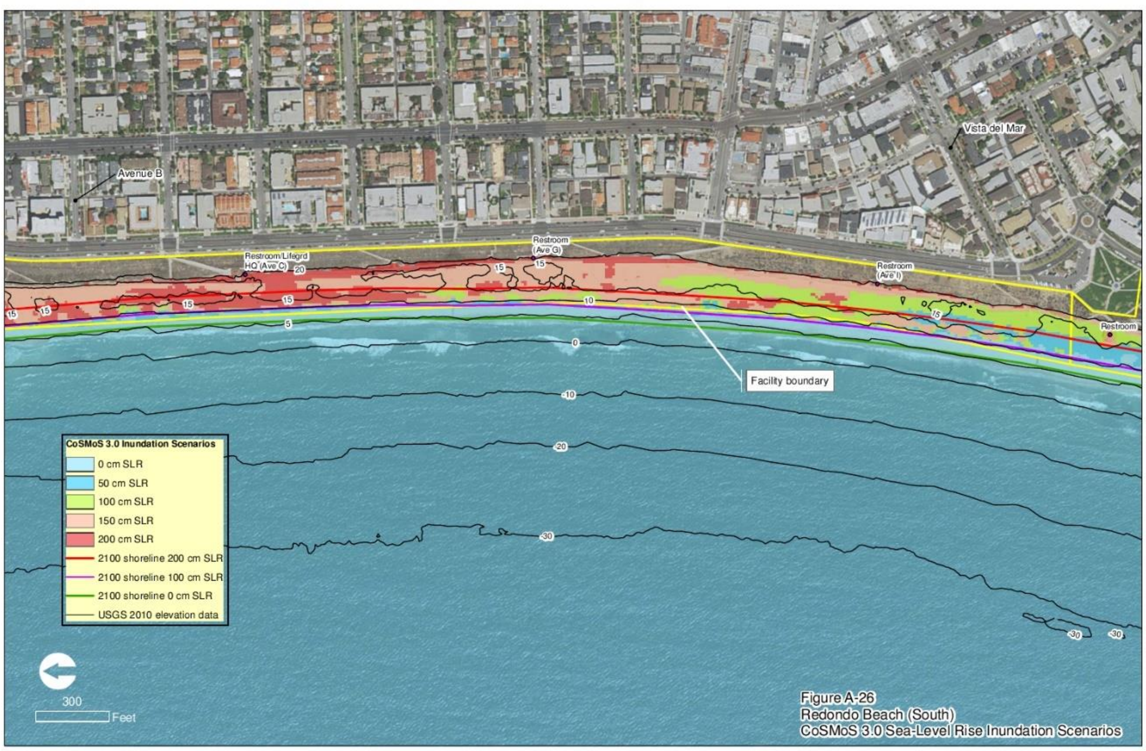
Appendix B: Beach Facilities Impacted from Sea Level Rise

(Source: Los Angeles County Public Beach Facilities Sea Level Rise Vulnerability Assessment, 2016)






Vista del Mar
Via Riviera
Restroom (Ave I)
Parking Lot
Restroom
Restroom / Lifeguard (TCO)
Concession
Facility boundary
CoSMoS 3.0 Inundation Scenarios
0 cm SLR
50 cm SLR
100 cm SLR
150 cm SLR
200 cm SLR
2100 shoreline 200 cm SLR
2100 shoreline 100 cm SLR
2100 shoreline 0 cm SLR
USGS 2010 elevation data
500
Feet
Figure A-27
Torrance Beach
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios


Vista del Mar
Avenue B
Restroom/Lifegrd HQ (Ave C)
Restroom (Ave G)
Restroom (Ave I)
Restroom
Facility boundary
CoSMoS 3.0 Inundation Scenarios
0 cm SLR
50 cm SLR
100 cm SLR
150 cm SLR
200 cm SLR
2100 shoreline 200 cm SLR
2100 shoreline 100 cm SLR
2100 shoreline 0 cm SLR
USGS 2010 elevation data
300
Feet
Figure A-26
Redondo Beach (South)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

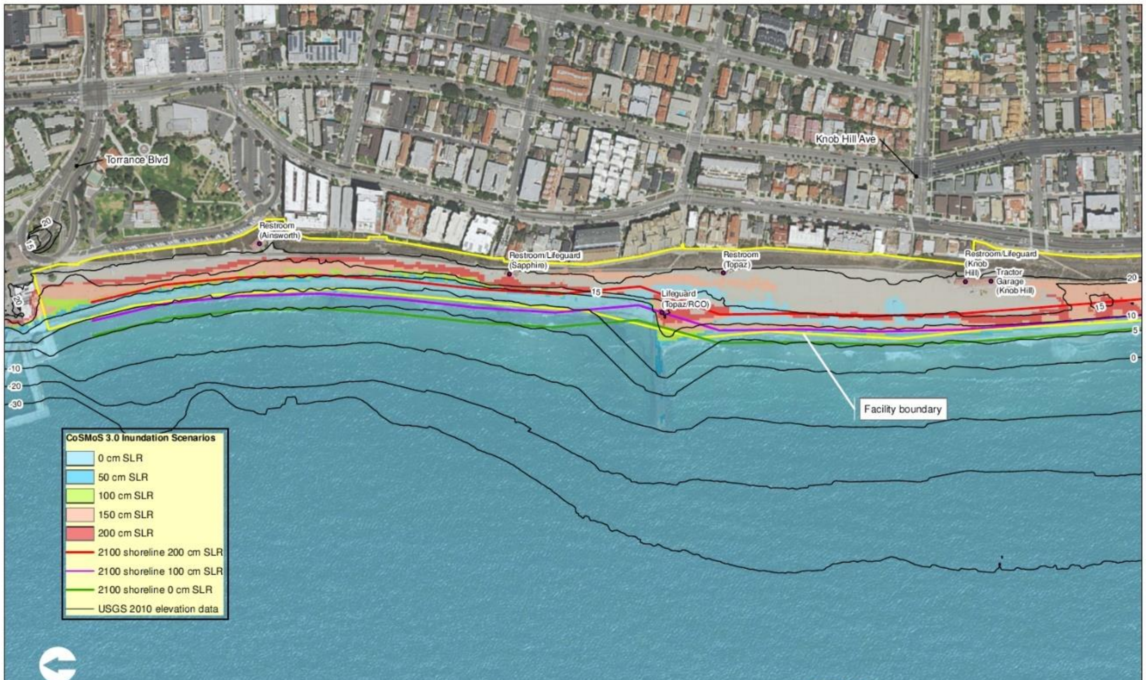


Figure A-25
Redondo Beach (North)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

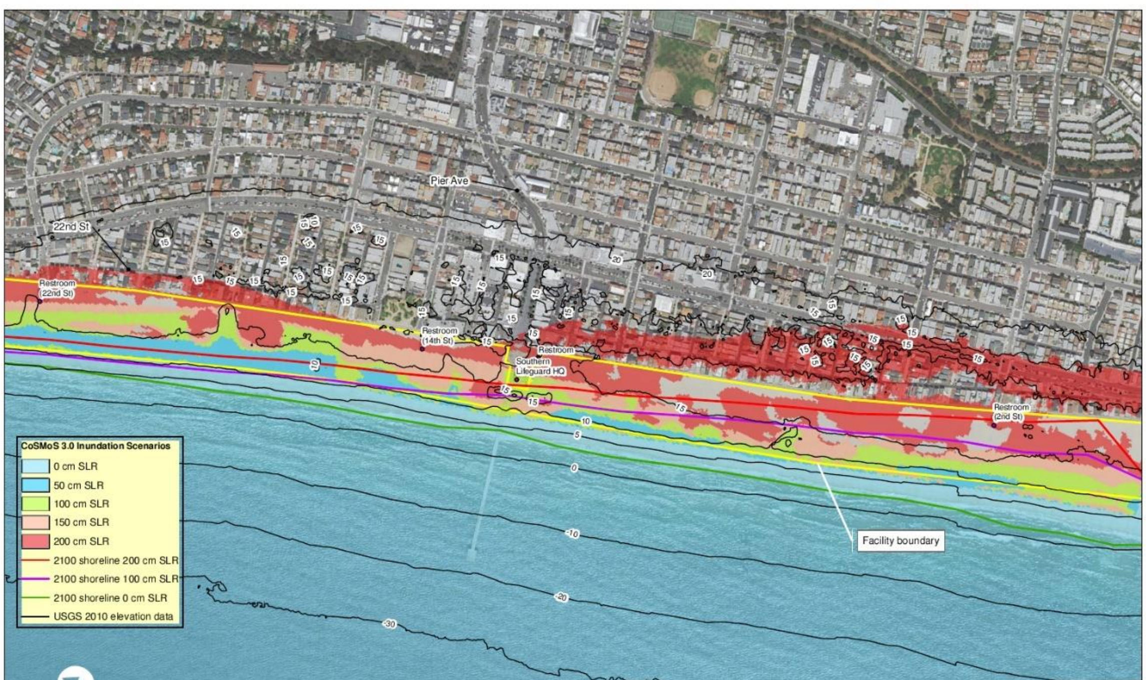


Figure A-24
Hermosa Beach
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

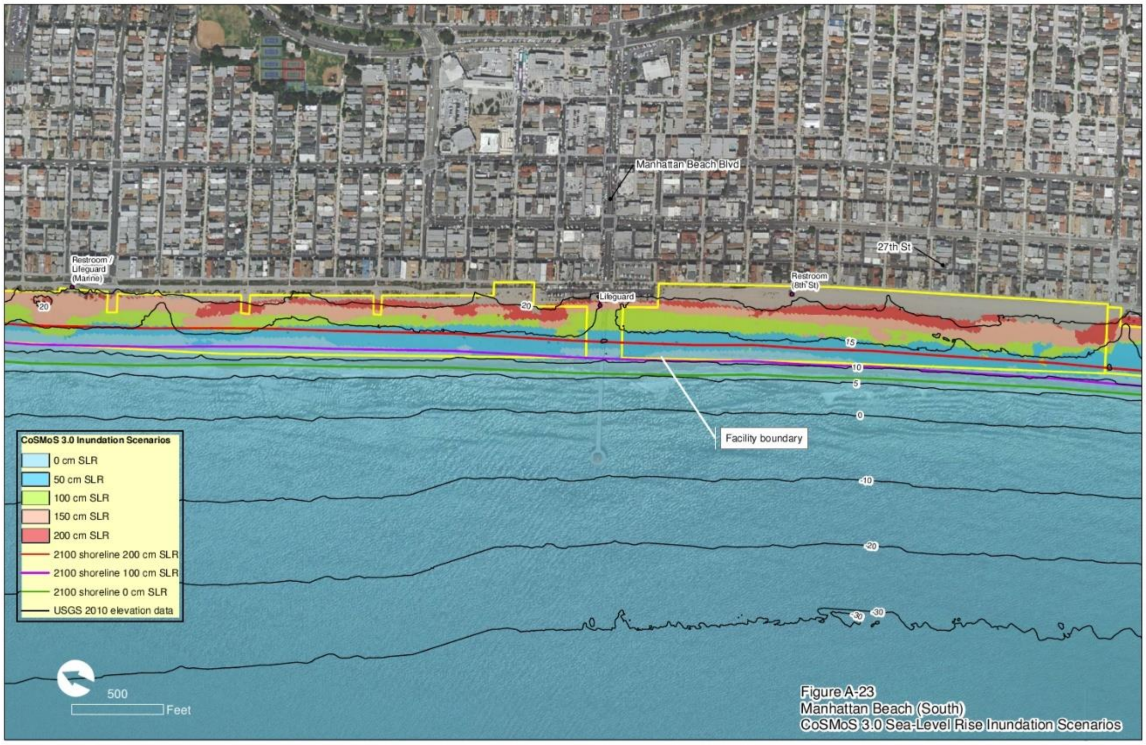


Figure A-23
Manhattan Beach (South)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

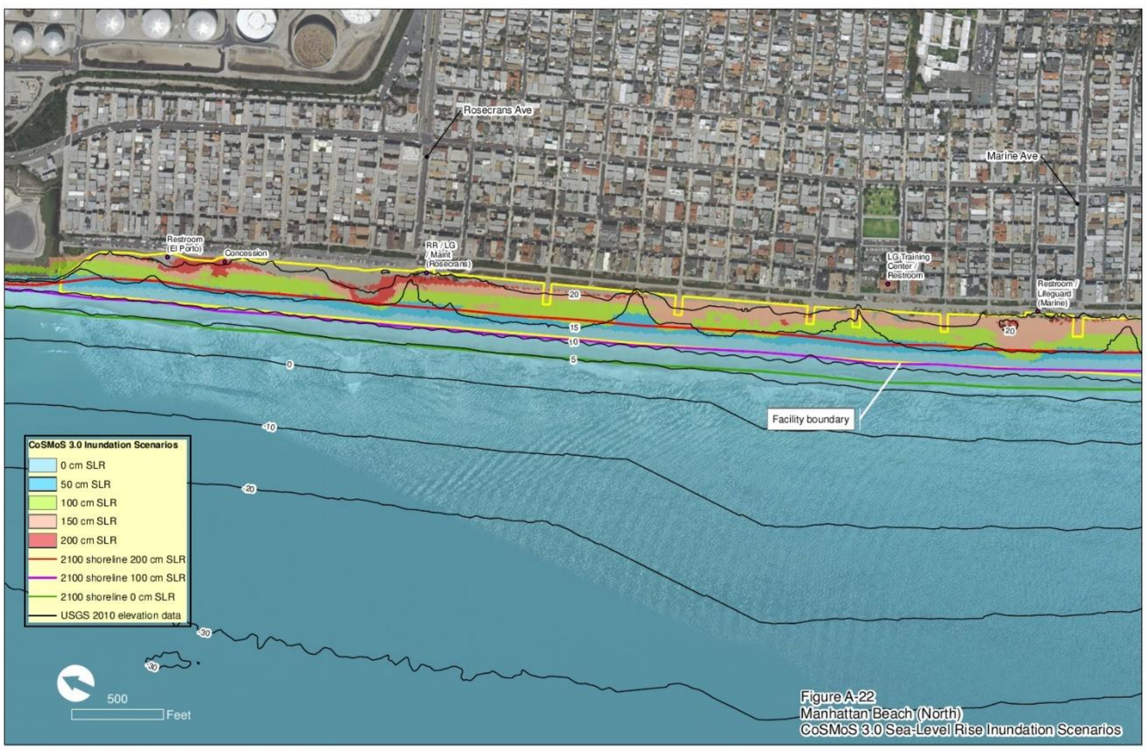


Figure A-22
Manhattan Beach (North)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

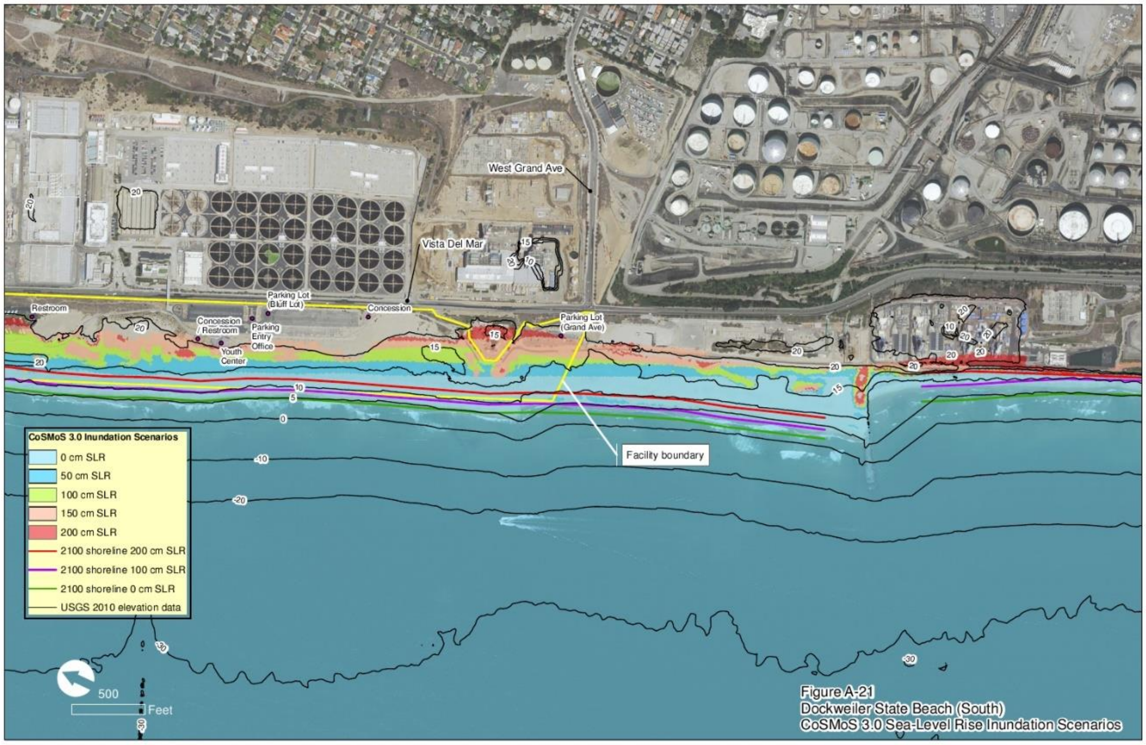


Figure A-21
Dockweiler State Beach (South)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

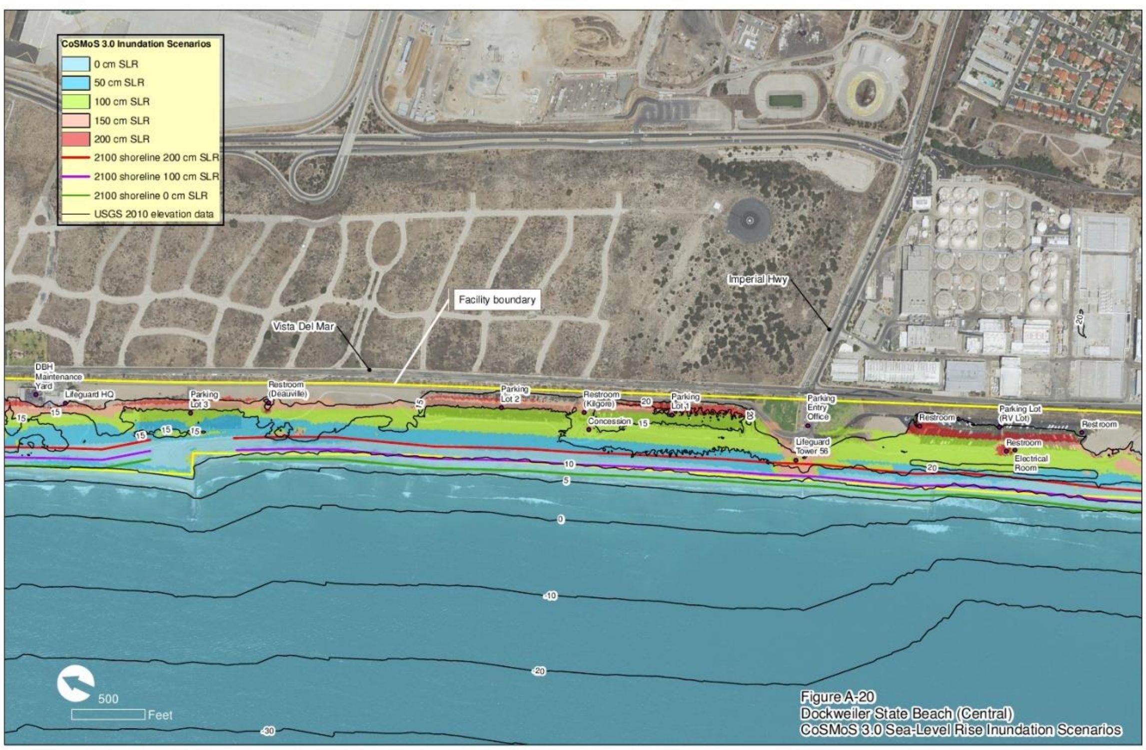
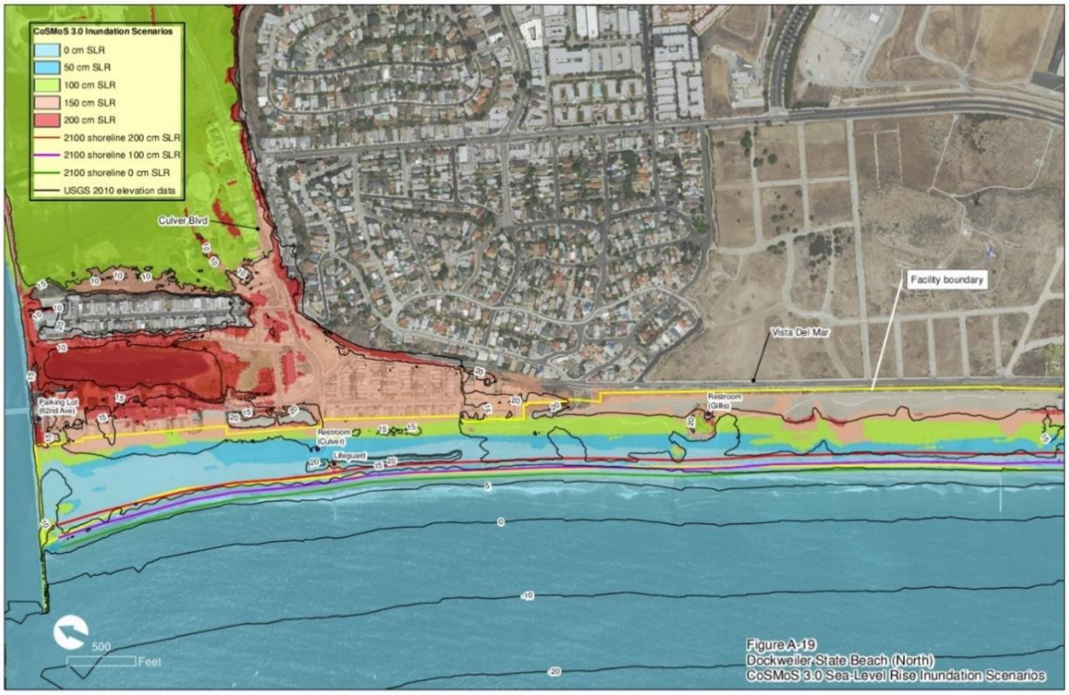
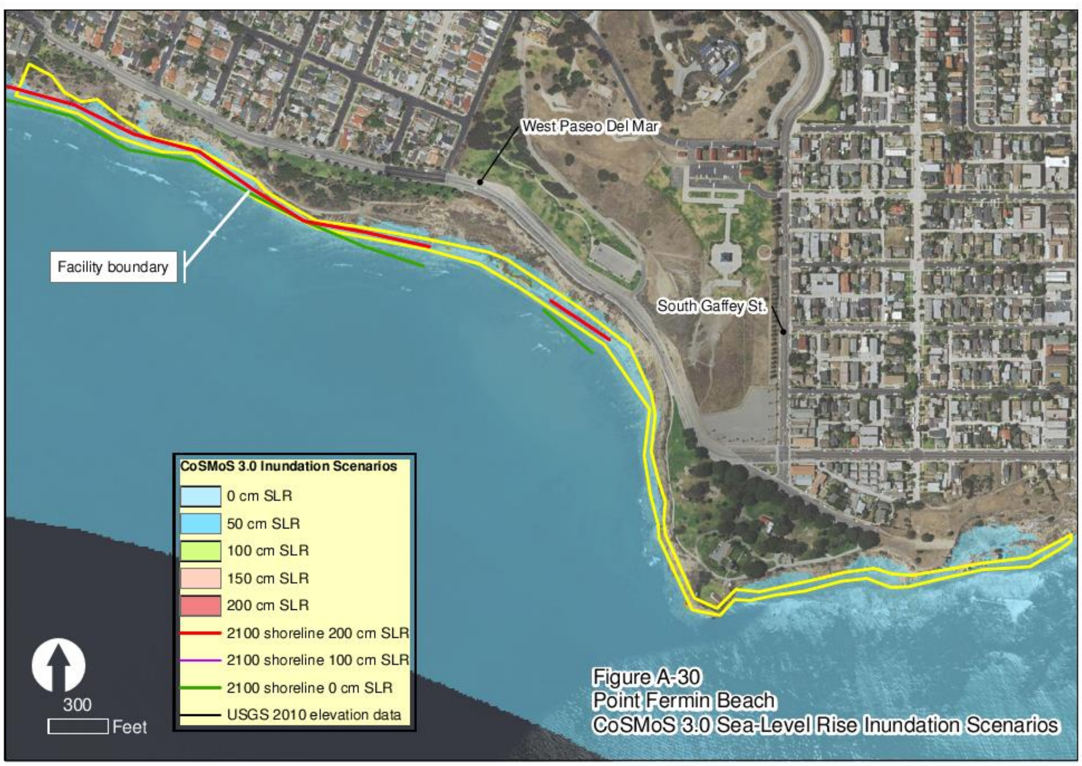


Figure A-20
Dockweiler State Beach (Central)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios


CoSMoS 3.0 Inundation Scenarios
0 cm SLR
50 cm SLR
100 cm SLR
150 cm SLR
200 cm SLR
2100 shoreline 200 cm SLR
2100 shoreline 100 cm SLR
2100 shoreline 0 cm SLR
USGS 2010 elevation data
Culver Blvd
Facility boundary
Vista Del Mar
Restroom (Gillis)
Restroom (Culver)
Lifeguard
500
Feet
Figure A-19
Dockweiler State Beach (North)
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios


West Paseo Del Mar
Facility boundary
South Gaffey St.
CoSMoS 3.0 Inundation Scenarios
0 cm SLR
50 cm SLR
100 cm SLR
150 cm SLR
200 cm SLR
2100 shoreline 200 cm SLR
2100 shoreline 100 cm SLR
2100 shoreline 0 cm SLR
USGS 2010 elevation data
300
Feet
Figure A-30
Point Fermin Beach
CoSMoS 3.0 Sea-Level Rise Inundation Scenarios

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