FINAL DRAFT

Los Angeles County Coastal Hazard Modeling and Vulnerability Assessment

Technical Methods Report

Prepared for
City of Santa Monica

September 30, 2016

ESA

FINAL DRAFT

Los Angeles County Coastal Hazard Modeling and Vulnerability Assessment

Technical Methods Report

Prepared for
City of Santa Monica

September 30, 2016

550 Kearny Street
Suite 800
San Francisco, CA 94108
415.896.5900
www.esassoc.com

Los Angeles

Oakland

Orlando

Palm Springs

Petaluma

Portland

Sacramento

San Diego

Santa Cruz

Seattle

Tampa

Woodland Hills

130524.00

TABLE OF CONTENTS

Figures

Tables

Appendices

1. INTRODUCTION

1.1 Purpose

This report presents technical documentation of the methods used to map coastal erosion and flood hazards under projected future climate scenarios for the entire coast of Los Angeles County (County), California (Figure 1). This report supplements the metadata associated with each geospatial dataset by documenting the input data (Section 3), hazard mapping methods (Sections 4-7), and vulnerability analysis (Section 9).

1.2 Background

Los Angeles County is a valuable economic and environmental section of the California coast. Much of the County's coast is eroding, including almost all exposed cliffs and approximately one third of beaches, and some of the developed areas are in the current 100-year flood plain. Both erosion and flooding are expected to increase with sea level rise (SLR). The City contracted ESA to assess the potential impacts of sea level rise on major coastal hazards: erosion, and periodic and episodic flooding.

This Los Angeles County Coastal Hazard Assessment follows the approach ESA developed for The Nature Conservancy's Coastal Resilience Ventura project.[1] For Los Angeles County, ESA, the City of Santa Monica, USC Sea Grant and others are working with local communities to assess the County coastline's vulnerability to potential future impacts of sea level rise.

This project is funded by the Ocean Protection Council (OPC) under the "Local Coastal Program (LCP) Sea Level Rise Adaptation Grant" program and jointly administered by the State Coastal Conservancy (SCC) and California Coastal Commission (CCC). This funding is available for work that supports LCP updates specifically to address sea-level rise, including sea-level rise modeling, vulnerability assessments, adaptation planning, and policy development.

This grant effort was administered by the City of Santa Monica, but was conducted with guidance and close collaboration with 11 participating jurisdictions. As part of this project, USC Sea Grant and ESA also facilitated a stakeholder group to solicit input from local organizations and agencies.

Project collaborators included the University of Southern California (USC) Sea Grant Program; TerraCosta Consulting Group (TCG); and the United States Geological Survey (USGS). USC Sea Grant provided technical coordination and public outreach. TCG provided sea level rise projection guidance and assessed coastal erosion with complimentary methods. The USGS shared data and predictions from their Coastal Storm Modeling System (CoSMoS) for Southern California (also funded by SCC). Other participants included the Los Angeles Regional Collaborative on Climate Action and Sustainability (LARC); Adapt LA, a Los Angeles regional capacity building initiative also funded by the SCC; Heal the Bay; and the Santa Monica Bay Restoration Commission (SMBRC).

[1] A partnership project with Ventura County, Naval Base Ventura County, and the incorporated Cities of Ventura, Oxnard and Port Hueneme and the Nature Conservancy. See http://coastalresilience.org/

1.3 Previous Coastal Hazards Analysis

Multiple coastal hazards assessments already exist for the Los Angeles study area:

- FEMA flood hazard maps, which are used for the National Flood Insurance Program, present coastal and fluvial flood hazards; however, the current effective maps were published in the 1980s and are believed to underestimate coastal flood hazards. FEMA is currently updating coastal flood hazard maps according to the 2005 Pacific Coast Guidelines (FEMA 2005a). The extent of flood hazards is expected to increase because of changes in FEMA methodology and sea level rise since the 1980s. These maps will only assess existing hazards and will not consider future erosion or projected sea level rise. Provisional updated maps were released in 2016 (personal communication with FEMA IX). The latest FEMA National Flood Hazard Layer is hosted online via an ArcGIS webmap[2].

- In 2012, the NOAA Coastal Services Center created the Digital Coast Sea Level Rise and Coastal Flooding Impact Viewer[3] for the entire U.S. coastline. Users of the viewer can view flooding by existing high tide (Mean Higher High Water) and see how this daily area will change with 1-ft increments of sea level rise. A “confidence” layer, based on uncertainty in the LiDAR surface and modeled tidal surface, classifies hazard areas as high or low confidence. The Viewer also displays qualitative water depth and classifies disconnected low-lying areas separately. The Viewer does not present storm hazards such as extreme tides and wave run-up, and coastal erosion is not considered.

- Tsunami inundation maps, developed by the California Emergency Management Agency (CalEMA), the University of Southern California, and the California Geological Survey, are also available for the entire state of California.

- In 2009, Philip William and Associates, Ltd. (PWA, now ESA) was funded by the Ocean Protection Council to provide the technical hazards analysis supporting the Pacific Institute report on the “Impacts of Sea Level Rise to the California Coast” (“The Pacific Institute study,” PWA 2009). In the course of this work, PWA projected future coastal flooding hazards for the entire state based on a review of existing FEMA hazard maps. In addition, PWA projected future coastal erosion hazard areas for the northern and central California coastline, ending at Santa Barbara. These hazard areas were used in the Pacific Institute study, which evaluated potential socio-economic impacts of sea level rise. The maps completed as part of the Pacific Institute study specifically stated that the results were not to be used for local planning purposes, given the use of “best statewide available data sets”; however, the modeling methods (Revell et al 2011) were developed to be readily re-applied as improved regional and local data became available. An example of coastal flooding hazards mapped in LA for the Pacific Institute study is shown in Figure 2.

- Noble Consultants provided a storm and tidal waves study for the Los Angeles region to the USACE (Noble 2010). The study consisted of an assessment of historic and existing conditions of the coastline, quantification of shoreline changes, evaluation of oceanographic conditions (coastal flooding by waves and tides) considering local environmental and man-made interventions, and formulation of a sand management plan for the County’s coastline.

2 http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=cbe088e7c8704464aa0fc34eb99e7f30
3 “NOAA SLR Viewer” available at http://coast.noaa.gov/slr/

- Noble also prepared a sea level rise vulnerability assessment for Los Angeles County public beach facilities, funded by Climate Ready Grant No. 13-085 from the CA Coastal Conservancy (Noble 2016). The study area covered all public beach facilities spanning from Nicholas Canyon County Beach to Point Fermin Beach.

The present study has improved the methods from the Pacific Institute Study and applied them to the Los Angeles County study area with higher-resolution local data and review by local experts. This work builds upon enhancements developed during the mapping of Ventura County (ESA 2013), Monterey Bay (ESA 2014) and Santa Barbara County (ESA 2015a). These improved methods provide projections of future coastal hazards that are suitable for local planning processes (e.g. LCP) and General Plan updates, and permit applications).

1.4 Los Angeles County Study Area

This study assesses coastal hazards along approximately 65 miles of coastline from the Ventura-Los Angeles County border to the Los Angeles-Orange County border, excluding the Ports of Los Angeles and Long Beach (Figure 1). The coastline from Ventura County east to Point Dume is characterized by a series of sea cliffs that are punctuated by private and public development and state beaches. East of Point Dume to Will Rodgers State Beach, the coastline is dominated by oceanfront homes and the Pacific Coast Highway, fronting the mountainous coast, and beaches are narrow to non-existent. Armoring along this stretch of coast indicates the existing coastal hazards there. Wider beaches emerge at Will Rodgers State Beach and south along the Santa Monica Bay shoreline to Malaga Cove, a result of numerous historic beach nourishment projects supplied with sand from dredging of Marina Del Rey and Redondo Harbors, as well as other regional offshore and beneficial reuse projects. Inland from the northern Santa Monica Bay beaches, the backshore descends to flat coastal plains, while further south the backshore is comprised of a mix of developed dunes and short cliffs. The shore stretching around Palos Verdes to Cabrillo Beach and the LA Harbor breakwater is comprised of steep eroding cliffs with little to no beach. East of the Port of Long Beach is the Long Beach / Belmont Shore, which is protected by a breakwater system. Additional information can be found in Griggs, Patsch and Savoy (2005).

1.5 Disclaimer and Use Restrictions

Funding Agencies

These data and this report were prepared as the result of work funded by the Ocean Protection Council (OPC) and jointly administered by the State Coastal Conservancy (SCC) and California Coastal Commission (CCC) (“funding agencies”). The data and report do not necessarily represent the views of the funding agencies, their respective officers, agents and employees, subcontractors, or the State of California. The funding agencies, the State of California, and their respective officers, employees, agents, contractors, and subcontractors make no warranty, express or implied, and assume no responsibility or liability, for the results of any actions taken or other information developed based on this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. These study results are being made available for informational purposes only and have not been approved or disapproved by the funding agencies, nor have the funding agencies passed upon the accuracy, currency, completeness, or adequacy of the information in this report. Users of this information agree by their use to hold blameless each of the funding agencies, study participants and authors for any liability associated with its use in any form.

ESA

This information is intended to be used for planning purposes only. Site-specific evaluations may be needed to confirm/verify information presented in these data. Inaccuracies may exist, and Environmental Science Associates (ESA) implies no warranties or guarantees regarding any aspect or use of this information. Further, any user of these data assumes all responsibility for the use thereof, and further agrees to hold ESA harmless from and against any damage, loss, or liability arising from any use of this information.

Commercial use of this information by anyone other than ESA is prohibited.

Data Usage

These data are freely redistributable with proper metadata and source attribution. Please reference ESA as the originator of the datasets in any future products or research derived from these data.

The data are provided "as is" without any representations or warranties as to their accuracy, completeness, performance, merchantability, or fitness for a particular purpose. Data are based on model simulations, which are subject to revisions and updates and do not take into account many variables that could have substantial effects on erosion, flood extent and depth. Real world results will differ from results shown in the data. Site-specific evaluations may be needed to confirm/verify information presented in this dataset. This work shall not be used to assess actual coastal hazards, insurance requirements, or property values, and specifically shall not be used in lieu of Flood Insurance Studies and Flood Insurance Rate Maps issued by FEMA.

The entire risk associated with use of the study results is assumed by the user. The City of Santa Monica, ESA and all of the funders shall not be responsible or liable for any loss or damage of any sort incurred in connection with the use of the report or data.

2. SUMMARY OF COASTAL HAZARD ASSESSMENTS

This section summarizes this project's coastal hazard assessments, as represented by the project's GIS deliverables, and points to the relevant sections in this document that describe how each was developed. An example map is included for each type of data. A complete list of GIS deliverables is provided in Appendix 1. Hazard zones were developed for existing conditions (2010) and three planning horizons (2030, 2050, and 2100) based on direction received during the County stakeholder process and consistent with the California Coastal Commission guidance on sea level rise (CCC, 2015). Two future sea level rise scenarios (Medium and High) were assessed for each type of hazard. In addition, an extreme sea level rise scenario was considered, in which the 2100 high scenario occurs earlier, in 2080. These scenarios are summarized in Section 3 and are described in detail in Section 0. All GIS deliverables are provided in the NAD 1983 datum and UTM Zone 11N projection. Horizontal units are in meters.

2.1 Shoreline Erosion Hazard Zones (Sections 5.1 & 5.2, Figure 3)

These zones represent future long-term and storm-induced dune and shoreline erosion hazard zones. Model results incorporate site-specific historic trends in erosion, additional erosion caused by accelerating sea level rise, and (in the case of the "storm erosion hazard zones") the potential erosion impact of a large storm wave event. The inland extents of the hazard zones represent projections of the future crest of the dunes or shoreline position for a given sea level rise scenario and planning horizon.

- Long-term erosion hazard zones
  8 polygon shapefiles: Existing conditions eroded dune/shoreline zone plus 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario

- Storm erosion hazard zones*8 polygon shapefiles: storm erosion from existing dune/shoreline plus 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario*

2.2 Cliff Erosion Hazard Zones (Sections 5.3 & 5.4, Figure 4)

These zones represent cliff erosion hazard zones between the existing cliff edge and the projected future cliff edge. These results are derived by incorporating site-specific historic trends in erosion, additional erosion caused by accelerating sea level rise, and a factor of safety to account for alongshore variability in cliff erosion rates. The inland extent of the hazard zone represents the future cliff edge projected for each planning horizon and future scenario.

- Long-term erosion hazard zones
  8 polygon shapefiles: existing cliff zone plus 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario

- Cliff erosion with factor of safety hazard zones (erosion rate uncertainty)
  8 polygon shapefiles: existing cliff zone with uncertainty buffer plus 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario

- Landslide hazard zone (Palos Verdes only)
  1 polygon shapefile for potential landslide hazard

- Terrestrial erosion zone
  4 polygon shapefiles: existing terrestrial erosion zone plus 3 planning horizons (not SLR dependent)

2.3 Coastal Storm Flood Hazard Zones (Section 6.1, Figure 5)

These hazard zones depict flooding that may be caused by a coastal storm and are described separately by mechanism. The processes considered include (1) elevated ocean levels due to climate effects (e.g. elevated water levels during El Niño phases) and storm surge (a rise in the ocean water level caused primarily by winds and pressure changes during a storm), (2) wave run-up (includes wave setup and waves running up over the beach and coastal property (calculated using the computed 100-year total water levels), (3) extreme lagoon water levels, which can occur when lagoons fill up when the mouths are closed (using maximum potential beach berm elevations), and (4) additional flooding caused by rising sea level in the future. These hazard zones do NOT consider upland fluvial (river) flooding and local rain/run-off drainage, which likely play a large part in coastal flooding, especially around coastal confluences where the creeks meet the ocean. For item (1) "elevated ocean levels", the 100-year recurrence water level based on tide gauge data was used.

- Storm flood hazard zones
  8 polygon shapefiles: existing conditions and 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario

  There are two types of storm flood areas: (1) areas that appear to have a surface connection over the existing digital elevation through low topography, and (2) other low-lying areas that don't have an apparent connection, as indicated by the digital elevation model, but are low-lying and flood prone from groundwater levels and any connections (culverts, underpasses) that are not captured by the digital elevation model. This difference is captured in the "Connection" attribute (either "connected" or "connectivity uncertain") in each geospatial dataset. We recommend these be mapped as separate colors, as shown in Figure 5*).*

2.4 Extreme Monthly Tidal Flooding Zones (Section 6.2, Figure 6 & Figure 7)

These zones show the area and depth (in meters) of flooding caused by rising tide and groundwater levels (not considering storms, erosion, or river discharge). The water level mapped in these flooding areas is the Extreme Monthly High Water (EMHW) level, which is a high water level that is reached approximately once a month (2.0 m (6.55 ft) NAVD, calculated from LA Harbor Tide gauge data). These zones do not, however, consider coastal erosion or wave overtopping, which may change the extent and depth of regular tidal flooding in the future.

- Potential tidal flooding area of Extreme Monthly High Water (Figure 7)
  8 polygon shapefiles: existing conditions and 2 planning horizons x 3 SLR scenarios plus extreme SLR scenario

  Note: There are two types of tidal flooding areas: (1) areas that appear to be connected over the existing digital elevation through low topography, and (2) other low-lying areas that don't have an apparent connection, as indicated by the digital elevation model, but are low-lying and flood prone from groundwater levels and any connections (culverts, underpasses) that are not captured by the digital elevation model. This difference is captured in the "Connection" attribute (either "connected" or "connectivity uncertain") in each geospatial dataset. We recommend these be mapped as separate colors, similar to the NOAA SLR Viewer (described in Section 1.3).

- Depth of water within the rising tidal flooding zone (in meters) (Figure 8)
  8 rasters (1 meter cell size): existing conditions and 3 planning horizons x 2 SLR scenarios plus extreme SLR scenario

  Note: A value of 999 represents areas where depth data is voided for the input digital elevation model.

2.5 Spatial Aggregation Relative Risk Zones (Section 7, Figure 8)

These data layers represent the overlap of all of the scenarios and hazards mapped through 2100. The intent is to represent the uncertainty associated with the various projections by clearly illustrating which areas are always hazardous at a given time horizon and which areas are only hazardous during more extreme scenarios of sea level rise and storminess. To the extent that this project is used to make individual permit decisions, it is our recommendation that this spatial aggregation layer be used to evaluate the potential coastal hazards for a specific location. The higher the attributed number, the more likely the area is to become exposed to coastal hazards.

3. INPUT DATA

This study relied upon multiple existing data as input for the coastal hazard assessments. This section describes the data types, sources, and extents.

3.1 Planning Horizons and Sea Level Rise Projections

The selected planning horizons of 2030, 2050, and 2100 were based on stakeholder input. These planning horizons are consistent with the recent guidance document from the California Coastal Commission (CCC, 2015) and therefore suitable for use in the LCP process. The CCC (2015) guidance recommends scenario-based planning by examining the consequences of multiple sea level rise projections, as well as extreme water levels and waves associated with storms. The two primary sea level rise scenarios used in this project are based on the study by the National Research Council (NRC, 2012) that has been adopted as State guidance (OPC, 2013).

The Medium and High sea level rise projections are based on the ranges for Los Angeles in NRC (2012)'s Table 5.3. Sea level rise policy guidance from the California Coastal Commission (CCC, 2015) recommends using the regional values reported in NRC (2012) and provides polynomial fit functions for projecting SLR for the High scenario (Equation B4 in CCC (2015)'s Appendix B: Developing Local Hazard Conditions). NRC (2012) provides sea level rise amounts relative to 2000, rather than 2010 (the baseline year for this study), but following CCC (2015) guidance, sea level rise was assumed to be zero for the 2010 baseline. This project's SLR projections used for the Medium and High scenarios are shown in Table 1. for this project's selected planning horizons. These SLR projects are also depicted as continuous curves in Figure 9.

Ongoing discussions on the state level suggest that there will be revised guidance on what SLR scenarios should be considered. Revised guidance will probably recommend that the Low scenario (42 cm by 2100) should not be considered. The Low scenario is largely based on 20th century sea level rise rates, which are unlikely given current emission and sea level rise trends (Cayan et al., 2016). In addition, revised guidance will probably recommend that an extreme scenario should be considered. The extreme case "is currently considered the maximum of what is physically possible" (Cayan et al., 2016). Accordingly, this study dropped the NRC Low scenario and qualitatively considers the Extreme scenario listed in Table 1 and Figure 9.

Cayan et al. (2016) also provide probabilistic estimates of SLR projections given a specific emission scenario. At 2030 and 2050, the NRC medium projection is between the 50th and 95th percentiles of all the emission scenarios, and the NRC High projection is higher than the 95th percentiles of all the emission scenarios. However, at 2100, the NRC Medium projection is typically between the 25th and 75th percentile for all but the lowest emission scenario and the NRC High projection is exceed by more than three feet by the 95th percentile of the highest emission scenario. The Extreme scenario corresponds to the 99.9th percentile, or conditions that only have a 1-in-1,000 chance of being exceeded.

Table 1. Sea level rise projections used in this study,

	Sea Level Rise Scenarios		
Year	***Medium SLR****	***High SLR****	***Extreme SLR*****
2030	13.5 cm (5.3 in)	30.7 cm (12.1 in)	17.8 cm (7 in)
2050	29.4 cm (11.6 in)	60.5 cm (23.8 in)	51.9 cm (20.4 in)
2100	93 cm (36.6 in)	167.6 cm (66 in)	288 cm (113 in)

* Based on projected (for Medium scenario) and upper limit (for High scenarios) values for Los Angeles in Table 5.3 of NRC (2012)

** Based on 99.9th percentile for Representative Concentration Pathway 8.5 from Cayan et al. (2016)

The San Andreas regional vertical land motion rate of -1.5 mm/yr (from Table 5.3 of NRC 2012) is included in the Medium and High SLR scenarios in Table 1. . The sea level rise scenarios used in this study are defined as Medium (3 ft SLR by 2100), High (5.5 ft SLR by 2100), and Extreme (9.4 ft SLR by 2100) in this report.

3.2 Aerial Imagery

Digital Orthophotography

ESA downloaded the aerial mosaics from the NOAA Digital Coast Data Access Viewer (NOAA, 2012a). This imagery is the California Coastal ADS40 4-Band 8-bit dataset collected from May to October 2010 as part of the 2009 – 2011 Coastal LiDAR project. This imagery is reported to have 30 cm resolution with a horizontal accuracy of 2 meters or better at the 95% confidence level.

Oblique Aerial Imagery

ESA used the California Coastal Records Project website to identify coastal armoring and other relevant structures along the coast and to inform the backshore characterization. These photos were accessed through the project website (Adelman and Adelman, 2013). The most recent photos in Los Angeles County were collected in September 2013.

3.3 Digital Elevation Model

This study used the same merged digital elevation model (DEM) that was developed by the USGS for the CoSMoS 3.0 modeling effort. The majority of the data in the DEM was derived from the Coastal CA Data Merge Project. It is mostly comprised of the 2013 NOAA Coastal California TopoBathy Merge Project[4], updated with bathymetry in harbors and nearshore areas that were previously devoid of data and interpolated.

Coastal California Data Merge Project

This merged DEM combines topographic and bathymetric elevation data along the entire California coastline (NOAA 2013). Topographic LiDAR data was provided by NOAA, collected for the California Coastal Mapping Project (CCMP). Bathymetric LiDAR data were provided by the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX), also collected for the CCMP. Multibeam Acoustic data was provided by the California Seafloor Mapping Program (CSMP), Ocean Protection Council, NOAA, and USGS where available.

The topographic LiDAR dataset used in this merged project was from the 2009-2011 CA Coastal Conservancy LiDAR Project. The data were collected between October 2009 and August 2011[5]. This was the primary DEM used for conducting topographic analysis and mapping coastal erosion and flood hazard zones. The dates associated with the 2009-2011 LiDAR were determined from the flight lines, which were important in updating the USGS historic cliff and sandy shore erosion rates.

[4] https://data.noaa.gov/dataset/2013-noaa-coastal-california-topobathy-merge-project-digital-elevation-model-dem

[5] Additional metadata can be found at: http://www.ngdc.noaa.gov/docucomp/page?xml=NOAA/NESDIS/NGDC/MGG/Lidar/iso/xml/2013_CA_TopoBathy_m2612.xml&view=getDataView&header=none

3.4 Geology

Several geologic maps were used to classify the backshore into contiguous geologic units (Dibblee 1999, Dibblee 2007, Dibblee and Ehrenspeck 1990, Yerkes and Cambpell 1980 and 1994, Campbell et al 1996). Figure 10 shows the spatial distribution of coastal geology. The geology map was used in development of the backshore classification and division of the coast into analysis blocks.

3.5 Tides

The Los Angeles tide gauge (NOAA #9410660) tidal datum was selected because it is within the study area. The primary use of this datum was for shoreline analysis and flood mapping. Mean high water (MHW) was used as the representative elevation for shoreline change analysis (see Section 4.1) and the Extreme Monthly High Water (EMHW) was mapped for the tidal hazard zones (see Section 6.1). These tide levels are listed in Table 2 and the tide gauge's location is shown in Figure 11.

Table 2. Los Angeles tidal datums

Tide	meters, NAVD88	feet, NAVD88
100-year High Water Level*	2.34	7.67
Highest Observed Water Level (Jan 27, 1983)	2.35	7.71
Extreme Monthly High Water**	2.00	6.56
Mean Higher High Water	1.61	5.28
Mean High Water	1.39	4.56
Mean Tide Level	0.81	2.66
Mean Sea Level	0.8	2.62
Mean Low Water	0.22	0.72
NAVD88	0	0
Mean Lower Low Water	-0.06	-0.20
Lowest Observed Water Level	-0.89	-2.92

Notes: The tidal datum analysis period was 1983 - 2001 at National Oceanic and Atmospheric Administration stations #9410660; NAVD88 = North American Vertical Datum of 1988. Sources: Tidal Datums (NOAA, 2005)
* from NOAA Tides & Currents "Exceedance Probability Levels and Tidal Datums," for the Los Angeles tide gauge available at http://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=9410660. Accessed 9/3/2015.
** Extreme Monthly High Water was calculated by averaging the maximum monthly high water for all monthly data available at the Los Angeles tide gauge (553 months).

3.6 Waves and Water Levels

Wave and water levels were provided by project collaborators at the USGS. These data were predicted for future conditions using the Coastal Storm Modeling System (CoSMoS) implemented for Southern California (Version 3.0).

Regional Wave and Water Level Data

CoSMoS 3.0 combines the inputs of offshore waves with nearshore wind and atmospheric conditions from global climate models to generate synthetic projections of nearshore waves and non-tidal residuals (NTRs) along the southern California coastline. As in previous studies (ESA 2015a), these CoSMoS output data were reviewed by ESA prior to implementation and then used unmodified as inputs to the coastal erosion model and flood calculations (Section 4.2).

Synthetic Nearshore Wave Data: ESA worked with USGS staff to incorporate the wave climate output from global climate modeling of the moderate emission scenario[6]. Future projected wave conditions at a standard offshore location coincident with CDIP Buoy 028 - Santa Monica Bay (labeled MOP 4809, see Figure 11 for location) were compared to real historic records at the buoy. These future predictions were found to be similar to the real wave data. Discussions with USGS indicated this finding to be consistent with their research, with the potential for the highest 1% waves to come from a more westerly direction with more intense global warming[7] Owing to computational demands, wave spectra were not available and only wave parameters were provided by the USGS: significant wave height, peak spectral period, and peak direction. A cumulative distribution comparison of the significant wave height (Hs), peak spectral period (Tp), and peak spectral direction (Dp) for real data from the Santa Monica Bay Buoy (CDIP Station 028) and synthetic data from the global model[8] provided by the USGS (at location MOP 4809 in Figure 11) are shown in Figure 12. Real data spans from 1981-2016; synthetic data is broken up by planning horizon. A comparison of the real and synthetic wave roses (frequency plots of wave direction and height) is shown in Figure 13.

Synthetic Water Levels: The USGS also provided CoSMoS synthetic water level non-tidal residuals (NTRs) that were generated coincident with the synthetic wave data. These data did not include all non-tidal residual constituents but did provide coincident timing that is important to capture the combined effect of storm events on waves and water levels. Synthetic water level NTRs from climate modeling at MOP 2080 (near south LA Harbor entrance) were compared with real data from the Los Angeles Harbor tide gauge. The locations of MOP 2080 and the LA Harbor tide gauge are shown in Figure 11. Overall, the synthetic data has closer agreement with real data than previous CoSMoS results. In Figure 14, the probability density distributions show that the CoSMoS model predictions compare favorably with observed Los Angeles water levels in terms of the mean being slightly greater than LA historic in the near term (2013-2030) and shifting further positive by 2100. In Figure 15, the cumulative distribution is used to show that the higher values of the synthetic distribution are smaller than the observations. This suggests that while the synthetic data are similar to historic in the overall distribution, the highest NTRs are under-predicted. Despite this finding, no modifications were made to the model predictions to remain consistent with CoSMoS nearshore modeling. The unadjusted synthetic NTR data at MOP 2080 were added to projected astronomic tides for the LA Harbor location based on publicly available software called Xtide (a tool from the model Ttide)[9] and used with the synthetic waves.

[6] The global climate models used moderate emission scenario Representative Concentration Pathway 4.5, often considered similar to the prior B2 “mid-range” climate scenario.
[7] E.g. Representative Concentration Pathway 8.5.
[8] GFDL-ESM2M for climate scenario RCP4.5
[9] http://www.flaterco.com/xtide/ last visited June, 2015.

CoSMoS Model Output Locations

ESA selected 39 locations to represent the varied wave exposure along the Los Angeles County shoreline. CoSMoS 3.0 model coverage spans from Point Conception to San Diego, and includes nearshore model output points at approximately 10-m depth at approximately 100-m spacing alongshore. These selected MOP locations can be seen in Figure 11. Coordinates for the chosen MOP locations are given in Table 3 below.

Table 3. Locations of USGS MOP points used in Los Angeles County study area

MOP ID	Northing UTM Z11 (meters)	Easting UTM Z11 (meters)	MOP ID (cont'd)	Northing UTM Z11 (meters)	Easting UTM Z11 (meters)
1888[1]	3733260.568	395135.1447	2583	3762888.83	361745.3026
1912[1]	3734732.599	393391.1647	2610	3764657.021	359923.8368
1939[1]	3735623.611	391085.3348	2644	3766370.172	357363.4184
2094	3729876.038	381102.0245	2663	3766916.605	355709.4376
2119	3730672.561	378609.4266	2681	3767025.148	354418.2523
2134	3731265.713	377319.4303	2691	3767088.076	353218.7227
2174	3733239.713	373916.2488	2719	3767149.311	350726.3138
2202	3734007.273	372073.2473	2739	3767105.473	348601.6034
2243	3734815.083	368933.9645	2759	3767212.87	346756.3472
2284	3737852.948	367401.0925	2788	3766379.071	344156.7867
2298	3739384.014	368163.2307	2821	3766673.784	341113.8489
2331	3741493.675	370414.4635	2862	3765984.087	337315.2221
2346	3742397.923	370797.066	2885	3765418.811	335365.6362
2363	3744015.624	370911.5695	2927	3764197.032	332295.5626
2374	3745087.473	371203.7525	2967	3766865.476	329479.6115
2406	3747580.427	369757.0774	2992	3767495.19	327181.9832
2426	3749418.978	369134.6997	3022	3767926.765	324234.439
2494	3755624.36	366354.2712	3053	3768441.012	321658.0804
2520	3757891.133	365277.0792	3061	3768526.786	320643.7938
2551	3760409.98	363649.6115	-	-	-

[1] Diffraction applied to MOP 9495 to yield nearshore wave conditions

By comparing the NTRs at each of the MOP locations in Table 3 above, it was determined that NTRs from MOP 2080 could be applied for the entire coastline.

Long Beach Harbor wave transformations

CoSMoS wave modeling outputs within the Long Beach Harbor are overestimated due to the lack of resolution in the wave modeling grids and relative orientation of the grid and breakwaters (Li Erikson, personal communication, June 15 2015). To increase the nearshore resolution and accuracy of the results, wave heights within the Harbor at MOPs 1939, 1912, and 1888 were estimated by ESA by manually diffracting waves from MOP 9495 (shown in Figure 16). The Goda et al. (1978) method was used to calculate diffracted wave height ratios inside of the eastern breakwater, represented as a straight, semi-infinite breakwater, based on the offshore MOP 9495.

To perform diffraction analysis, several assumptions were made. Wave conditions at the easternmost edge of the breakwater were assumed to be the same as those specified at the offshore MOP ID 9495, located east of the breakwater. Waves were assumed to approach normal to the breakwater, and the period of the waves was assumed to be unchanged by interaction with the breakwater.

A set of wavelengths were calculated at each of the Harbor points using each site's respective depth and a specified range of likely wave periods (4 to 26 seconds, in 2 second intervals). The horizontal and vertical distance offsets from the easternmost edge of the breakwater to MOPs 1939, 1912, and 1888 were calculated and then scaled by the range of Harbor wavelengths for each point. The scaled offsets were then used on a shallow-water diffraction diagram, reproduced in Figure 16, to estimate wave height ratios. Estimated wave height ratios were applied to the MOP 9495 time series to generate wave time series at each of the Harbor MOP points. Wave height ratios estimated using the Goda method were also checked using the Weigel (1962) method, which yielded similar results.

3.7 Historic Shoreline Positions

USGS National Assessment of Shoreline Change for Sandy Shorelines

This California-wide USGS assessment calculated short- (1970s to 1998) and long-term (1870s to 1998) shoreline change rates for sandy shorelines along the California Coast (Hapke et al. 2006) and was downloaded from the USGS website[10]. The report includes a GIS database containing three historic shorelines and other GIS files used to calculate the rates of change. The shoreline position error for each time period ranged from 1.5 to 17.8 meters. Section 4.1 discusses how these erosion rates were updated with the 2009-2011 LiDAR dataset.

USGS National Assessment of Cliff Erosion

This California-wide USGS assessment calculated long-term cliff edge erosion rates (end point rate between 1930s and 1998) along the California Coast (Hapke and Reid 2007) and was downloaded from the USGS website[11]. The report includes a GIS database containing two historic cliff edges and other GIS files used to calculate the rates of change. The annualized retreat rate uncertainty for California cliff edges was reported at 0.2 m/year, with the major uncertainties attributed to georectification of historic (1930s) T-Sheets. Section 4.1 discusses how these erosion rates were updated with an additional cliff edge digitized from recent LiDAR.

Zoulas & Orne Shoreline Data

Additional shoreline data developed by James Zoulas (Zoulas & Orne 2007) were obtained for select beaches and added to the USGS shoreline dataset to update historic shoreline erosion. Shorelines were added for Sequit East and West, Zuma, and Westward beaches.

[10] http://pubs.usgs.gov/of/2006/1251/
[11] http://pubs.usgs.gov/of/2007/1112/

3.8 Coastal Armoring Database

The coastal armoring database (Dare, 2005) was based on interpretation of oblique aerial photography from the California Coastal Records Project (www.californiacoastline.org). The dataset provides offset reference line representing the observable coastal armoring structures. The polyline layer of coastal armoring was updated using the aforementioned aerial topography and imagery, and used in the development of erosion hazard zones that consider armor, discussed in Section 5.5.

4. ANTECEDENT DATA ANALYSIS

Prior to conducting the coastal erosion and flood hazard analysis, ESA conducted antecedent analysis using some of the data described above. This antecedent analysis transformed the input data into parameters used to predict the hazard zones.

4.1 Topographic Analysis

Shore and Cliff Profiles

Shore and cliff profiles were analyzed to identify topographic features pertinent to the coastal erosion analysis. Every 100 meters along the shore, a shore-normal profile were extracted from the digital elevation model described in Section 3.3. The points in each profile were spaced 1 meter apart. These profiles were then plotted and analyzed to identify various geomorphic features including the foreshore beach slope (approximately between mean low water and mean high water), back beach (dune, seawall) toe, and beach crest elevations. All geomorphic feature locations were then mapped in plan-view over high-resolution aerial imagery and DEM hillshade to verify the profile-based interpretation. In some areas, especially where development encroaches on the beach and the profile shows a consistently flat beach surface, a “dune crest elevation” was estimated by choosing a point directly shoreward of development.

Shore Change and Cliff Edge Erosion Rates

Shoreline change rates were computed from the USGS 2006 National Assessment of Shoreline Change[12] updated with a 2010 MHW shoreline extracted from the 2009-2011 LiDAR. Cliff erosion rates were also computed from the USGS assessment updated with the digitized cliff edge from the 2009-2011 LiDAR dataset. Linear regression rates for shorelines and cliffs were measured at 100-meter spacing alongshore and compiled. Cliff erosion rates were checked against erosion rates from local studies covering most of the County coastline west of Los Angeles Harbor (Deiner, 2000). The updated USGS historic rates for sandy shoreline and cliff erosion along Los Angeles County are presented in Figure 17 and Figure 18, respectively.

[12] GIS shorelines available at; http://pubs.usgs.gov/of/2006/1251/#gis.

From the updated USGS erosion rates analyses, the linear regression rate (LRR, the rate computed from more than two cliff edges) was used as the primary erosion rate. There are data gaps in the USGS geodatabase for cliff erosion, so the longest end point rate (EPR, computed from two cliff edges) was used when the LRR could not be calculated. For shoreline erosion, short-term rates were selected to exclude the effect of historic sand placement activities. Because the beaches in Los Angeles oscillate with large storms and Pacific Decadal Oscillation cycles, it was assumed that any accretion rates (negative erosion rates) were a short-term oscillation and not indicative of a long-term trend: All historic accretion rates were set to zero (neither eroding nor accreting) for baseline conditions. Table 4 lists the geologic units and average erosion rates (computed from the USGS cliff erosion database updated with the 2009-2011 LiDAR cliff edge).

Table 4. Geologic units in coastal Los Angeles County

Geologic Unit	Average Erosion Rate (m/yr)	Standard Deviation of Erosion Rates, Along Shore (m/yr)
Kt	-0.28	0.17
Qal	0.03	0.22
Qls	-0.29	0.71
Qoa	-0.06	0.24
Qos	-0.09	0.06
Qs	-0.09	0.1
Qsp	-0.37	0.21
Qtc	-0.08	0.11
Qtm	-0.12	0
Qtn	-0.11	0.12
Qts	-0.08	0.08
Tb	-0.12	0.39
Tcb	-0.83	0.01
Tcob	-0.1	0
Tm	-0.14	0.17
Tma	-0.18	0.26
Tmat	-0.17	0.35
Tmd	-0.26	0.35
Tmf	-0.19	0.17
Tmg	-0.34	0.2
Tr	0.1	1.43
Ts	-0.73	0.51
Tso	-0.59	1.22
Tt	-0.13	0.04
Ttls	0.02	0.51
Tttc	-0.39	0.52

Ttub	-0.12	0.09
Ttus	-0.2	0.23
Tv	-0.89	0.21
Tz	-0.22	1.05

4.2 Backshore Characterization

ESA used a backshore characterization scheme that follows previous studies ESA conducted for the Pacific Institute, Monterey Bay and Ventura County (ESA 2013; ESA 2014; Revell et al 2011; PWA 2009). An offshore baseline (smoothed line offset seaward from the current shoreline) was divided into units based on backshore type (dune/sandy shoreline, inlet, or cliff) and geology. The baseline units were then segmented at 500-meter spacing ("blocks") to conduct the coastal modeling at a scale appropriate to decision making. The datasets described in Section 3 and the results from the topographic analysis (Section 4.1) were summarized into each of these alongshore blocks (269 in total). Each block was assigned a set of parameters including backshore type (shore/cliff/inlet), presence of coastal armor, geology, erosion rates, median/minimum toe elevations, dune/cliff crest elevation, beach slope, foreshore slope, and the 100-year water level (see Section 6.1, below).

4.3 Wave Run-up Calculations and Total Water Level Curves

The total water level is a water elevation determined by the sum of tides, waves, and wave run-up, as well as other components including nearshore currents, storm surge, and atmospheric forcing. As sea level rises, total water levels will rise, as well, such that the amount of time that water reaches the backshore will increase. This increase is the key driving factor forcing the backshore erosion model.

For each alongshore study block, the wave run-up was calculated with inputs of median beach slope for the block and the time series of wave height and period at the nearest of the 39 nearshore CoSMoS model output points (Section 3.6). Wave run-up was added to the ocean water levels. As described in Section 3.6, ocean water levels were generated by combining astronomic tides and synthetic NTRs with synthetic wave conditions. The ocean water levels were added to the computed run-up to produce a total water level time series for each block. Sea level rise amounts were then added to these computed total water levels for future conditions.

The time series of total water levels for each block and scenario was converted to a total water level exceedance curve, which shows the relative amount of time that wave run-up reaches a certain elevation. These curves are the key input to the shoreline erosion model discussed in the following section. An example of total water level exceedance curves for an exposed (high total water level) and sheltered (low total water level) location is presented in Figure 19.

The Stockdon run-up equation was developed for natural shores and includes wave setup and run-up. It is used as a first approximation for run-up but is replaced with a more accurate representation for backshores where inland extents of wave run-up are computed (Section 6.1 Wave Run-up). Some steep portions of the coast were not suited for the Stockdon (2006) method that was developed for flat wide beaches. For the blocks that had beach slopes steeper than 0.1, the TAW method of wave run-up calculation was used in computing the total water level time series (TAW 2002).

5. COASTAL EROSION HAZARD ZONES

5.1 Shoreline Erosion Methods

Shoreline erosion hazard zones were developed by modifying the methodology described in the Pacific Institute (PI) study, with the backshore characterization as the main input (see Section 4.2). The most important variables in the PI model are the backshore toe elevation and the total water level curve, with the beach berm elevation used in place of the backshore toe at wide beaches. This section gives a brief description of the erosion hazard zone methods. For more details about the methods please see the complete Pacific Institute study (PWA 2009 and Revell et al 2011).

Existing erosion methods from previous studies were modified to account for the wide beaches in Los Angeles County that have been artificially widened (Zuma, Santa Monica, etc.). The sandy backshore is not currently eroding at these wide beaches; historic shoreline erosion therefore does not directly correspond to backshore erosion in these locations. To account for these existing conditions, coastal erosion was first projected from the existing shoreline instead of the backshore. Once the calculated beach width dropped below a certain threshold (and in locations where it is currently below the threshold), increased coastal erosion was projected to occur at the backshore. In reality, the backshore is protected against wave attack by a wide beach; the level of backshore toe protection is a function of beach width. Everts (1991) studied beach widths and backshore erosion in Oceanside, CA and found that there was little backshore erosion when the fronting beach was greater than 30 m wide, and near complete protection was provided against large coastal storms by a 60-m beach width. Thus, a trigger distance of 60 m was selected to activate backshore erosion at sandy beaches in the Los Angeles County study area. An example of the mapping result is shown in Figure 3; the beach width north of Venice Pier drops below 60 m between 2050 and 2100 and erosion is projected from the backshore while the beach south of the pier remains wider than 60 m and erosion is only projected form the shoreline.

Types of Shoreline Erosion Hazard Zones

Two types of shoreline erosion hazard zones were prepared for this study. This separation was provided to further delineate long-term SLR induced changes from storm induced changes. These shoreline erosion zones represent the potential maximum retreat of the shoreline for any given year. While the shoreline used for erosion offsets was digitized from October 2010, the shoreline typically reaches its maximum yearly retreat at the end of the winter season. Thus an envelope of seasonal shoreline variation was included in each type of shoreline erosion hazard zone until backshore erosion was activated. In lieu of observational data for the entire Los Angeles County coastline, a representative value was gleaned from prior studies. The USACE conducted a breakwater feasibility study for Santa Monica Bay in which they used observational data from Bolsa Chica to the south that showed seasonal shoreline fluctuation of 15 meters. This value is consistent with the seasonal shoreline fluctuations found by Zoulas and Orne (2007).

1. **Long-Term Erosion.** This can be interpreted as the potential future location of the shoreline (defined as the MHW[13] contour). Not all areas within the hazard zone are expected to erode to this extent by the specified planning horizon, but any location has the potential to erode to this extent (for the scenario specified). This type of coastal erosion hazard zone is the sum of two components: historic erosion and additional erosion due to sea level rise. The historic erosion rate is multiplied by the planning horizon to get the baseline erosion. The shoreline retreat from sea level rise is calculated by multiplying the increase in run-up above the berm elevation by the overall profile slope (between the beach berm and the depth of closure). The potential erosion model ignores the effect of coastal armoring at mitigating erosion; however, if shoreline armoring has been present and maintained over a number of years its presence will be reflected in the calculated historic erosion rates. Additionally, the model does not account for other shore management actions such as sand placement to mitigate future shore recession. The long-term shoreline erosion zones are based on an October-November shoreline, and thus can be considered the typical future fall shoreline position, when the beaches are their widest.

2. **100-Year Storm Erosion.** This type of erosion hazard zone adds the erosion caused by a large storm event to the long-term zone described above and includes an offset to account for seasonal shoreline fluctuations. The potential inland shoreline retreat caused by the impact from a large storm event (100-year) was estimated using the geometric model of dune erosion originally proposed by Komar et al (1999) and applied with different slopes to make the model more applicable to sea level rise (Revell et al 2011). This method is consistent with the FEMA Pacific Coast Flood Guidelines (FEMA 2005a). The 100-year (0.01 annual exceedance probability) was computed by extrapolation with the generalized extreme value distribution (GEV) fitted to the computed total water level time series and compared to the beach berm elevation. Following the FEMA guidelines, the erosion extent was limited by a duration factor of 50% for cases of activated backshore erosion to account for material that would be provided to the beach from the backshore. For cases of projected erosion of the shoreline, no duration factor was applied.

5.2 Shoreline Erosion Mapping

The shoreline erosion hazard zones were mapped for each type of hazard zone (long-term and with 100-year storm), sea level rise scenario and planning horizon using a one-sided buffer (offset) in ESRI's ArcGIS software with an ArcINFO® license. The reference line for the erosion hazard zone is the location of the MHW shoreline at the time of the statewide LiDAR data collection. The hazard zone also includes the area from the arbitrary offshore baseline to the reference line, as this area is already in the active erosive coastal zone. Resulting hazard zones were visually inspected and edited for anomalies. The hazard zones thus represent the inland retreat of the shoreline or backshore, depending on whether the backshore is triggered. An additional set of shoreline erosion hazard zones was developed to consider existing coastal armoring structures, discussed in Section 5.5.

[13] MHW: A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch. MHW at the Los Angeles tide gauge equals 4.56 ft NAVD88.

5.3 Cliff Erosion Methods

Similar to the two sets of shoreline erosion hazard zones that were developed in this study, cliff erosion was projected for both long-term rates and with a factor of safety included for uncertainty. Additional non-coastal erosion zones were also identified for particular areas in the County.

Long-Term Erosion

The Pacific Institute study (PWA 2009 and Revell et al 2011) estimated future erosion rates using the following equation,

$$Erosion\ Rate_{future}(t) = Erosion\ Rate_{historic} * \left(1 + \alpha \frac{P_f - P_e}{P_e}\right)$$

Where P_f and P_e are the future and existing probability of total water level exceedance above the cliff toe elevation, respectively. Since the Pacific Institute study, a number of studies have proposed additional relationships for estimating cliff/bluff erosion rates under accelerated sea level rise (Walkden and Dickson 2008, Ashton et al 2011). Walkden and Dickson (2008) found that the following equation applied well for the cliff backed/low volume beaches undergoing a historic trend in sea level rise at the Naze Peninsula on the Essex coast in Southern England:

$$Erosion\ Rate_{future}(t) = Erosion\ Rate_{historic} * \left(\frac{Rate\ of\ Sea\ Level\ Rise\ (t)}{Rate\ of\ Sea\ Level\ Rise\ (historic)}\right)^m$$

In this equation m =0.5. Ashton et al 2011 investigated the value of m using various data sets for calibration and confirmed that m = 0.5 applies to cliffs/bluffs dominated by wave-driven erosion. In particular, rocky shore platforms and cliffs fronted by low-sediment-volume beaches, both of which apply for the cliffs of Western Los Angeles County.

For this study, Walkden and Dickson 2008 equation was modified, as follows:

$$Erosion\ Rate_{future}(t) = Erosion\ Rate_{historic} * \left(\frac{A\ (t)}{A\ (historic)}\right)^m$$

Where A is the area below the total water level exceedance curve and above the existing toe elevation (Figure 20). This area is a combination of the duration of wave impact above the toe elevation and the intensity of that contact (how high above the toe the waves and wave run-up are reaching). The exponent, m, was kept at 0.5, in agreement with the previous studies.

Erosion landward of wide beaches

There are a number of reaches along the LA coastline characterized by artificially widened beaches (due to historic sand nourishment) that front a coastal cliff, suggesting that the backshore is not exposed to wave action under current conditions. To account for the effect of wide beaches on limiting cliff erosion, the beach width trigger of 60 m was used (see Section 5.1) to initiate accelerated cliff erosion. For years when a fronting beach is above the threshold, the measured historic erosion rates were projected at these particular cliff locations.

Erosion Factor of Safety

The future erosion rates were integrated through time to obtain an erosion distance at each of the planning horizons. To include a factor of safety, an additional offset was included in the erosion distances for each block as a second set of cliff erosion hazard zones. This second set of erosion hazards includes two standard deviations in the alongshore erosion rate for each block.

Terrestrial Erosion / Landslide Zones

In addition to ocean-driven erosion, cliffs along the Los Angeles County coast are subject to erosion from terrestrial forces. USGS National Assessment of Shoreline Change (Section 4.1) indicated that many of the cliffs in the western part of the county are eroding due to runoff and gravity, even if they are not directly affected by the ocean, and geologic maps of the Palos Verdes region clearly indicate that landslides have played a major role in shaping the landscape. Though these hazards are not ocean-driven, since they occur in the coastal zone, this study includes terrestrial erosion hazards, albeit in a cursory manner. For planning projects in areas with potential for significant terrestrial erosion or landslides, additional analysis is needed.

Much of the western part of Los Angeles County is dominated by cliffs. Erosion of the cliff closest to the ocean was analyzed according to the methods outlined above. The next set cliffs are subject to terrestrial erosion. To indicate general erosion patterns and the associated terrestrial erosion hazard area, an annual erosion rate from the USGS National Assessment of Shoreline Change across the county was used to project the cliff edge (digitized as described in Section 4.1) inland for each time horizon in this study. Since cliff erosion often occurs in large events, an additional uncertainty buffer was added to this hazard zone representing 100 years of erosion under the annual rate. This represents the case where there is steady erosion through the time horizon under consideration, plus a severe “100-year” event.

The terrestrial erosion rates were selected as follows. The USGS rates are reported on a transect-by-transect basis and were determined using digitized cliff edges from the 1930s to the 1990s. In many cases, the cliff edges have moved due to human action, i.e. road construction or terracing, yielding very high rates in the USGS study that are not actually representative of natural terrestrial erosion rates. To compare, statistics from the full set of transects intersecting this study’s terrestrial cliff line (“All Transects”) and from a subset including only transects that do not cross significant man-made features (“Natural Transects”) are reported in the Table 5below (in m/yr). Because there is a lot of spatial variability in the USGS erosion rates, it was decided to round the median rate from natural transects up to 10 cm/yr and use that for all terrestrial cliffs. Therefore, the severe event buffer, 100 years of the annual erosion rate, is 10 meters. An example of terrestrial erosion zones is shown in Figure 21 along with the coastal erosion hazards.

Table 5. Statistics from annual terrestrial erosion rates presented by USGS.

	All Transects	Natural Transects
Min	-1.77	-1.19
Max	0.00	0.00
Mean	-0.44	-0.15
Median	-0.30	-0.09
Mode	-0.03	-0.03

StDev	0.43	0.18

Further east, the Palos Verdes region has been greatly influenced be landslides. Similar to the severe event considered in the terrestrial erosion hazard envelope in the west of the county, these events are infrequent but large. To account for this additional hazard, a landslide hazard envelope was developed for the Palos Verdes region using a geologic map of the area (Dibble 1999) and the digital elevation model (c.f. Section 3.3 and Section 3.4). According to the geologic map, Palos Verdes is primarily composed of two geologic units: the lower and upper parts of Tertiary Altamira Shale. In each geologic unit, the maximum landslide width (measured in the cross-shore direction) indicated on the geologic map and the maximum width measured from the digital elevation model and orthoimagery were compared, and the largest width from these two sources was used. This led to a buffer of 360 meters for lower Altamira Shale (at the northwest and southeast of the region) and 1975 meters for upper Altamira Shale (in the southwest of the region, e.g. Portuguese Bend and its environs). The Palos Verdes landslide zone is shown in Figure 22 along with the coastal erosion hazard zone under high SLR at 2100 for reference.

5.4 Cliff Erosion Mapping

The cliff erosion hazard zones were mapped for each sea level rise scenario and planning horizon using a one-sided buffer (offset) in ESRI's ArcGIS software with an ArcINFO® license. The reference line for the erosion hazard zone is the edge of the cliff, which was digitized from recent LiDAR. The hazard zone also includes the beach area shoreward of the cliffs, as this area is already in the active erosive coastal zone. Resulting hazard zones were visually inspected and edited for anomalies.

5.5 Mapping Revisions for Coastal Armoring

The coastal armoring structure data described in Section 3.8 were used to generate a separate set of erosion hazard zones for a theoretical management scenario in which existing armoring structures were maintained and upgraded into the future. This scenario was modeled at the request of study leaders as one “bookend” that compliments the alternative “bookend” that armoring is removed or ineffective, thereby providing a range of mapped hazards associated with the range of potential future armor effectiveness. The erosion hazard zones developed in this study were simply clipped landward of the existing coastal armoring structures in GIS, as shown in Figure 23. These “theoretical” hazards assume the following:

- Existing coastal armoring structures are sufficiently engineered to stop coastal erosion under existing conditions.

- Future scenarios – coastal armoring structures are maintained and upgraded to withstand increased loadings associated with sea level rise and thereby prevent erosion during a 100-year coastal storm, even with the much greater loadings expected in the future due to sea level rise.

- Modeling does not consider active erosion processes (e.g. increased erosion associated with the effects of armoring).

- Resulting hazard zones do not consider maintenance costs, loss of natural beach defenses (ecosystem services), or recreational value associated with eco-tourism and indirect benefits. ESA is mapping the City’s anticipated management scenario of maintain armoring to contrast with the approximate “no armoring” hazard zones.

6. COASTAL FLOOD HAZARD ZONES

Three types of coastal flood zones were developed for this study to characterize potential impacts associated with a coastal storm event: back beach flooding (lagoon flooding behind a built up beach berm), wave run-up (computed from maximum historic and projected wave conditions), and 100-year tidal flooding (generated in tidally open systems). Another set of hazard zones was developed to illustrate changes in coastal inundation associated with more frequent high water levels caused by increasing extreme monthly high water.

6.1 Coastal Storm Flood Hazard Zones

Flooding along the coast is driven by various processes, with the dominant process (likely to cause the most flooding) varying by location and geomorphology. Most sea level rise analyses and maps focus on ocean-storm related flooding (e.g. how a 100-year ocean water level will change with sea level rise). While this may be the dominant process in many sheltered, open-tidal systems, this simplistic approach ignores many of the dominant processes in the Los Angeles study area. For this study, the shoreline was broken into regions based on the geomorphology and dominant process driving coastal flood levels (Figure 24). The following flood processes were considered:

- 100-year water level

- Wave run-up
- Beach berm closure of seasonal lagoons

The subsequent sections describe how these processes were analyzed and mapped for this study. The last section describes how these maps were then combined with the effects of coastal erosion on flooding to create the final coastal storm flood hazard zones.

The major processes that have not been considered are (1) flooding from large precipitation events and (2) river run-off. When combined with high tides and sea level rise at the coastal confluences, these processes likely dominate flooding along the major creeks and rivers in the study area, particularly in the urbanized watersheds. Climate change may also increase rainfall intensity, which would increase 100-year storm flood extents along creeks and rivers (ESA PWA 2015; ESA 2016). This potential effect of climate change was not evaluated in this study.

100-year Ocean Water Level

The 100-year water level (2.34 m NAVD88, Table 2) was assumed to be the major coastal flood process in predominantly open tidal systems as presented in Figure 24 (e.g. Malibu Lagoon, Marina Del Rey, Ballona Creek, Redondo Harbor, Los Angeles/Long Beach Harbor, Alamitos Bay and the San Gabriel River). The 100-year water level was raised by sea level rise for future planning horizons.

Wave Run-up

The wave run-up elevation typically exceeds that of the 100-year tide water level and the lateral extent of flooding is therefore greater in a number of locations, and especially important in low-lying areas. In these areas a wave run-up analysis was conducted to estimate the limit of wave run-up on the profile.

Thirty-five representative profiles were analyzed along the entire Los Angeles County study area (Figure 25). The profiles were taken from the topography and bathymetry datasets described in Section 3.3. Profile locations were optimized locally to limit the amount of interpolated profile resulting from bathymetric data gaps. They reflect the wide range in topography and bathymetry across the Los Angeles County study area.

The Stockdon run-up method (Stockdon et al 2006), developed to calculate run-up on natural, gently-sloping beaches, was used to identify the wave event that caused the maximum run-up at every study block. These wave parameters (significant wave height, wave length, direction) were then used as inputs to a run-up program that is valid for a wider range of profile configurations than just natural beaches. This run-up program, developed by ESA (previously PWA) and consistent with FEMA guidelines, was used to iteratively calculate the dynamic water surface profile along each representative shore profile, the nearshore depth-limited wave, and the run-up elevation at the end of the profile. The dynamic water surface is the water level at the coast that is driven by sets of waves (or wave groups) that cause superelevation of these water levels. Wave run-up is computed using the method of Hunt (1959) which is based on the Iribarren number (also called the Surf Similarity Parameter), a non-dimensional ratio of shore steepness to wave steepness. The run-up is limited to a maximum of about three times the incident wave height, which is generally consistent with other methods that rely on the Iribarren number, as depicted in Figure 26. While there are a variety of run-up equations, they provide a range of results and hence the most simple and direct was chosen (Hunt, 1959).

The program also uses the Direct Integration Method (DIM) to estimate the static and dynamic wave setup and resulting high dynamic water surface profile (FEMA 2005a; Dean and Bender 2006; Stockdon 2006). The methodology is consistent with the FEMA Guidelines for Pacific Coastal Flood Studies for barrier shores, where wave setup from larger waves breaking farther offshore and wave run-up directly on barriers combine to generate the highest total water level and define the flood risk (FEMA 2005a). This program also incorporates overland and structure surface roughness, which act as friction on the uprush of the waves, thus reducing the extent of wave run-up. This method also uses a composite slope technique as outlined in the Shore Protection Manual (USACE 1984) and Coastal Engineering Manual (USACE 2002).

The wave run-up inland extents were projected inland from the zero-meter NAVD contour (reference elevation for composite slope run-up computations) to develop the flood hazard map for the regions where wave run-up was identified as the dominant flood hazard (Figure 24). The calculated maximum elevation of run-up was then used to limit run-up extents over the topography within the mapped extent using tools in ArcGIS.

Seasonally Closed Lagoons

The Los Angeles County shoreline is punctuated by coastal lagoon systems, which occur at confluences between creeks/rivers and the ocean. These systems, also referred to as 'bar-built estuaries' are seasonally controlled by opposing forces: (1) waves that build up the sandy beach, causing the lagoon to close (usually in the summer/fall) and fill with water behind the beach and (2) rainfall runoff that encourages the lagoon to breach the sandy beach and flow into the ocean through a channel. Unlike open tidal systems, these seasonally closed lagoons often experience their highest water levels during closed conditions, when a high beach berm develops and runoff fills the lagoon but does not breach it. This is complicated by management activity (e.g. mechanical or artificial breaching), which varies greatly between lagoons. For this study, a number of seasonally closed lagoons were identified along the Los Angeles shoreline (Figure 24). By using the spring 2009-2011 LiDAR combined with geomorphic assessment of sediment grain size characteristics, beach slopes and wave exposure, the maximum potential beach berm elevation that would back up lagoon waters and cause the highest flooding were estimated (Table 6). It was assumed that the maximum flood level would occur when the lagoon filled up to the beach berm just before spilling over and naturally breaching, which is typically during rainfall events. These water levels are not associated with a return interval (e.g. 100-year), which would require a joint probability analysis of waves building up the beach with the timing/ magnitude/probability of large rainfall events, and is beyond the scope of this project.

Table 6. Geomorphic estimates of maximum berm crest elevations for seasonally closed lagoons – existing conditions

Name	"Maximum" Berm Crest *ft NAVD88*
Arroyo Sequit	11.5
Trancas Canyon	11.8
Zuma Canyon	12.8
Malibu Lagoon	12.8
Topanga Creek	11.5
Santa Monica Canyon	12.1

In the future, the sediment supply is assumed to be consistent with existing conditions to allow the "maximum beach berm elevation" to rise in equilibrium with sea level (i.e. the maximum flood elevation in the closed lagoon rises at the same rate as sea level). The existing and future maximum flood elevations were mapped over existing topography to identify the flood hazard zone in these seasonally closed lagoons systems.

Mapping Coastal Storm Flood Hazard Zones

The individually mapped regions described in the previous sections were merged with the shoreline and cliff erosion hazard zones for each SLR scenario and time horizon. This merging was to include all areas that become hazardous due to future erosion in the future flood hazard zones. Flooded areas with connectivity to the ocean (over the digital elevation model) were mapped, as well as any pools (greater than 3 m^2) within 5 meters of areas connected to the ocean to conservatively account for seepage and potential errors in the DEM. For the same reason, patches of dry land that are smaller than 1 acre and completely surrounded by inundated area are also shown as flooded. Areas without apparent connection to the ocean were kept but were labeled as "connectivity uncertain" in the attribute table. These should be displayed in a different shade to show that unless there is a connection (e.g. through a culvert/under a bridge), those areas will not necessarily flood due to coastal processes. Wave run-up flood hazard areas are considered "connected" as the modeling results show that wave run-up can connect those low-lying areas to the ocean.

6.2 Rising Tides Hazard Zones

To address coastal flooding based on higher water levels becoming generally more frequent, the Extreme Monthly High Water (EMHW) (highest tidal water level per month, on average) was mapped along the coastline, for existing conditions and future sea level rise (not considering storm events). Two types of datasets were developed: a general tidal flooding area and a depth grid (or raster). These hazard areas do not consider future erosion, so the coastal erosion hazard zones should be used in combination with these rising tidal flooding zones for any applications in the planning process.

EMHW was estimated by averaging the maximum monthly water level for every month recorded at the Los Angeles tide gauge (EMHW = 2.0 meters (6.6 ft) NAVD88). In reality, EMHW varies along the coast, especially in the inlets and sloughs; however, for this project, which is focused on the open coast, a single value of EMHW was used. Sea level rise projections were added to the EMHW for each sea level rise and planning horizon (Section 3.1) and mapped over the DEM (Section 3.3). Areas in the DEM below the flood elevation were marked as flooded, and those areas with a direct connection with the ocean were labeled "connected" in the "Connection" attribute. The other low-lying areas were also included and were labeled "connection uncertain". The connectivity of these areas should be assessed for individual sites in the planning process to determine whether they are connected to the ocean (e.g. through culverts, under bridges).This method is similar to the identification of "low lying areas" in the NOAA SLR viewer. Areas that are labeled as "connection uncertain" may become impacted by rising groundwater levels in the future, whether or not they are connected to the ocean over the ground surface.

Depth maps (separate datasets for the "connected" and "connectivity uncertain" maps) were developed by overlaying the monthly tidal flooding area over the topography and using the difference between the flood elevation and the topography to calculate depth. The 2009-2011 CA Coastal Conservancy DEM is hydroflattened, which means that the reported elevations in wet areas correspond to an approximate water surface elevation rather than the actual bathymetry. These areas (as identified by the 3D breaklines provided with the DEM) were assigned a value of 999. This value was specified because depth could not be calculated in these areas (as the LiDAR does not penetrate water). These areas are considered already hazardous as they are already flooded.

7. DISCUSSION OF MODEL UNCERTAINTY

Coastal erosion and flood modeling include uncertainties regarding the input data, shore and human responses, and the methodologies employed. Some uncertainties are more easily managed than others. This section describes the uncertainties inherent to coastal erosion modeling results for this regional level assessment, and presents recommendations on how to interpret the results with caution. There are also uncertainties with coastal flood modeling which are generally more intuitive and therefore not described here.

Uncertainty Alongshore

In some cases, projected erosion can vary significantly between two adjacent coastal analysis blocks (blocks are sections of shore; Section 4.2). Uncertainty in erosion is partially addressed within each analysis block by including an uncertainty buffer that is calculated based on the along-shore range in erosion rates per block (Section 5.3), but significant variations in the range of erosion extents exist in the historical data, and therefore future erosion may also vary substantially by location.

Projected erosion can vary significantly between 2050 and 2100 between adjacent blocks, even those of similar type (cliff) and geology. Variation can be due to differences in key backshore attributes (i.e. shore geometry, toe elevation, slope, geology) or oceanographic conditions (i.e. waves, water levels, sea level rise). Also, localized variations in erosion resistance are not modeled except to the extent represented in historical erosion. The methods for modeling accelerated coastal erosion were developed for cliffs that are currently eroding under existing conditions and are exposed to the ocean total water levels to some degree (Section 5.3). If the toe of a cliff is not exceeded under current conditions (meaning that waves do not presently induce erosion), even a small change in exposure to wave action is a large relative increase from historical conditions. Mathematically, the resulting erosion rate increases drastically due to the ratio of future to existing exposure. This is seen in a number of locations along the coastline, and an example is shown in Figure 27 along with plots of the relevant analysis components. To conservatively account for possible erosion extents, the interpreter may look to adjacent blocks of similar backshore type and geology to determine the range of projected erosion for a given year. This comparison will indicate greater uncertainty than the local uncertainty (block-averaged deviations from the mean erosion rate), and a greater maximum erosion. This concept is illustrated in Figure 27, where the greater erosion extent is projected to an adjacent area.

Projected erosion can vary significantly between adjacent backshore types. This is due to the simplified modeling approach which was developed for either sandy shorelines or cliffs, rather than accounting for the full range of intermediate conditions (see Section 5.1 and 5.3, respectively, for a discussion of sandy and cliff backshores). An example of different erosion extents for different adjacent backshore types is shown in Figure 28, where erosion of sandy shores is greater than those characterized as cliffs, resulting in discontinuities in the potential erosion extents at the reach boundaries.

It is important to note that these erosion hazard zones are not predictions of the future shore and cliff edges, but rather envelopes of potential erosion extents. This means that the erosion could extend to these limits in any particular location, but erosion may not extend to the mapped limits in all locations by the date specified. Of course, it is also possible that these hazard zones under-predict localized erosion extents. Therefore, these maps do define boundaries between risky and risk-free areas, but rather provide a geo-spatial and temporal estimate of hazard extents for planning purposes: The risk to assets near the ocean is inherent in their location and therefore independent of the accuracy and uncertainty associated with erosion and flooding forecasts.

8. ASSESSING A RANGE OF SCENARIOS

This study considered a range of future scenarios related to sea level rise and coastal erosion. A set of simple layers were developed to easily visualize the range of hazard outcomes from all scenarios. For existing conditions and all planning horizons (2030, 2050, 2100), all the hazard zones were overlaid to identify how “hazardous” a given location is by any coastal hazard type. The level of hazard was quantified by counting the number of hazards to which a location is exposed. This process of overlaying and counting the number of overlapping hazards is called “spatial aggregation,” and is shown in Figure 29. The spatial aggregation includes both erosion types (long term, event), all flood types (100-year ocean water level, wave run-up, lagoon beach berm), and long-term inundation for existing conditions (2010), medium and high SLR for 2030, 2050, 2100 and the extreme SLR case at 2080. An example of the spatially aggregated output is shown in Figure 8.

These spatially aggregated layers do not, by any means, contain a comprehensive range of possible future scenarios, and none of the scenarios presented are associated with a particular probability of future occurrence (which requires statistical approaches which are exceedingly complex given the large range of uncertainty associated with projections of sea level rise). This is simply a way to visualize the full range of scenarios and hazards assessed and understand qualitatively, how projected future hazards vary (e.g. if a site is hazardous regardless of the scenario, or whether the site is only hazardous for the most extreme scenarios).

9. VULNERABILITY ASSESSMENT

This section describes the assets vulnerable to the different coastal erosion and flood hazard scenarios. The county's assets are classified by sector into transportation infrastructure, buildings and structures, public facilities (fire, police, hospitals, and schools), sanitary sewer infrastructure, storm drain infrastructure, and ecosystem assets. The data sources for each asset class are described in the sections below, along with tables tallying the number of assets in each city and unincorporated regions of the county that are vulnerable to different hazard scenarios.

The vulnerability assessments in the sections below divide hazards into four groups: long-term erosion, long-term tidal flooding, storm/event erosion, and storm/event flooding. Long-term erosion includes both shoreline and cliff erosion (Section 5.1 and Section 5.3). Long-term inundation comes from the extreme monthly high water analysis (Section 6.2). Storm/event erosion combines shoreline and cliff erosion with their standard deviations and wave run-up areas to account for a single storm event's erosion (Section 5.1, Section 5.3, and Section 6.1, Wave Run-up). Storm/event flooding combines the 100-year tide, wave run-up areas, bar built estuaries, and long-term erosion of shorelines and cliffs (Section 6.1, Section 5.1, and Section 5.3). These four hazards represent decreasing severity:

- areas subject to long-term erosion would be lost entirely
- areas experiencing long-term tidal flooding would be regularly flooded by monthly high tides
- areas experiencing storm or event erosion are likely damaged but could be recoverable
- areas experiencing storm or event flooding are likely to return to service when floodwaters recede.

The tables in the sections below are presented in this order of decreasing severity.

While the severity of consequences decreases across these hazards, the number of assets affected may not increase because different regions are more exposed to different risk. This is particularly clear when comparing long-term tidal flooding exposure and event erosion exposure between communities like Malibu and Long Beach. The former is dominated by cliffs, so event erosion generally affects more assets, while the latter is dominated by lower, sandy shorelines, so long-term tidal flooding generally affects more assets. Nevertheless, the first two hazards are steadily rising into the future, while the second two occur in sudden steps (storm events) at an unknown time in the future, so it is logical to order them this way.

It is also worth noting that the number of assets affected increase over time and with increasing sea level rise scenario, except for the Extreme case, with 5.5 feet of sea level rise in 2080. For hazards that include an erosion component (long-term erosion, event erosion, and storm flooding), the High 2100 case and the Extreme 2080 case have the same water level, but the High 2100 case includes an additional 20 years of erosion. Thus, even though the Extreme case includes a more aggressive sea level rise estimate, it may have fewer assets exposed in areas where long-term erosion plays a significant role.

In addition to the tables summarizing the intersection of the hazard and asset layers, planners may also choose to review this study's hazard and asset layers using GIS software. Within the GIS environment, planners can select their area(s) of interest from the county's 65 miles of coastline, choose an appropriate viewing scale, and add other information, such as an aerial photograph as a basemap. The formats and availability of the GIS files are described in Appendix 1.

9.1 Methodology

To assess the vulnerability of the county's assets, the assets in different categories were identified and intersected with each hazard layer. For each city and for the county as a whole, point assets in each hazard zone were counted, linear assets (like roads and pipelines) were measured by mile, and planar assets (like ecosystem areas) were measured by acre. These results are reported in tables in the following sections.

Asset data were provided by Los Angeles County agencies. Some of these data leave gaps in certain cities, since the cities and the county do not always maintain the same data or level of detail. In these cases, it was noted that data were not available, as opposed to areas with data coverage that simply have no assets in a particular sector. Asset data for the electric and energy supply systems were not available, so this asset class was not considered. The asset data provided by the county and their sources are summarized in Table 7.

TABLE 7. DATA SOURCES

Dataset	Source	Year
Roads	LA Department of Beaches and Harbors	2016
Bikeways	LA County GIS Portal	2012
Building Footprints	Los Angeles Region Imagery Acquisition Consortium (LARIAC) *via LA County GIS Portal*	2008
Parking Lot Footprints	LARIAC *via LA County GIS Portal*	2014
Public Facilities	Location Management System via *via LA County GIS Portal*	2016
Wastewater Treatment Plants	LA Department of Public Works	2013
Sanitary Pump Stations	LA Department of Public Works	2013
Sanitary Sewer Pipelines	LA Department of Public Works	2013
LA CSD Sanitary Pipelines	LA County Sanitation Districts	2015
Storm Drain Pump Stations	LA Department of Public Works	2013
Storm Drain Gravity Mains	LA Department of Public Works	2013
Storm Drain Force Mains	LA Department of Public Works	2013
Storm Drain Culverts	LA Department of Public Works	2013
Wetlands and Beaches	National Wetlands Inventory	2016

9.2 Transportation Infrastructure

Data Sources

Transportation data include road centerlines and bikeway centerlines. Road data were taken from the Los Angeles County Department of Beaches and Harbors (Noble 2016), and bikeway data were taken from the Los Angeles County GIS portal[14]. Airports and major rail stations (Amtrak and Intermodal stations) were also considered, but none was impacted under any of the hazard scenarios.

Countywide Infrastructure

Though transportation infrastructure has been divided by city and community, there are some assets that would affect the entire county if interrupted. In particular, Highway 1 acts as a main artery for the coastal communities in Los Angeles County, and if it were damaged and experienced a significant loss of service, transportation along coast would be impacted. Even if the reach of Highway 1 in a particular city were unaffected, damage in a neighboring city could cause similar disruption, making this a “cross-cutting” vulnerability. As such, it was deemed valuable to emphasize the length of Highway 1 at risk in the entire county under each hazard scenario.

TABLE 8. COUNTYWIDE TRANSPORTATION - HIGHWAY 1 VULNERABILITY

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
Hazard	**2010**	**2030**	**2050**	**2100**	**2050**	**2050**	**2100**	**2080**
Long-term Erosion	0	0	0	2.1	0	0	5.9	2.5
Long-term tidal flooding	0.3	0.3	0.3	0.4	0.3	0.4	2.2	2.2
Storm/Event Erosion	2.9	3.5	4.7	9.8	4.1	8.5	12.5	12.4
Storm/Event Flooding	3.3	3.8	5.8	12.6	4.5	9.1	16.3	14.3

NOTES:
Measurements given in miles of roadway.

Vulnerability Summary

14 http://egis3.lacounty.gov/dataportal/

TABLE 9. TRANSPORTATION – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0.2	0.4	0.2	0.4	0.5	0.5
Hermosa Beach	0	0	0	0.8	0	0	1.4	1.3
Long Beach	0	0.3	0.6	2.2	0.4	1.1	4.0	3.7
Los Angeles	0.5	0.7	1.2	5.7	1.1	1.6	11.0	8.1
Malibu	1.3	1.3	1.6	8.1	1.4	1.9	13.6	9.7
Manhattan Beach	0	0	0	1.1	0	0.1	2.6	2.6
Palos Verdes Estates	0.3	0.3	0.4	1.4	0.3	0.4	2.5	1.6
Rancho Palos Verdes	0.4	0.4	0.4	1.3	0.4	0.4	1.8	1.0
Redondo Beach	1.2	1.3	1.3	1.3	1.3	1.3	2.1	2.0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0.4	0.4	0.4	0.5	0.4	0.4	1.0	0.6
Unincorporated	0	0.1	0.2	1.4	0.1	0.4	2.5	1.8
Full County	4.0	4.7	6.2	24.1	5.5	8.1	42.9	33.0

NOTES:
Measurements given in miles of roadway and bikeway affected.

TABLE 10. TRANSPORTATION – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2050**	**2050**	**2050**	**2100**	**2080**
Carson	0	0	0	0.1	0	0	0.3	0.3
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	17.3	26.5	40.2	90.5	41.2	72.9	130.4	130.4
Los Angeles	18.5	24.7	30.2	51.6	30.6	41.3	86.2	86.2
Malibu	0.1	0.1	0.1	0.3	0.1	0.1	0.5	0.5
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0.2	0	0	1.3	1.3
Santa Monica	0	0	0	0.1	0	0	0.5	0.5
Torrance	0	0	0	0	0	0	0	0
Unincorporated	1.3	1.4	1.4	2.4	1.4	1.5	4.0	4.0
Full County	37.3	52.7	71.8	145.1	73.3	115.8	223.2	223.2

NOTES:
Measurements given in miles of roadway and bikeway affected.

TABLE 11. TRANSPORTATION – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0	0	0	0	0	0	0	0
El Segundo	0.4	0.4	0.5	0.5	0.5	0.5	0.8	0.8
Hermosa Beach	0	0.1	1.1	4	0.4	3	5.9	5.7
Long Beach	3.8	4.3	4.9	6.2	4.8	5.7	8.2	8.1
Los Angeles	3.9	4.7	6.6	16.7	5.5	8.8	23.6	21.2
Malibu	7	9.3	14	25.7	11.5	20.7	29.6	27.7
Manhattan Beach	0.2	0.6	1.3	2.4	1.3	2.1	6.4	6.4
Palos Verdes Estates	0.3	0.4	0.7	2.2	0.4	0.8	3.7	2.2
Rancho Palos Verdes	0.4	0.7	1.2	3.1	0.7	1.2	3.6	2.6
Redondo Beach	1.6	1.7	1.7	2.2	1.7	1.7	4.3	3.3
Santa Monica	0.2	0.2	0.7	3	0.3	2.7	4.3	4.3
Torrance	0.4	0.4	0.4	0.9	0.4	0.4	1.2	0.9
Unincorporated	1.8	2.3	2.5	3.7	2.4	2.7	4.2	3.9
Full County	20	25.1	35.6	70.7	29.8	50.3	95.9	87.1

NOTES:
Measurements given in miles of roadway and bikeway affected.

TABLE 12. TRANSPORTATION – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0	0	0	0.2	0	0.1	0.5	0.5
El Segundo	0	0.1	0.3	0.4	0.3	0.4	0.5	0.5
Hermosa Beach	0	0.1	1.1	3.3	0.4	3.0	5.0	5.0
Long Beach	48.4	65.7	77.7	113.1	78.1	95.2	147.1	147.1
Los Angeles	36.2	41.7	47.6	78.4	47.5	59.3	122.1	120.3
Malibu	7.0	8.5	11.4	22.4	10.1	19.9	26.9	25.8
Manhattan Beach	0.2	0.5	1.1	2.1	1.0	2.1	2.6	2.6
Palos Verdes Estates	0.3	0.3	0.4	1.4	0.3	0.4	2.5	1.6
Rancho Palos Verdes	0.4	0.4	0.4	1.3	0.4	0.5	1.8	1.1
Redondo Beach	1.3	1.3	1.3	2.0	1.3	1.6	4.0	4.0
Santa Monica	0.2	0.2	0.7	3.0	0.3	2.7	4.3	4.3
Torrance	0.4	0.4	0.4	0.5	0.4	0.4	1.0	0.6
Unincorporated	3.2	3.4	3.6	5.7	3.5	4.8	8.2	8.1
Full County	97.3	122.4	145.9	233.6	143.4	190.4	326.5	321.4

NOTES:
Measurements given in miles of roadway and bikeway affected.

9.3 Buildings and Structures

Data Sources

Building and structure data include building and parking lot footprints. The building and parking lot footprints were taken from the LA County GIS portal, which provides building footprints generated in 2008 and parking lot footprints generated in 2014.

In the tables below, buildings and parking lots are counted in each city and community and in the county as a whole. Buildings and parking lots crossing the border between two cities are counted in both of the cities, but only once in the full county sum. This avoids double-counting in the full county sum, but it means that the sum of buildings in each city may be more than the full county sum.

Vulnerability Summary

TABLE 13. BUILDINGS AND STRUCTURES – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0	0	0	0	0	0	0	0
El Segundo	0	1	4	11	4	7	25	25
Hermosa Beach	0	0	0	9	0	0	92	85
Long Beach	27	58	100	243	72	136	321	280
Los Angeles	52	76	106	382	83	130	581	469
Malibu	698	917	1054	1419	1011	1136	1629	1576
Manhattan Beach	0	0	0	2	0	0	40	46
Palos Verdes Estates	12	34	56	97	34	58	139	98
Rancho Palos Verdes	27	39	43	74	39	47	86	78
Redondo Beach	12	14	16	23	14	19	62	56
Santa Monica	2	2	2	3	2	2	6	6
Torrance	13	42	48	52	42	48	87	56
Unincorporated	4	6	8	14	7	9	17	15
Full County	847	1189	1436	2328	1308	1591	3083	2788

NOTES:
Numbers reported are the sum of building and parking lot footprints affected by this hazard.

TABLE 14. BUILDINGS AND STRUCTURES – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2050**	**2050**	**2050**	**2100**	**2080**
Carson	5	6	6	20	6	11	194	194
El Segundo	3	3	3	4	3	3	4	4
Hermosa Beach	0	0	0	6	0	1	57	57
Long Beach	1080	1958	3686	7503	3775	6435	10147	10147
Los Angeles	1729	2373	2903	4733	2940	3881	7080	7080
Malibu	159	183	214	343	216	267	553	553
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	16	19	20	34	20	29	58	58
Santa Monica	2	2	2	4	2	4	16	16
Torrance	0	0	0	0	0	0	0	0
Unincorporated	26	31	43	110	43	56	263	263
Full County	3020	4575	6876	12754	7004	10683	18365	18365

NOTES:
Numbers reported are the sum of building and parking lot footprints affected by this hazard.

TABLE 15. BUILDINGS AND STRUCTURES – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	10	13	16	26	18	25	33	33
Hermosa Beach	3	4	7	223	6	126	326	312
Long Beach	278	293	325	447	316	364	593	552
Los Angeles	150	214	305	788	232	346	1218	995
Malibu	1218	1279	1368	1707	1290	1505	1939	1854
Manhattan Beach	0	0	0	48	0	1	396	403
Palos Verdes Estates	24	57	77	116	57	79	171	123
Rancho Palos Verdes	39	53	77	127	57	78	142	109
Redondo Beach	47	49	51	56	50	55	108	101
Santa Monica	10	14	19	71	16	31	161	161
Torrance	39	49	51	81	49	51	125	82
Unincorporated	9	15	15	22	15	16	40	32
Full County	1826	2039	2309	3710	2105	2675	5250	4755

NOTES:

Numbers reported are the sum of building and parking lot footprints affected by this hazard.

TABLE 16. BUILDINGS AND STRUCTURES – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	7	7	11	71	11	21	374	374
El Segundo	3	4	7	14	7	10	26	26
Hermosa Beach	3	5	8	158	7	132	343	337
Long Beach	4278	5713	6610	8722	6658	7617	12066	12066
Los Angeles	3222	3673	4156	6224	4159	5032	9378	9268
Malibu	1205	1299	1364	1695	1324	1520	1916	1874
Manhattan Beach	0	0	0	2	0	0	40	46
Palos Verdes Estates	12	34	56	97	34	58	139	98
Rancho Palos Verdes	27	39	47	78	41	51	90	82
Redondo Beach	31	37	43	71	41	54	132	127
Santa Monica	10	14	20	72	17	32	165	165
Torrance	13	42	48	52	42	48	87	56
Unincorporated	54	59	66	222	67	136	327	325
Full County	8863	10924	12430	17472	12403	14705	25073	24834

NOTES:

Numbers reported are the sum of building and parking lot footprints affected by this hazard.

9.4 Public Facilities

Data Sources

Public Facilities data include police stations, fire stations, hospitals, and schools. Building footprints available through the LA County GIS portal were combined with infrastructure identifications from the County Location Management System (also available through the LA County GIS portal) to determine the footprints of public facilities. In some cases, construction since 2008 (the source year of the footprint data) led to public facility points without footprints, and in these cases the footprints were digitized from satellite imagery. Thus, these counts include any buildings identified as public facilities, whose footprints intersect each hazard area.

Vulnerability Summary

Tables list four public facilities separated by slashes: Fire Stations \ Police Stations \ Hospitals \ Schools.

TABLE 17. PUBLIC FACILITIES – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
El Segundo	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Hermosa Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Long Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Los Angeles	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Malibu	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Manhattan Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Palos Verdes Estates	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Rancho Palos Verdes	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Redondo Beach	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0
Santa Monica	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Torrance	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Unincorporated	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Full County	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0

NOTES:

Numbers reported are the sum of public facility footprints affected by this hazard. They are divided as: Fire Stations \ Police Stations \ Hospitals \ Schools

TABLE 18. PUBLIC FACILITIES – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
El Segundo	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Hermosa Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Long Beach	1 \ 0 \ 0 \ 0	1 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	3 \ 0 \ 0 \ 4	3 \ 0 \ 0 \ 4
Los Angeles	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	4 \ 0 \ 0 \ 2	4 \ 0 \ 0 \ 2
Malibu	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Manhattan Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Palos Verdes Estates	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Rancho Palos Verdes	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Redondo Beach	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0
Santa Monica	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Torrance	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Unincorporated	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	1 \ 0 \ 0 \ 0	1 \ 0 \ 0 \ 0
Full County	4 \ 1 \ 0 \ 0	4 \ 1 \ 0 \ 1	5 \ 1 \ 0 \ 1	6 \ 1 \ 0 \ 1	5 \ 1 \ 0 \ 1	6 \ 1 \ 0 \ 1	9 \ 1 \ 0 \ 6	9 \ 1 \ 0 \ 6

NOTES:

Numbers reported are the sum of public facility footprints affected by this hazard. They are divided as: Fire Stations \ Police Stations \ Hospitals \ Schools

TABLE 19. PUBLIC FACILITIES – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
El Segundo	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Hermosa Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Long Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Los Angeles	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Malibu	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	1 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	2 \ 0 \ 0 \ 0	2 \ 0 \ 0 \ 0
Manhattan Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Palos Verdes Estates	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Rancho Palos Verdes	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Redondo Beach	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0
Santa Monica	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Torrance	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Unincorporated	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Full County	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	0 \ 1 \ 0 \ 0	2 \ 1 \ 0 \ 0	2 \ 1 \ 0 \ 0

NOTES:

Numbers reported are the sum of public facility footprints affected by this hazard. They are divided as: Fire Stations \ Police Stations \ Hospitals \ Schools

TABLE 20. PUBLIC FACILITIES – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
El Segundo	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Hermosa Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Long Beach	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 1	3 \ 0 \ 0 \ 3	2 \ 0 \ 0 \ 1	2 \ 0 \ 0 \ 2	3 \ 0 \ 0 \ 6	3 \ 0 \ 0 \ 6
Los Angeles	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	4 \ 0 \ 0 \ 1	3 \ 0 \ 0 \ 0	3 \ 0 \ 0 \ 0	4 \ 0 \ 0 \ 3	4 \ 0 \ 0 \ 3
Malibu	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	2 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	2 \ 0 \ 0 \ 0	2 \ 0 \ 0 \ 0
Manhattan Beach	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Palos Verdes Estates	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Rancho Palos Verdes	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Redondo Beach	0 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0
Santa Monica	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Torrance	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0
Unincorporated	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	1 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	0 \ 0 \ 0 \ 0	1 \ 1 \ 0 \ 0	1 \ 1 \ 0 \ 0
Full County	5 \ 1 \ 0 \ 1	6 \ 1 \ 0 \ 1	6 \ 1 \ 0 \ 1	11 \ 1 \ 0 \ 4	6 \ 1 \ 0 \ 1	6 \ 1 \ 0 \ 2	11 \ 2 \ 0 \ 9	11 \ 2 \ 0 \ 9

NOTES:

Numbers reported are the sum of public facility footprints affected by this hazard. They are divided as: Fire Stations \ Police Stations \ Hospitals \ Schools

9.5 Sanitary Sewer Infrastructure

Data Sources

Sanitary sewer data include sewer pipes, pump stations, and wastewater treatment plants; however the data used in this study do not cover the whole county. The data provided for this study are from the Consolidated Sewer Maintenance District (SMD, administered by the Los Angeles County Department of Public Works). This organization (SMD) maintains sanitary and collection systems, not trunk systems, thus the dataset was augmented with main lines from the Los Angeles County Sanitation Districts (CSD, a partnership of wastewater districts in the county). Infrastructure maintained by other sanitation districts in the county (municipal or otherwise) was not included in the files provided for this study.

Countywide Infrastructure

Though sanitary sewer infrastructure has been divided by city and community, there are some assets that would affect the entire county if interrupted. In particular, much of county depends on the Hyperion Water Reclamation Plant in Playa Del Rey for treatment of wastewater. Without this plant, the collection systems in each city and community that pump to the facility would begin to back up. Even though the asset itself is technically within the City of Los Angeles, the impacts of a loss of service would be felt countywide. The plant is elevated and set back from the ocean, so it is not exposed to any of the hazards on the time horizons addressed in this study; however, it is an important enough asset that it should be considered in any adaptation plans developed by the county.

Vulnerability Summary

TABLE 21. SANITARY SEWER (POINT) – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	1	1	1	4	1	2	7	7
Malibu	1	1	1	2	1	2	2	2
Manhattan Beach	0	0	0	1	0	0	2	2
Palos Verdes Estates	0	1	1	1	1	1	1	1
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	4	4	4	4	4	4	7	6
Santa Monica	0	0	0	0	0	0	0	0
Torrance	1	1	1	1	1	1	1	1
Unincorporated	0	1	1	1	1	1	1	1
Full County	7	9	9	14	9	11	21	20

NOTES:
Numbers reported are the sum of water treatment plants and pump stations affected by this hazard.

TABLE 22. SANITARY SEWER (POINT) – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2050	2050	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0	0	0
Malibu	0	0	0	0	0	0	0	0
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0	0	0	0	0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0	0	0	0	0	0	0	0
Full County	0	0	0	0	0	0	0	0

NOTES:
Numbers reported are the sum of water treatment plants and pump stations affected by this hazard.

TABLE 23. SANITARY SEWER (POINT) – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	3	4	4	7	4	5	11	11
Malibu	1	2	2	2	2	2	2	2
Manhattan Beach	0	0	0	2	0	0	3	3
Palos Verdes Estates	0	1	1	1	1	1	2	1
Rancho Palos Verdes	0	0	0	1	0	0	1	1
Redondo Beach	4	4	5	6	5	5	7	6
Santa Monica	0	0	0	0	0	0	0	0
Torrance	1	1	1	1	1	1	1	1
Unincorporated	0	1	1	1	1	1	1	1
Full County	9	13	14	21	14	15	28	26

NOTES:
Numbers reported are the sum of water treatment plants and pump stations affected by this hazard.

TABLE 24. SANITARY SEWER (POINT) – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	3	4	4	4	4	4	7	7
Malibu	1	1	1	2	1	2	2	2
Manhattan Beach	0	0	0	1	0	0	2	2
Palos Verdes Estates	0	1	1	1	1	1	1	1
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	4	4	5	5	5	5	7	6
Santa Monica	0	0	0	0	0	0	0	0
Torrance	1	1	1	1	1	1	1	1
Unincorporated	0	1	1	1	1	1	1	1
Full County	9	12	13	15	13	14	21	20

NOTES:
Numbers reported are the sum of water treatment plants and pump stations affected by this hazard.

TABLE 25. SANITARY SEWER (LINEAR) – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo [b]	0	0	0	0	0	0	0	0
Hermosa Beach [b]	0	0	0	0	0	0	0	0
Long Beach [b]	0	0	0	0	0	0	0	0
Los Angeles [b]	0.7	0.7	0.7	0.8	0.7	0.7	0.9	0.8
Malibu [b]	0.1	0.1	0.2	0.8	0.1	0.3	1.2	0.9
Manhattan Beach [b]	0	0	0	0	0	0	2.2	2.2
Palos Verdes Estates	0	0	0.1	1.1	0	0.2	2.3	1.4
Rancho Palos Verdes	0	0	0	0.6	0	0.1	1.6	1.2
Redondo Beach [b]	0	0	0	0	0	0	0.5	0.2
Santa Monica [a]	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
Torrance [b]	0	0	0	0.1	0	0	0.5	0.2
Unincorporated	0	0	0	0.1	0	0	0.1	0.1
Full County	0.9	0.9	1.1	3.5	0.9	1.3	9.4	6.9

NOTES:

Measurements reported are the sum of sewer pipes from SMD and CSD affected by this hazard in miles.

[a] No data were provided for this asset in this city, so counts exposed to hazard scenarios are unknown.

[b] Only trunk line data were provided for in this city, so exposure to hazard refers only to these. Full County is mixed.

TABLE 26. SANITARY SEWER (LINEAR) – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2050	2050	2050	2100	2080
Carson	0.3	0.3	0.3	0.4	0.3	0.4	2.6	2.6
El Segundo [b]	0	0	0	0	0	0	0	0
Hermosa Beach [b]	0	0	0	0	0	0	0	0
Long Beach [b]	0.6	0.8	1.1	3.0	1.1	1.7	7.4	7.4
Los Angeles [b]	0.4	0.4	0.4	0.5	0.4	0.5	0.6	0.6
Malibu [b]	0	0	0	0	0	0	0	0
Manhattan Beach [b]	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach [b]	0	0	0	0	0	0	0	0
Santa Monica [a]	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
Torrance [b]	0	0	0	0	0	0	0	0
Unincorporated	1.6	1.7	1.8	4.6	1.8	2.0	7.4	7.4
Full County	2.9	3.2	3.6	8.4	3.6	4.5	17.9	17.9

NOTES:

Measurements reported are the sum of sewer pipes from SMD and CSD affected by this hazard in miles.

[a] No data were provided for this asset in this city, so counts exposed to hazard scenarios are unknown.

[b] Only trunk line data were provided for in this city, so exposure to hazard refers only to these. Full County is mixed.

TABLE 27. SANITARY SEWER (LINEAR) – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo [b]	0	0	0	0	0	0	0	0
Hermosa Beach [b]	0	0	0	0.2	0	0	0.5	0.5
Long Beach [b]	0	0	0	0	0	0	0	0
Los Angeles [b]	0.7	0.8	0.9	1.2	0.8	0.9	1.3	1.2
Malibu [b]	0.1	0.3	0.6	1.2	0.4	0.6	1.4	1.4
Manhattan Beach [b]	0	0	0	0.4	0	0	2.8	2.8
Palos Verdes Estates	0	0.1	0.4	2.0	0.1	0.5	3.8	2.1
Rancho Palos Verdes	0	0.1	0.4	3.3	0.1	0.4	4.1	2.8
Redondo Beach [b]	0	0	0	0.8	0	0.1	1.2	1.1
Santa Monica [a]	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
Torrance [b]	0	0	0.1	0.5	0	0.1	0.6	0.6
Unincorporated	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Full County	1.0	1.5	2.6	9.9	1.6	2.9	15.9	12.5

NOTES:

Measurements reported are the sum of sewer pipes from SMD and CSD affected by this hazard in miles.

[a] No data were provided for this asset in this city, so counts exposed to hazard scenarios are unknown.

[b] Only trunk line data were provided for in this city, so exposure to hazard refers only to these. Full County is mixed.

TABLE 28. SANITARY SEWER (LINEAR) – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0.3	0.4	0.4	0.7	0.4	0.4	5.0	5.0
El Segundo [b]	0	0	0	0	0	0	0	0
Hermosa Beach [b]	0	0	0	0	0	0	0	0
Long Beach [b]	1.1	1.3	1.7	5.1	1.7	3.1	10.8	10.8
Los Angeles [b]	0.9	0.9	1.0	1.1	1.0	1.0	1.4	1.4
Malibu [b]	0.1	0.1	0.2	0.8	0.1	0.3	1.2	0.9
Manhattan Beach [b]	0	0	0	0	0	0	2.2	2.2
Palos Verdes Estates	0	0	0.1	1.1	0	0.2	2.3	1.4
Rancho Palos Verdes	0	0	0	0.6	0	0.1	1.6	1.2
Redondo Beach [b]	0	0	0	0	0	0	0.5	0.2
Santa Monica [a]	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
Torrance [b]	0	0	0	0.1	0	0	0.5	0.2
Unincorporated	1.9	2.0	2.1	6.4	2.2	4.8	8.1	8.1
Full County	4.4	4.8	5.6	15.9	5.4	10.0	33.7	31.4

NOTES:

Measurements reported are the sum of sewer pipes from SMD and CSD affected by this hazard in miles.

[a] No data were provided for this asset in this city, so counts exposed to hazard scenarios are unknown.

[b] Only trunk line data were provided for in this city, so exposure to hazard refers only to these. Full County is mixed.

9.6 Storm Drain Infrastructure

Data Sources

Storm drain data include pump stations, gravity mains, force mains, and culverts used in stormwater conveyance and management that are exposed to different hazards at different time horizons. These data were provided by the LA County Department of Public Works. The tables for this category have been split between pump stations, which are point assets counted by instance, and mains and culverts, which are linear assets measured in miles.

Vulnerability Summary

TABLE 29. STORM DRAIN PUMP STATIONS) – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0	2	2
Malibu	0	0	0	0	0	0	0	0
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0	0	0	0	0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0	0	0	0	0	0	0	0
Full County	0	0	0	0	0	0	2	2

NOTES:
Numbers reported are the number of pump stations affected by this hazard.

TABLE 30. STORM DRAIN (POINT) – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2050	2050	2050	2100	2080
Carson	1	1	1	1	1	1	1	1
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	6	7	10	15	10	14	18	18
Los Angeles	0	0	0	2	0	0	5	5
Malibu	0	0	0	0	0	0	0	0
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0	0	0	0	0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0	0	0	0	0	0	0	0
Full County	7	8	11	18	11	15	24	24

NOTES:
Numbers reported are the number of pump stations affected by this hazard.

TABLE 31. STORM DRAIN (POINT) – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	5	0	4	5	5
Malibu	0	0	0	0	0	0	0	0
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0	0	0	0	0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0	0	0	0	0	0	0	0
Full County	0	0	0	5	0	4	5	5

NOTES:
Numbers reported are the number of pump stations affected by this hazard.

TABLE 32. STORM DRAIN (POINT) – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	1	1	1	1	1	1	1	1
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	10	11	15	16	15	16	19	19
Los Angeles	0	0	1	8	1	4	11	11
Malibu	0	0	0	0	0	0	0	0
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0	0	0	0	0	0	0	0
Redondo Beach	0	0	0	0	0	0	0	0
Santa Monica	0	0	0	0	0	0	0	0
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0	0	0	0	0	0	0	0
Full County	11	12	17	25	17	21	31	31

NOTES:
Numbers reported are the number of pump stations affected by this hazard.

TABLE 33. STORM DRAIN (MAINS AND CULVERTS) – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0.1	0	0	0.2	0.2
Long Beach	0	0	0	0.3	0	0	0.5	0.4
Los Angeles	0.6	0.7	0.9	1.9	0.8	1.0	2.7	2.3
Malibu	0.6	0.7	0.8	1.1	0.7	0.8	1.2	1.1
Manhattan Beach	0	0	0	0	0	0	0.2	0.2
Palos Verdes Estates	0.5	0.6	0.6	1.3	0.6	0.7	1.7	1.4
Rancho Palos Verdes	0.3	0.3	0.3	0.7	0.3	0.3	0.9	0.7
Redondo Beach	0.1	0.1	0.1	0.2	0.1	0.2	0.3	0.2
Santa Monica	0	0	0	0.1	0	0.1	0.1	0.1
Torrance	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2
Unincorporated	0	0	0	0	0	0	0	0
Full County	2.3	2.6	2.9	5.8	2.7	3.2	7.9	6.9

NOTES:
Measurements reported are the sum of gravity mains, force mains, and culverts affected by this hazard in miles.

TABLE 34. STORM DRAIN (MAINS AND CULVERTS) – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2050	2050	2050	2100	2080
Carson	0.1	0.1	0.1	0.1	0.1	0.1	1.4	1.4
El Segundo	0	0	0	0	0	0	0	0
Hermosa Beach	0	0	0	0	0	0	0	0
Long Beach	3.0	5.9	9.6	21.9	9.9	17.0	32.4	32.4
Los Angeles	1.8	2.6	3.5	8.4	3.6	5.9	14.8	14.8
Malibu	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Manhattan Beach	0	0	0	0	0	0	0	0
Palos Verdes Estates	0	0	0	0	0	0	0	0
Rancho Palos Verdes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Redondo Beach	0	0	0	0	0	0	0.2	0.2
Santa Monica	0	0	0	0.1	0	0	0.2	0.2
Torrance	0	0	0	0	0	0	0	0
Unincorporated	0.1	0.2	0.2	0.3	0.2	0.2	0.8	0.8
Full County	5.3	9.0	13.6	31.1	14.1	23.6	50.0	50.0

NOTES:
Measurements reported are the sum of gravity mains, force mains, and culverts affected by this hazard in miles.

TABLE 35. STORM DRAIN (MAINS AND CULVERTS) – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0	0	0	0	0	0	0	0
El Segundo	0	0	0	0	0	0	0.1	0.1
Hermosa Beach	0.1	0.1	0.2	0.4	0.2	0.3	0.6	0.6
Long Beach	0.3	0.4	0.5	0.8	0.4	0.6	1.2	1.1
Los Angeles	1.3	1.5	1.9	3.8	1.6	2.1	4.9	4.5
Malibu	0.9	1.0	1.2	1.5	1.1	1.3	1.6	1.5
Manhattan Beach	0	0	0	0	0	0	0.6	0.6
Palos Verdes Estates	0.6	0.6	0.9	1.8	0.6	0.9	2.1	1.8
Rancho Palos Verdes	0.3	0.4	0.7	1.1	0.4	0.7	1.2	1.0
Redondo Beach	0.2	0.2	0.2	0.4	0.2	0.3	0.5	0.5
Santa Monica	0.2	0.2	0.2	0.5	0.2	0.3	0.8	0.8
Torrance	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.2
Unincorporated	0	0	0	0	0	0	0	0
Full County	4.1	4.6	5.9	10.5	4.9	6.7	13.9	12.7

NOTES:
Measurements reported are the sum of gravity mains, force mains, and culverts affected by this hazard in miles.

TABLE 36. STORM DRAIN (MAINS AND CULVERTS) – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	2010	2030	2050	2100	2030	2050	2100	2080
Carson	0.1	0.1	0.1	0.5	0.1	0.1	2.5	2.5
El Segundo	0	0	0	0	0	0	0.1	0.1
Hermosa Beach	0.1	0.1	0.2	0.3	0.2	0.3	0.5	0.5
Long Beach	11.0	14.7	17.5	27.1	17.7	22.3	37.7	37.7
Los Angeles	5.4	6.3	7.3	13.2	7.3	10.0	22.2	21.9
Malibu	0.9	1.0	1.1	1.7	1.1	1.4	2.1	2.1
Manhattan Beach	0	0	0	0	0	0	0.2	0.2
Palos Verdes Estates	0.5	0.6	0.6	1.3	0.6	0.7	1.7	1.4
Rancho Palos Verdes	0.3	0.3	0.4	0.8	0.3	0.4	0.9	0.8
Redondo Beach	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5
Santa Monica	0.2	0.2	0.2	0.5	0.2	0.3	0.8	0.8
Torrance	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2
Unincorporated	0.2	0.2	0.3	0.5	0.3	0.4	0.9	0.9
Full County	18.9	23.8	28.1	46.3	28.1	36.2	70.3	69.5

NOTES:
Measurements reported are the sum of gravity mains, force mains, and culverts affected by this hazard in miles.

9.7 Ecosystem Assets

Data Sources

Ecosystem data include beaches, brackish wetlands (i.e. estuarine), and fresh wetlands (i.e. riverine), as identified by the National Wetlands Inventory (US FWS 2015). The data were divided into these three categories based on “System,” the highest-level categorization provided by NWI. Marine systems were marked as beaches; estuarine systems were marked as brackish wetlands; and riverine, lacustrine, and palustrine systems were marked as fresh wetlands. To avoid erroneously identifying offshore areas as beaches, areas marked as “Marine, sub-tidal” were removed from the beach category. Finally, man-made structures were removed from the ecosystem layers. Most of these were rubble-mound breakwaters or groins, which had been marked “Marine, rocky, artificial substrate.” While they do act as habitats, they have been removed from this section since they function primarily as coastal protection structures.

It is worth noting that long-term tidal flooding at monthly high water may not have detrimental effects on some of these ecosystems (i.e. beaches and salty marshes), especially not in the same way as the other three hazards; however, changes in inundation will likely have an effect – positive or negative. For that reason and for consistency with the other sectors in this report, the areas are still tabulated in Table 38 below.

Vulnerability Summary

Tables list areas for three types of ecosystem separated by slashes: Beaches \ Salty Wetlands \ Fresh Wetlands. Areas are reported in acres, rounded to the nearest acre.

TABLE 37. ECOSYSTEM – LONG-TERM EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0
El Segundo	14 \ 0 \ 0	15 \ 0 \ 0	16 \ 0 \ 0	21 \ 0 \ 1	16 \ 0 \ 0	19 \ 0 \ 0	29 \ 0 \ 1	29 \ 0 \ 1
Hermosa Beach	27 \ 0 \ 0	32 \ 0 \ 0	38 \ 0 \ 0	53 \ 0 \ 0	37 \ 0 \ 0	46 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0
Long Beach	53 \ 0 \ 0	61 \ 0 \ 0	69 \ 0 \ 0	96 \ 0 \ 0	69 \ 0 \ 0	83 \ 0 \ 0	125 \ 0 \ 0	125 \ 0 \ 0
Los Angeles	231 \ 0 \ 0	257 \ 0 \ 0	289 \ 1 \ 0	392 \ 1 \ 0	282 \ 1 \ 0	329 \ 1 \ 0	462 \ 1 \ 0	460 \ 1 \ 0
Malibu	312 \ 10 \ 1	318 \ 13 \ 2	322 \ 16 \ 2	331 \ 23 \ 3	322 \ 14 \ 2	328 \ 17 \ 2	341 \ 29 \ 4	342 \ 25 \ 3
Manhattan Beach	37 \ 0 \ 0	43 \ 0 \ 0	50 \ 0 \ 0	77 \ 0 \ 0	50 \ 0 \ 0	62 \ 0 \ 0	103 \ 0 \ 0	103 \ 0 \ 0
Palos Verdes Estates	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1
Rancho Palos Verdes	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 2	66 \ 0 \ 1
Redondo Beach	31 \ 0 \ 0	32 \ 0 \ 0	33 \ 0 \ 0	34 \ 0 \ 0	33 \ 0 \ 0	34 \ 0 \ 0	35 \ 1 \ 0	35 \ 1 \ 0
Santa Monica	57 \ 0 \ 0	63 \ 0 \ 0	70 \ 0 \ 0	97 \ 0 \ 0	71 \ 0 \ 0	83 \ 0 \ 0	130 \ 1 \ 0	130 \ 1 \ 0
Torrance	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0
Unincorporated	36 \ 0 \ 0	38 \ 0 \ 0	38 \ 1 \ 0	38 \ 1 \ 0	38 \ 0 \ 0	38 \ 1 \ 0	38 \ 1 \ 0	38 \ 1 \ 0
Full County	891 \ 11 \ 3	949 \ 14 \ 3	1014 \ 17 \ 4	1232 \ 26 \ 6	1007 \ 15 \ 3	1112 \ 19 \ 4	1412 \ 33 \ 8	1410 \ 29 \ 7

NOTES:

Measurements reported are the sum of ecosystem areas (in acres) affected by this hazard. They are divided as: Beach \ Salty Wetland \ Fresh Wetland

TABLE 38. ECOSYSTEM – LONG-TERM TIDAL FLOODING (MONTHLY HIGH WATER) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 16 \ 84	0 \ 16 \ 85	0 \ 16 \ 86	0 \ 16 \ 90	0 \ 16 \ 86	0 \ 16 \ 88	0 \ 16 \ 93	0 \ 16 \ 93
El Segundo	7 \ 0 \ 0	8 \ 0 \ 0	8 \ 0 \ 0	10 \ 0 \ 0	8 \ 0 \ 0	9 \ 0 \ 0	17 \ 0 \ 0	17 \ 0 \ 0
Hermosa Beach	21 \ 0 \ 0	22 \ 0 \ 0	23 \ 0 \ 0	26 \ 0 \ 0	23 \ 0 \ 0	24 \ 0 \ 0	34 \ 0 \ 0	34 \ 0 \ 0
Long Beach	39 \ 2435 \ 134	43 \ 2441 \ 153	48 \ 2446 \ 176	102 \ 2465 \ 218	48 \ 2447 \ 177	72 \ 2460 \ 204	165 \ 2474 \ 248	165 \ 2474 \ 248
Los Angeles	183 \ 1788 \ 73	189 \ 1798 \ 106	195 \ 1804 \ 113	223 \ 1820 \ 133	195 \ 1805 \ 113	208 \ 1812 \ 121	267 \ 1826 \ 146	267 \ 1826 \ 146
Malibu	198 \ 29 \ 0	206 \ 31 \ 0	212 \ 34 \ 0	238 \ 41 \ 1	213 \ 34 \ 0	226 \ 38 \ 1	277 \ 43 \ 4	277 \ 43 \ 4
Manhattan Beach	30 \ 0 \ 0	31 \ 0 \ 0	32 \ 0 \ 0	36 \ 0 \ 0	32 \ 0 \ 0	34 \ 0 \ 0	44 \ 0 \ 0	44 \ 0 \ 0
Palos Verdes Estates	9 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0	10 \ 0 \ 0
Rancho Palos Verdes	43 \ 0 \ 0	46 \ 0 \ 0	48 \ 0 \ 0	53 \ 0 \ 0	48 \ 0 \ 0	51 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0
Redondo Beach	15 \ 102 \ 0	16 \ 102 \ 0	17 \ 102 \ 0	20 \ 104 \ 0	17 \ 102 \ 0	19 \ 103 \ 0	25 \ 104 \ 0	25 \ 104 \ 0
Santa Monica	49 \ 0 \ 0	51 \ 0 \ 0	52 \ 0 \ 0	60 \ 1 \ 0	52 \ 0 \ 0	56 \ 1 \ 0	95 \ 1 \ 0	95 \ 1 \ 0
Torrance	9 \ 0 \ 0	9 \ 0 \ 0	9 \ 0 \ 0	11 \ 0 \ 0	9 \ 0 \ 0	10 \ 0 \ 0	12 \ 0 \ 0	12 \ 0 \ 0
Unincorporated	21 \ 375 \ 5	22 \ 377 \ 6	23 \ 379 \ 6	26 \ 386 \ 6	23 \ 379 \ 6	25 \ 382 \ 6	31 \ 386 \ 7	31 \ 386 \ 7
Full County	626 \ 4745 \ 297	653 \ 4766 \ 351	678 \ 4783 \ 382	816 \ 4832 \ 456	680 \ 4784 \ 384	743 \ 4811 \ 424	1037 \ 4850 \ 512	1037 \ 4850 \ 512

NOTES:

Measurements reported are the sum of ecosystem areas (in acres) affected by this hazard. They are divided as: Beach \ Salty Wetland \ Fresh Wetland

TABLE 39. ECOSYSTEM – STORM EVENT EROSION HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5’ SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0	0 \ 0 \ 0
El Segundo	23 \ 0 \ 0	24 \ 0 \ 0	24 \ 0 \ 1	27 \ 0 \ 1	24 \ 0 \ 1	26 \ 0 \ 1	30 \ 0 \ 1	30 \ 0 \ 1
Hermosa Beach	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0
Long Beach	141 \ 2 \ 0	148 \ 2 \ 0	153 \ 3 \ 0	159 \ 3 \ 0	151 \ 3 \ 0	157 \ 3 \ 0	163 \ 4 \ 0	163 \ 4 \ 0
Los Angeles	460 \ 3 \ 0	476 \ 4 \ 0	494 \ 4 \ 0	527 \ 6 \ 0	488 \ 4 \ 0	519 \ 6 \ 0	540 \ 7 \ 0	539 \ 7 \ 0
Malibu	342 \ 17 \ 2	343 \ 19 \ 2	343 \ 21 \ 3	345 \ 29 \ 5	343 \ 19 \ 3	345 \ 23 \ 3	346 \ 34 \ 6	346 \ 30 \ 5
Manhattan Beach	68 \ 0 \ 0	73 \ 0 \ 0	80 \ 0 \ 0	101 \ 0 \ 0	79 \ 0 \ 0	94 \ 0 \ 0	104 \ 0 \ 0	104 \ 0 \ 0
Palos Verdes Estates	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1
Rancho Palos Verdes	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 2	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 3	66 \ 0 \ 2
Redondo Beach	35 \ 1 \ 0	35 \ 1 \ 0	35 \ 1 \ 0	35 \ 1 \ 0	35 \ 1 \ 0	35 \ 1 \ 0	35 \ 2 \ 0	35 \ 2 \ 0
Santa Monica	167 \ 1 \ 0	176 \ 1 \ 0	192 \ 1 \ 0	221 \ 1 \ 0	185 \ 1 \ 0	211 \ 1 \ 0	226 \ 1 \ 0	226 \ 1 \ 0
Torrance	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0
Unincorporated	38 \ 0 \ 0	38 \ 1 \ 0	38 \ 1 \ 0	38 \ 1 \ 1	38 \ 1 \ 0	38 \ 1 \ 0	38 \ 1 \ 1	38 \ 1 \ 1
Full County	1424 \ 25 \ 4	1461 \ 28 \ 5	1510 \ 32 \ 6	1603 \ 42 \ 9	1493 \ 29 \ 5	1575 \ 36 \ 6	1632 \ 50 \ 12	1631 \ 46 \ 10

NOTES:

Measurements reported are the sum of ecosystem areas (in acres) affected by this hazard. They are divided as: Beach \ Salty Wetland \ Fresh Wetland

TABLE 40. ECOSYSTEM – STORM FLOODING (100-YEAR EVENT) HAZARD

	Baseline	3' SLR by 2100			5.5' SLR by 2100			5.5' SLR by 2080
City	**2010**	**2030**	**2050**	**2100**	**2030**	**2050**	**2100**	**2080**
Carson	0 \ 16 \ 87	0 \ 16 \ 88	0 \ 16 \ 88	0 \ 16 \ 92	0 \ 16 \ 88	0 \ 16 \ 90	0 \ 16 \ 94	0 \ 16 \ 94
El Segundo	22 \ 0 \ 0	23 \ 0 \ 0	24 \ 0 \ 0	26 \ 0 \ 1	23 \ 0 \ 0	25 \ 0 \ 0	30 \ 0 \ 1	30 \ 0 \ 1
Hermosa Beach	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0	58 \ 0 \ 0
Long Beach	143 \ 2449 \ 181	152 \ 2458 \ 196	159 \ 2460 \ 205	170 \ 2470 \ 229	158 \ 2461 \ 206	165 \ 2466 \ 218	177 \ 2477 \ 263	177 \ 2477 \ 263
Los Angeles	464 \ 1807 \ 114	479 \ 1810 \ 118	498 \ 1814 \ 123	528 \ 1824 \ 140	491 \ 1814 \ 123	523 \ 1821 \ 134	542 \ 1829 \ 149	542 \ 1829 \ 149
Malibu	343 \ 43 \ 7	344 \ 43 \ 8	344 \ 43 \ 9	347 \ 43 \ 15	344 \ 43 \ 9	347 \ 43 \ 12	347 \ 43 \ 21	347 \ 43 \ 21
Manhattan Beach	68 \ 0 \ 0	72 \ 0 \ 0	79 \ 0 \ 0	96 \ 0 \ 0	76 \ 0 \ 0	92 \ 0 \ 0	104 \ 0 \ 0	104 \ 0 \ 0
Palos Verdes Estates	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1	10 \ 0 \ 1
Rancho Palos Verdes	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 1	66 \ 0 \ 2	66 \ 0 \ 1
Redondo Beach	37 \ 102 \ 0	37 \ 103 \ 0	37 \ 103 \ 0	37 \ 104 \ 0	37 \ 103 \ 0	37 \ 104 \ 0	37 \ 104 \ 0	37 \ 104 \ 0
Santa Monica	167 \ 1 \ 0	176 \ 1 \ 0	192 \ 1 \ 0	221 \ 1 \ 0	185 \ 1 \ 0	211 \ 1 \ 0	226 \ 1 \ 0	226 \ 1 \ 0
Torrance	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 0	14 \ 0 \ 1	14 \ 0 \ 1
Unincorporated	38 \ 380 \ 7	38 \ 381 \ 7	38 \ 383 \ 7	38 \ 386 \ 8	38 \ 383 \ 7	38 \ 386 \ 7	38 \ 386 \ 10	38 \ 386 \ 10
Full County	1432 \ 4798 \ 399	1470 \ 4812 \ 420	1520 \ 4820 \ 437	1613 \ 4844 \ 498	1503 \ 4821 \ 438	1588 \ 4837 \ 471	1652 \ 4857 \ 560	1652 \ 4857 \ 559

NOTES:

Measurements reported are the sum of ecosystem areas (in acres) affected by this hazard. They are divided as: Beach \ Salty Wetland \ Fresh Wetland

10. LIST OF PREPARERS

This report was prepared by James Jackson, P.E. (Hydrologist), with technical oversight by Matt Brennan (Project Manager); Bob Battalio, P.E. (Project Director). Additional support was provided by, Dane Behrens, Ph.D., P.E., Hannah Snow, EIT, and Alex Trahan, EIT.

We acknowledge our project collaborators. Garrett Wong managed the project on behalf of the City of Santa Monica. USC Sea Grant staff, including Juliette Finzi Hart, Alyssa Newton Mann, and Phyllis Grifman, coordinated stakeholder outreach and context for broader Los Angeles climate change planning. Ron Flick and Adam Young from the TerraCosta Consulting Group shared their insightful expertise and feedback on sea level rise projections and our technical methods. The US Geological Survey (USGS), in particular Li Erikson, provided the integrated DEM and CoSMoS model output. Dave Revell Ph.D. provided input on backshore characterization. We also acknowledge our use of public resources such as LiDAR, bathymetry, wave and tidal data.

We also acknowledge the valuable feedback received by the following stakeholders:

- City of Santa Monica (Lis Bar-El, Cary Fukui)
- Coastal Conservancy (Julia Elkin)
- City of Hermosa Beach (Leeanne Singleton, Kristy Morris)
- City of Long Beach (Russ Boudreau of Moffat Nichol)

11. REFERENCES

Barnard, P.L., M. van Ormondt, L. H. Erikson, J. Eshleman, C. Hapke, P. Ruggiero, P. N. Adams, A. C. Foxgrover. (2014) Development of the Coastal Storm Modeling System (CoSMoS) for predicting the impact of storms on high-energy, active-margin coasts. Natural Hazards 74(2): 1095-1125. doi:10.1007/s11069-014-1236-y

Campbell, R. H., Blackerby, B. A., Yerkes, R. F., Schoellhamer, J. E., Birkeland, P. W. and Wentworth, C. M. (1996). Geologic map of the Point Dume quadrangle, Los Angeles County, California, U. S. Geological Survey Map GQ-1747.

Cayan, D. R., J. Kalansky, S. Iacobellis, D. Pierce, and R. Kopp Kopp. (2016). Creating Probabilistic Sea Level Rise Projections to support the 4th California Climate Assessment. Prepared for the California Energy Commission.

Dare, J. 2005. Database of Coastal Bluff Erosion and Armor in California. Available at https://catalog.data.gov/dataset/coastal-erosion-armoring-2005dd8cc

Dewberry (2013). Coastal California Data Merge Project. Prepared for the National Oceanic and Atmospheric Administration (NOAA), October 31, 2013. NOAA Contract No. EA133C-11-007.

Dibblee, T.W. (1999). Geologic Map of the Palos Verdes Peninsula and Vicinity. Redondo Beach, Torrance, and San Pedro Quadrangles. Los Angeles County, California. Dibblee Geology Center Map #DF-70. Published by the Santa Barbara Museum of Natural History.

Dibblee, T.W. (2007). Geologic Map of the Venice and Inglewood Quadrangles. Los Angeles County, California. Dibblee Geology Center Map #DF-322. Published by the Santa Barbara Museum of Natural History.

Dibblee, T.W. and Ehrenspeck, H.E. (1990). Geologic Map of the Point Mugu & Triunfo Pass Quadrangles. Ventura and Los Angeles Counties, California. Dibblee Geology Center Map #DF-29. Published by the Santa Barbara Museum of Natural History.

ESA PWA (2012a). “California Coastal Armoring Geodatabase: Design and Construction.” Prepared for California Ocean Science Trust, California Coastal Commission, and the California Ocean Protection Council. March 30th, 2012.

ESA PWA (2012b). “Evaluation of Erosion Mitigation Alternatives for Southern Monterey Bay,” Prepared for the Monterey Bay Sanctuary Foundation and The Southern Monterey Bay Coastal Erosion Working Group. May 30, 2012.

ESA (2013). “Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping” Prepared for The Nature Conservancy, ESA PWA project number D211452 July 31, 2013.

ESA (2014). *Monterey Bay Sea Level Rise Vulnerability Study: Technical Methods Report* Monterey Bay Sea Level Rise Vulnerability Study. Prepared for The Monterey Bay Sanctuary Foundation, ESA PWA project number D211906.00, June 16, 2014.

ESA (2015a). Santa Barbara County Coastal Hazard Modeling and Vulnerability Assessment: Technical Methods Report. Prepared for the County of Santa Barbara. ESA project number 130526.00, June 19, 2015.

ESA PWA (2015). Calleguas Creek: Climate Change Impacts to Fluvial and Coastal Flooding. Prepared for the Nature Conservancy. ESA project number 140912.00, June 22, 2015.

ESA (2016). Monterey Bay Sea Level Rise: Climate Change Impacts to Combined Fluvial and Coastal Hazards. Prepared for Moss Landing Marine Labs with funding from the Ocean Protection Council. ESA project number 130523.00, May 13, 2016.

Everts, Craig H. (1991). Seacliff Retreat and Coarse Sediment Yields in Southern California. In N. Kraus, K. Gingerich, & D. Kreibel (Eds), Coastal Sediments ’91. Paper presented at A Specialty Conference on Quantitative Approaches to Coastal Sediment Processes, Seattle, Washington, United States, June 25-27, 1991. New York, NY: ASCE.

FEMA (2005a). “Final Draft Guidelines: Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States.” Prepared for the U.S. Department of Homeland Security.

FEMA (2005b). Flood Insurance Study. Los Angeles County, California and Incorporated Areas. September 30, 2005.

Griggs, G., K. Patsch, and L. Savoy (2005). Living with the Changing California Coast. Berkeley and Los Angeles, CA: University of California Press.

Goda, Y., Takayama, T. and Suzuki, Y. (1978). Diffraction diagrams for directional random waves. Proc. 16th International Conference Coastal Engineering. (Hamburg) pp. 628-650.

Hapke, C., D. Reid, D. Richmond, P. Ruggiero, and J. List (2006). "National Assessment of Shoreline Change, Part 3: Historical Shoreline Change and Associated Land Loss Along Sandy Shorelines of the California Coast." Santa Cruz, California: U.S. Geological Survey Open-file Report 2006-1219, 79p.

Hapke, C. and D. Reid (2007). "National Assessment of Shoreline Change, Part 4: Historical Coastal Cliff Retreat along the California Coast." Santa Cruz, California: U.S. Geological Survey Open-file Report 2007-1133, 57p.

Hunt, I. (1959). “Design of Seawalls and Breakwaters.” Journal of Waterways and Harbors Division, Proceedings of the American Society of Civil Engineers. Vol 85, No. WW3, Part 1, September 1959, pp. 123-152.

Komar, P.D., W.G. McDougal, J.J. Marra, and P. Ruggiero, (1999). The rational analysis of setback distances: applications to the Oregon Coast. Shore and Beach 67(1):41-49.

NRC (2012). “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.” Prepublication. National Academy Press: Washington, D. C.

NOAA (2012a). “2009 – 2011 CA Coastal ADS40 4-Band 8 bit Imagery.” NOAA Coastal Services Center. Charleston, South Carolina. Available online: http://www.csc.noaa.gov/dataviewer/#.

NOAA (2012c). "Airborne Lidar Assessment of Coastal Erosion (ALACE) Project." NOAA Coastal Services Center. Charleston, South Carolina. Available online: http://www.csc.noaa.gov/dataviewer/#.

NOAA (2013). "2013 NOAA Coastal California TopoBathy Merge Project" NOAA Coastal Services Center. Charleston, South Carolina. Available online: http://www.csc.noaa.gov/dataviewer/#.

NOAA (2013). "Los Angeles, CA Station Tidal Datum." NOAA National Ocean Service Tides & Currents. Station ID: 9410660. Available online: http://tidesandcurrents.noaa.gov/.

Noble Consultants (2010). Coast of California Storm and Tidal Waves Study Los Angeles Region. Prepared for the US Army Corps of Engineers. November 2010.

Noble Consultants (2016). Los Angeles County Public Beach Facilities Sea-Level Rise Vulnerability Assessment. Prepared for the Los Angeles County Department of Beaches and Harbors. April 2016.

OPC (2013). State Of California Sea-Level Rise Guidance Document, Developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust, March 2013 update: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/2013_SLR_Guidance_Update_FINAL1.pdf

Pacific Institute (2009). "The Impacts of Sea-Level Rise on the California Coast." A paper from the California Climate Change Center, May 2009.

PWA (2009). "California Coastal Erosion Response to Sea Level Rise - Analysis and Mapping." Prepared for the Pacific Institute.

Revell, D.L., R.Battalio, B. Spear, P. Ruggiero, and J. Vandever, (2011). A Methodology for Predicting Future Coastal Hazards due to Sea-Level Rise on the California Coast. Climatic Change 109:S251-S276. DOI 10.1007/s10584-011-0315-2.

Stockdon, H.F., Holman, R.A., Howd, P.A., and Sallenger, Jr., A.H. (2006) Empirical parameterization of setup, swash, and runup, Coastal Engineering, 53, pp. 573-588.

TAW, 2002. Technical Report Wave Run-up and Wave Overtopping at Dikes. TAW, Technical Advisory Committee on Flood Defences. Author: J.W. van der Meer.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan (2009). "Digital Shoreline Analysis System (DSAS) version 4.0—An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2008-1278." Available online at http://pubs.usgs.gov/of/2008/1278/.

U.S. Army Corps of Engineers (USACE) (1984). “Shore Protection Manual, Volume 2.” pp 7-35 to 7-43.

USACE (2002). “Coastal Engineering Manual, Engineer Manual 1110-2-1100.” U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

USACE (2011). “Sea-Level Change Considerations for Civil Works Programs.” US Army Corps of Engineers, EC 1165-2-212.

U. S. Fish and Wildlife Service (US FWS). 2015. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/

Walkden, M. and M. Dickson (2008). “Equilibrium erosion of soft rock shores with a shallow or absent beach under increased sea level rise.” Marine Geology 251, p. 75-84.

Wiegel, R.L. (1962). “Diffraction of Waves by Semi-infinite Breakwater,” Journal Hydraulic Div., Proc. ASCE, Vol. 88, No. HY1, pp. 27-44.

Yerkes, R. F., and Campbell, R. H. (1980). Geologic map of east-central Santa Monica Mountains, Los Angeles County, California: U. S. Geological Survey Map I-1146, scale 1:24,000.

Yerkes, R. F., and Campbell, R. H. (1994). Preliminary geologic map of the Topanga 7.5 minute quadrangle, southern California: U. S. Geological Survey Open-File Report 94-266.

Zoulas, J and Orne, (2007). Multidecadal-scale beach changes in the Zuma Littoral cell, California. Physical Geography, 28, 4 pp 277-300.

LA County Coastal Hazards Modeling . 130524.00

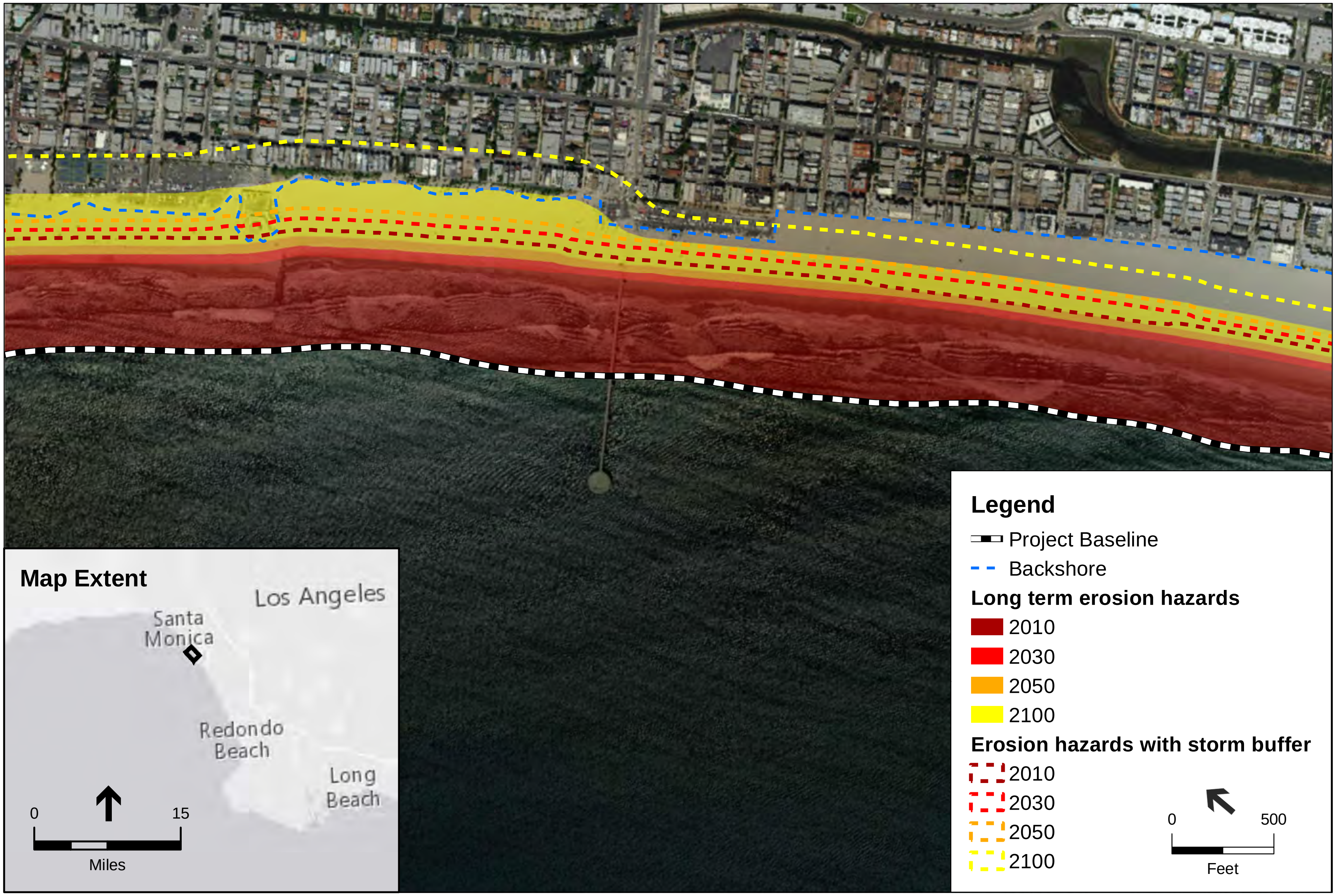
Figure 1
Los Angeles County study area

SOURCE: PWA 2009

LA County Coastal Hazards Modeling . 130524.00

Figure 2

Pacific Institute Coastal Flooding Hazard Zones



NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring.

Figure 3
Example of sandy shoreline erosion hazard zones

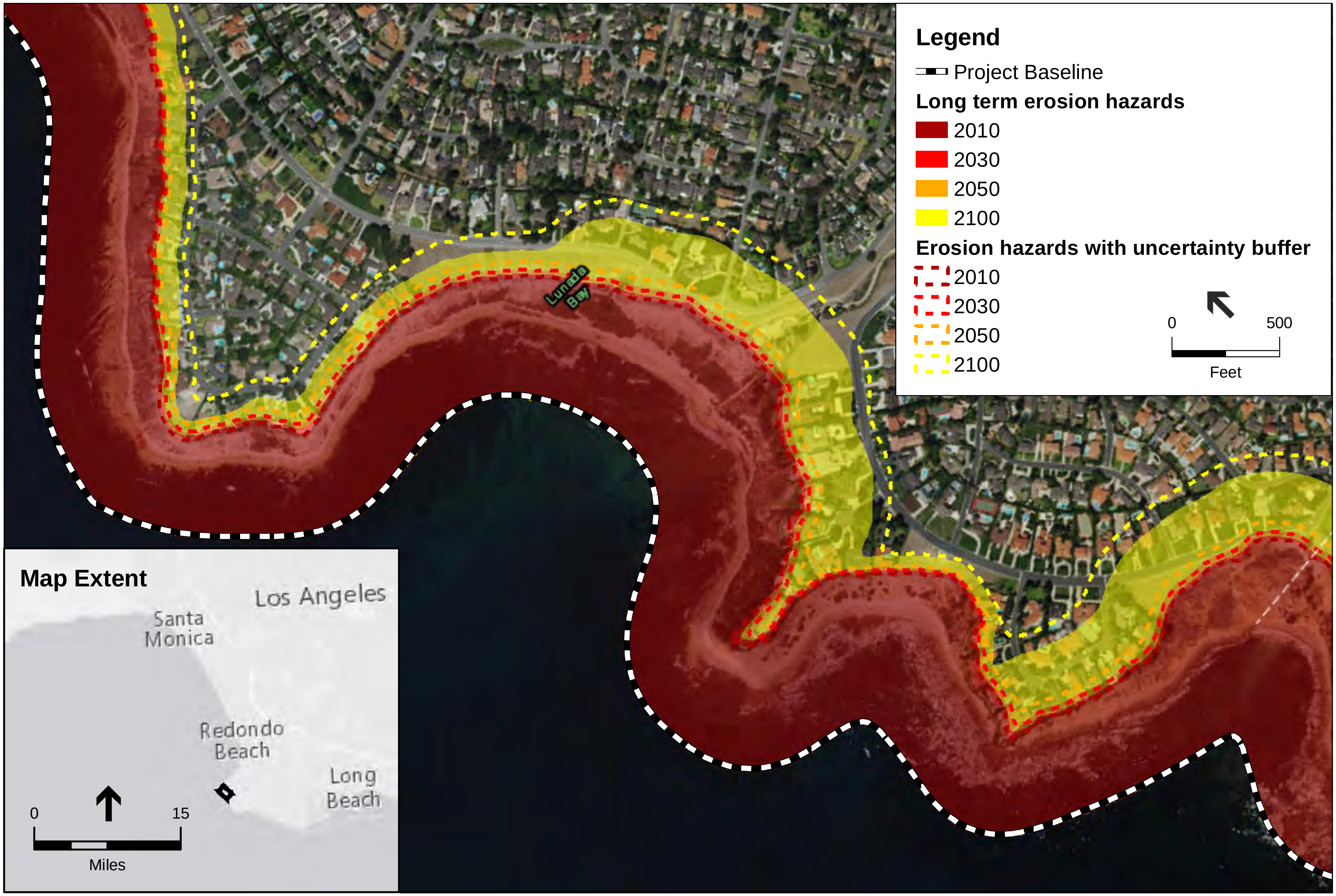


Figure 4
Example of cliff erosion hazard zones

NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring.

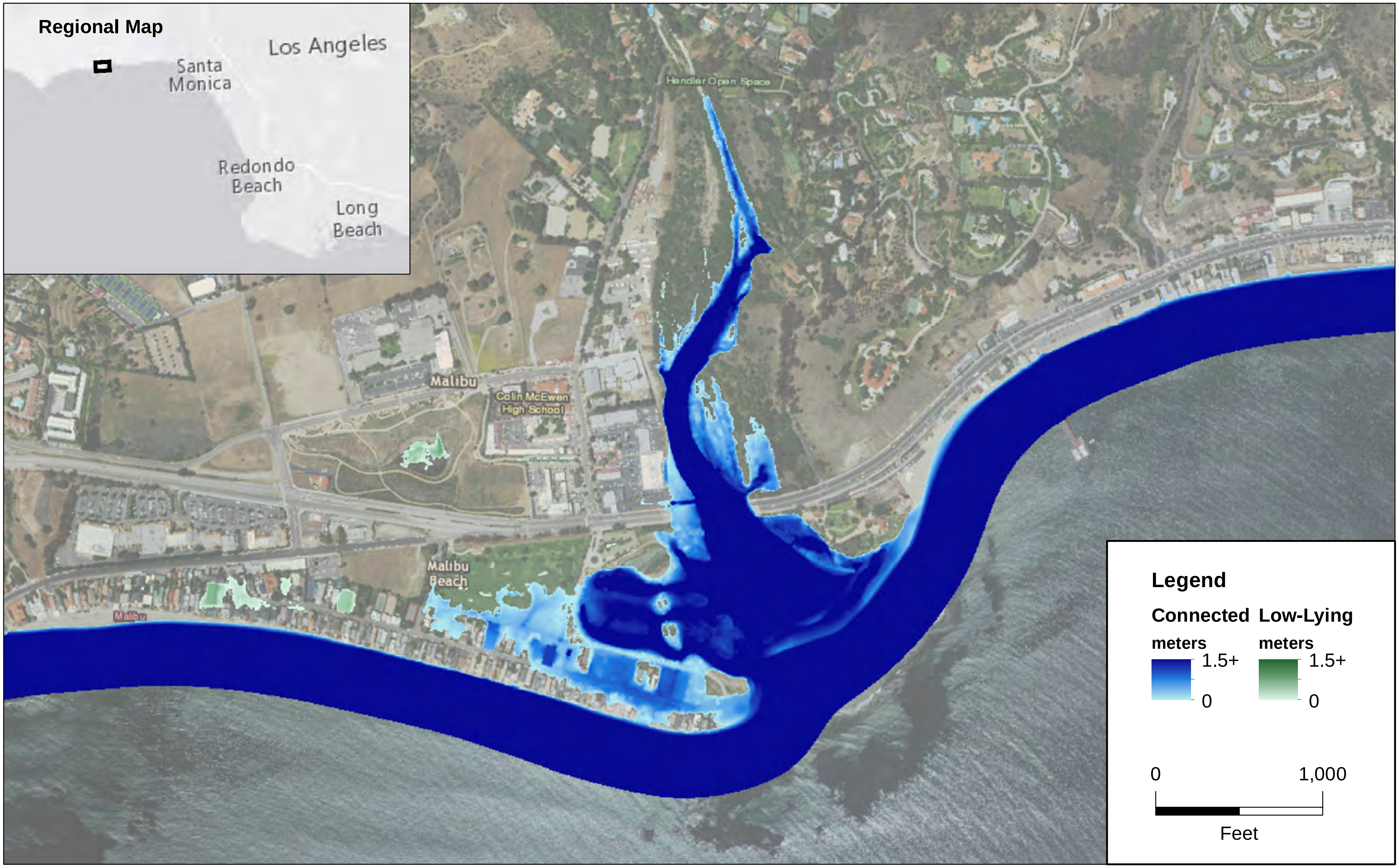
Figure 5
Coastal Flooding Hazard Zones

NOTES:
1. These future tidal flooding zones are for the High sea level rise scenario of 1.68 meters by 2100.
2. Assumes a monthly extreme water level of 2.0 m NAVD88 in 2010, as estimated by ESA.
3. This hazard zone does not consider future erosion of the coast and should be used in conjunction with the coastal erosion hazard zones.

LA County Coastal Hazards Modeling . 130524.00

Figure 6

Example of monthly tidal flooding area



NOTES:
1. These future tidal flooding zones are for the High sea level rise scenario of 1.68 meters by 2100.
2. Assumes a monthly extreme water level of 2.0 m NAVD88 in 2010, as estimated by ESA.
3. This hazard zone does not consider future erosion of the coast and should be used in conjunction with the coastal erosion hazard zones.

LA County Coastal Hazards Modeling . 130524.00

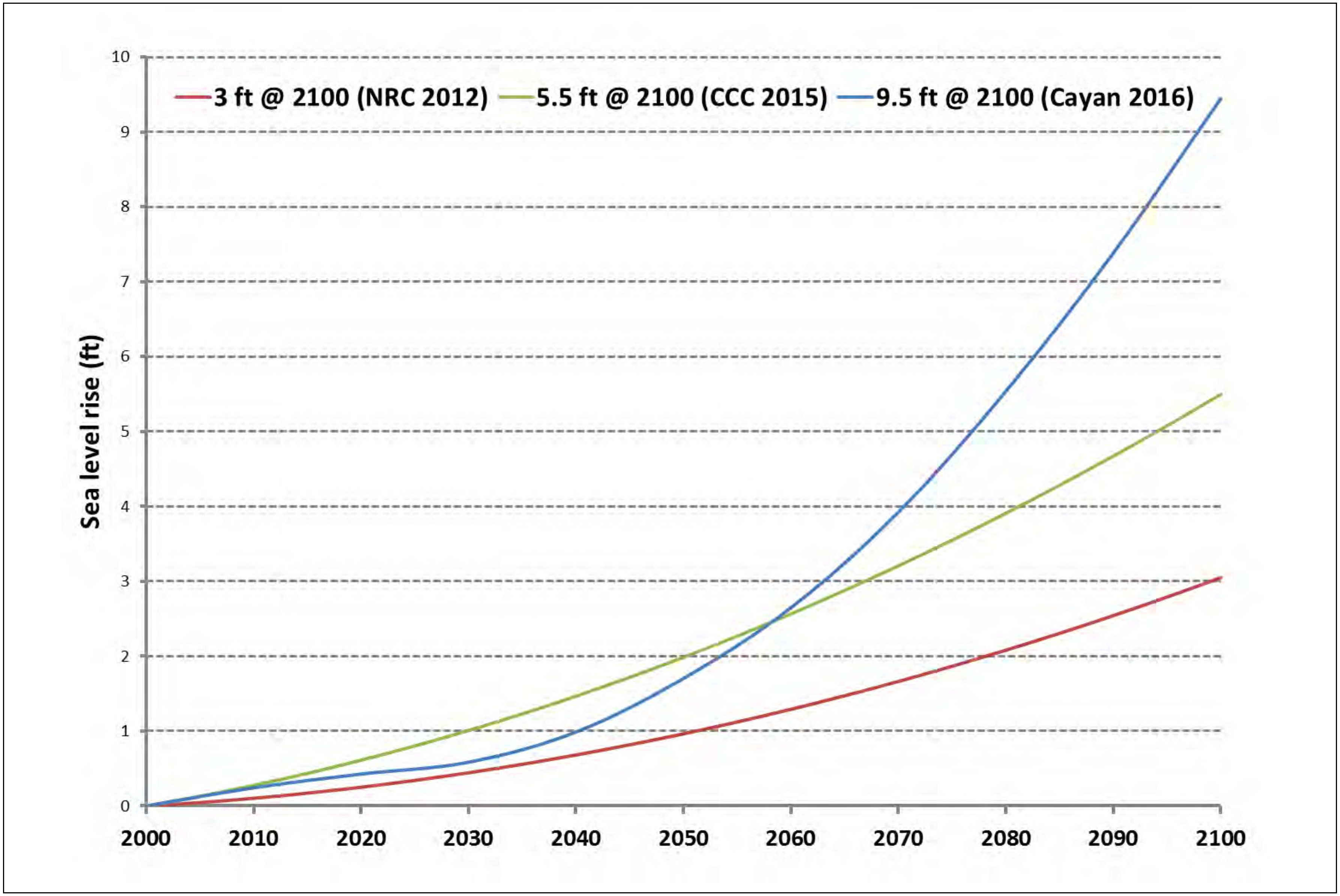
Figure 7
Example of monthly tidal flooding depth

NOTE:. This is an example of the spatial aggregation of hazards in Appendix 2. For maps of the rest of the Los Angeles County coastline, please see the appendix.

LA County Coastal Hazards Modeling . 130524.00

Figure 8

Example of spatial aggregation layers



SOURCE: NRC 2012 Table 5.3; CCC 2015 Equation B3; Cayan 2016.

NOTE: Data show NRC LA Regional curves with regional vertical land motion for the San Andreas region (-1.5 mm/yr).

Figure 9
Sea level rise curves

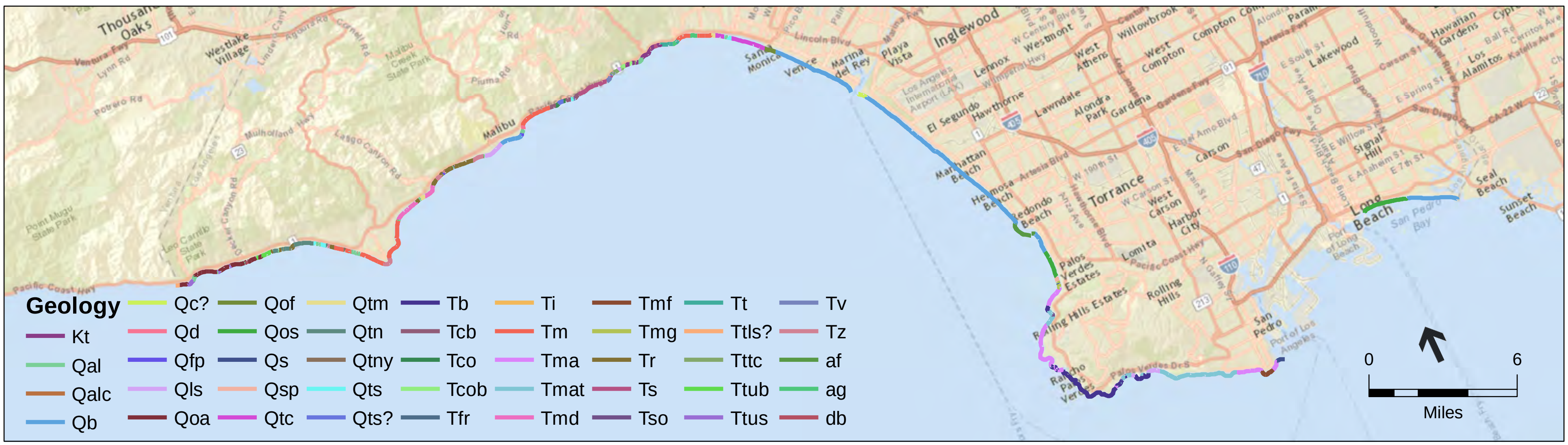
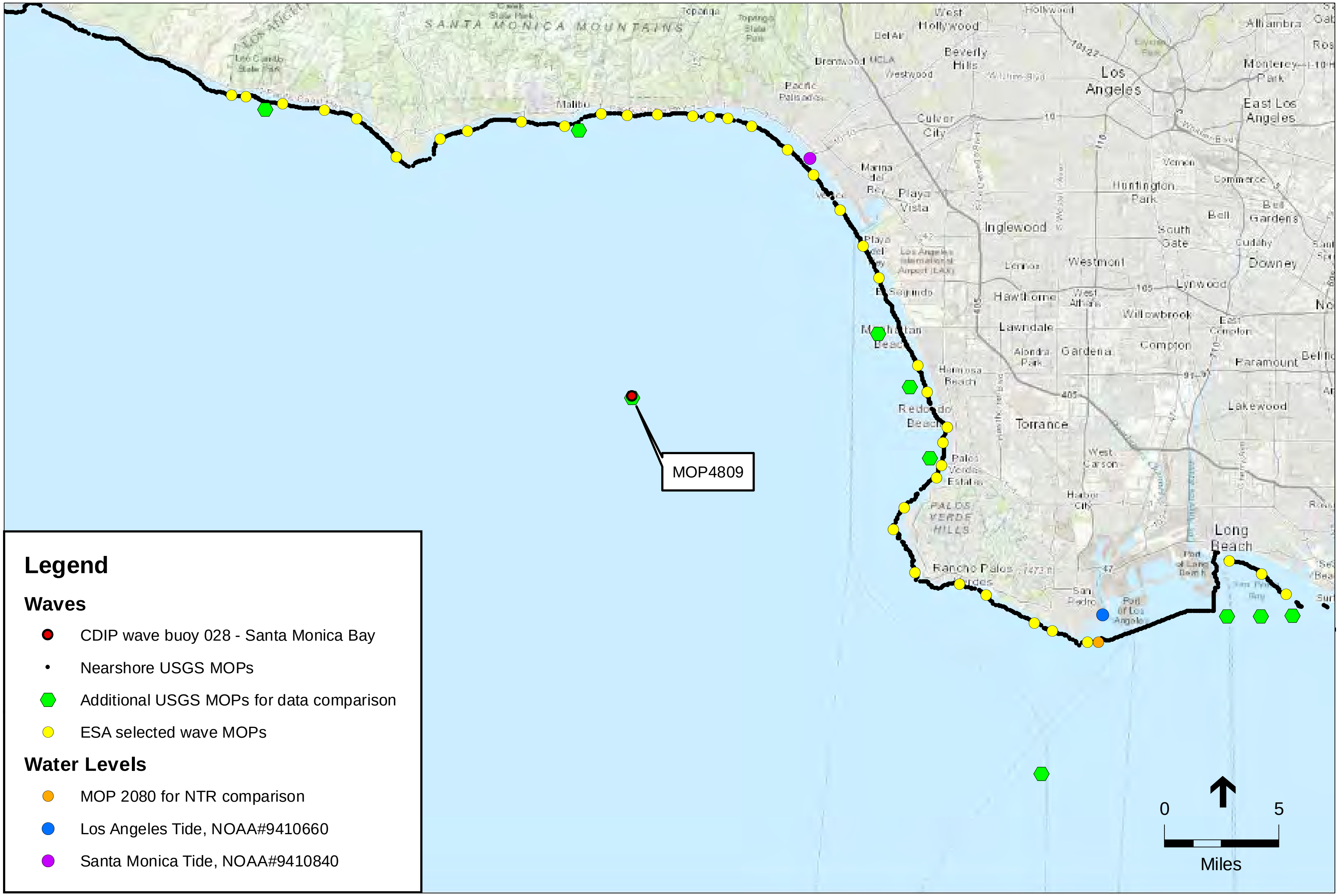


Figure 10

Los Angeles County backshore and geology

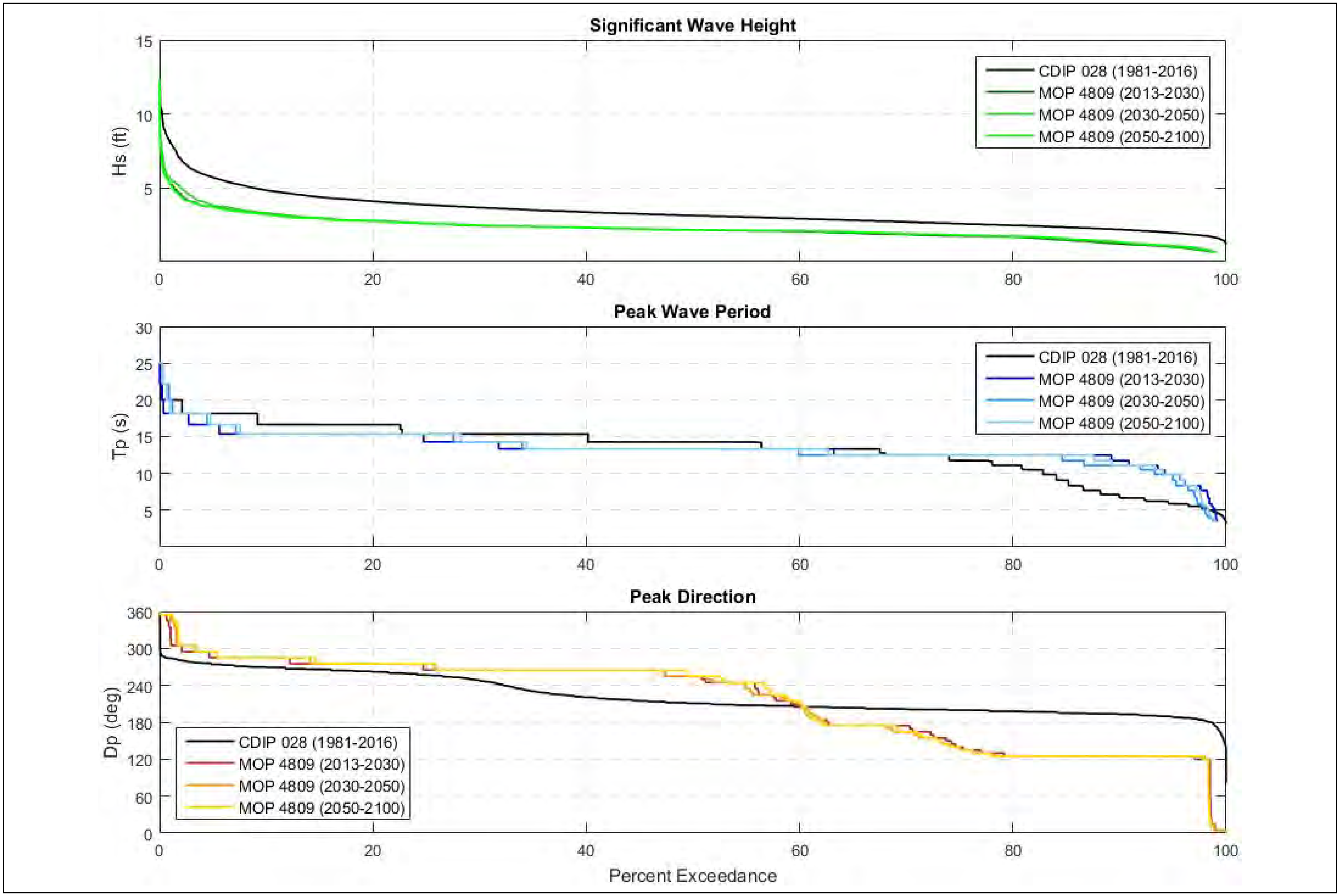


SOURCE: USGS, CDIP

LA County Coastal Hazard Modeling . 130524.00

Figure 11

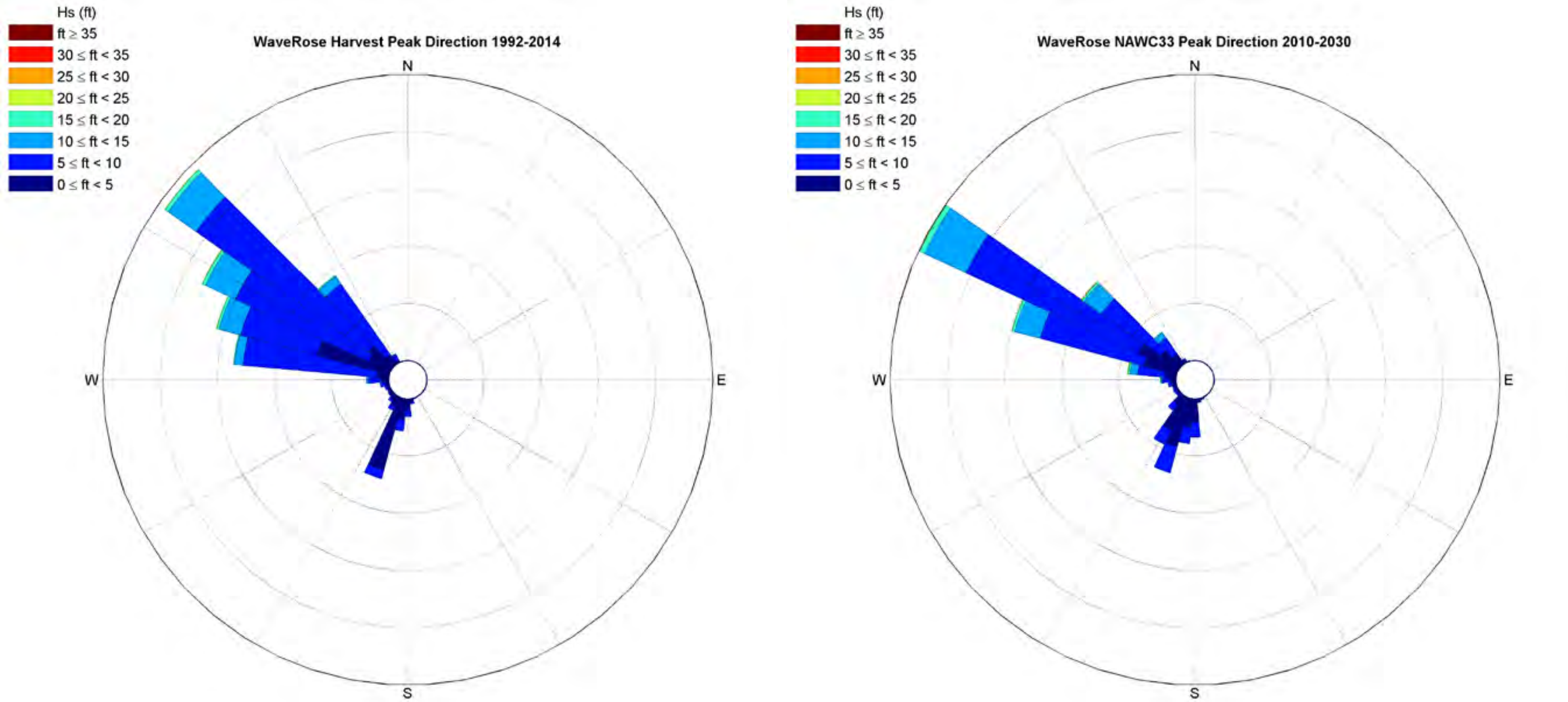
Wave buoys, tide gauges and MOP locations



SOURCE: NDBC, 2016; USGS, 2015.

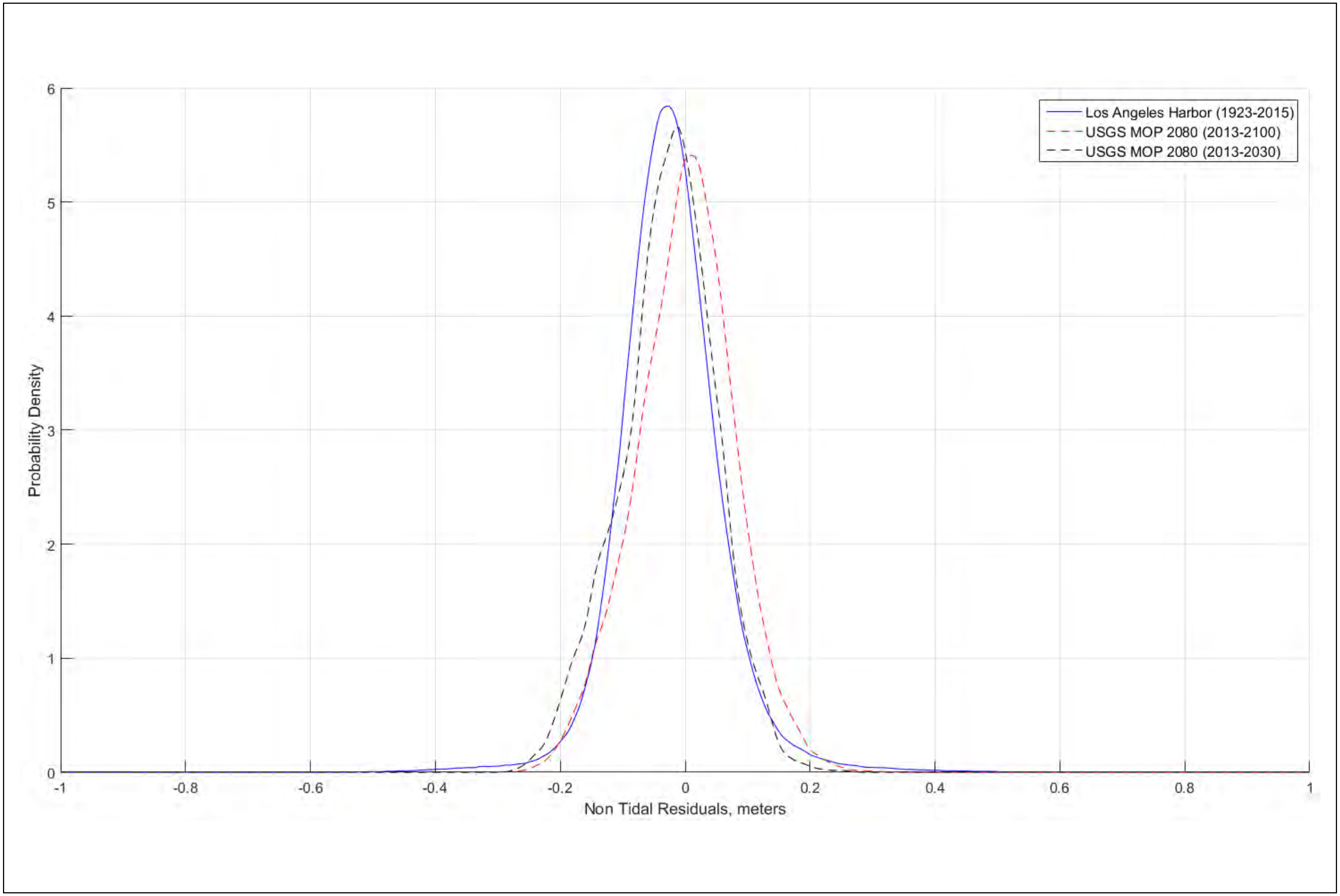
Figure 12

Cumulative distributions of wave parameters at the Santa Monica Bay buoy (real data at CDIP 028) and GCM output (synthetic data at MOP 4809)



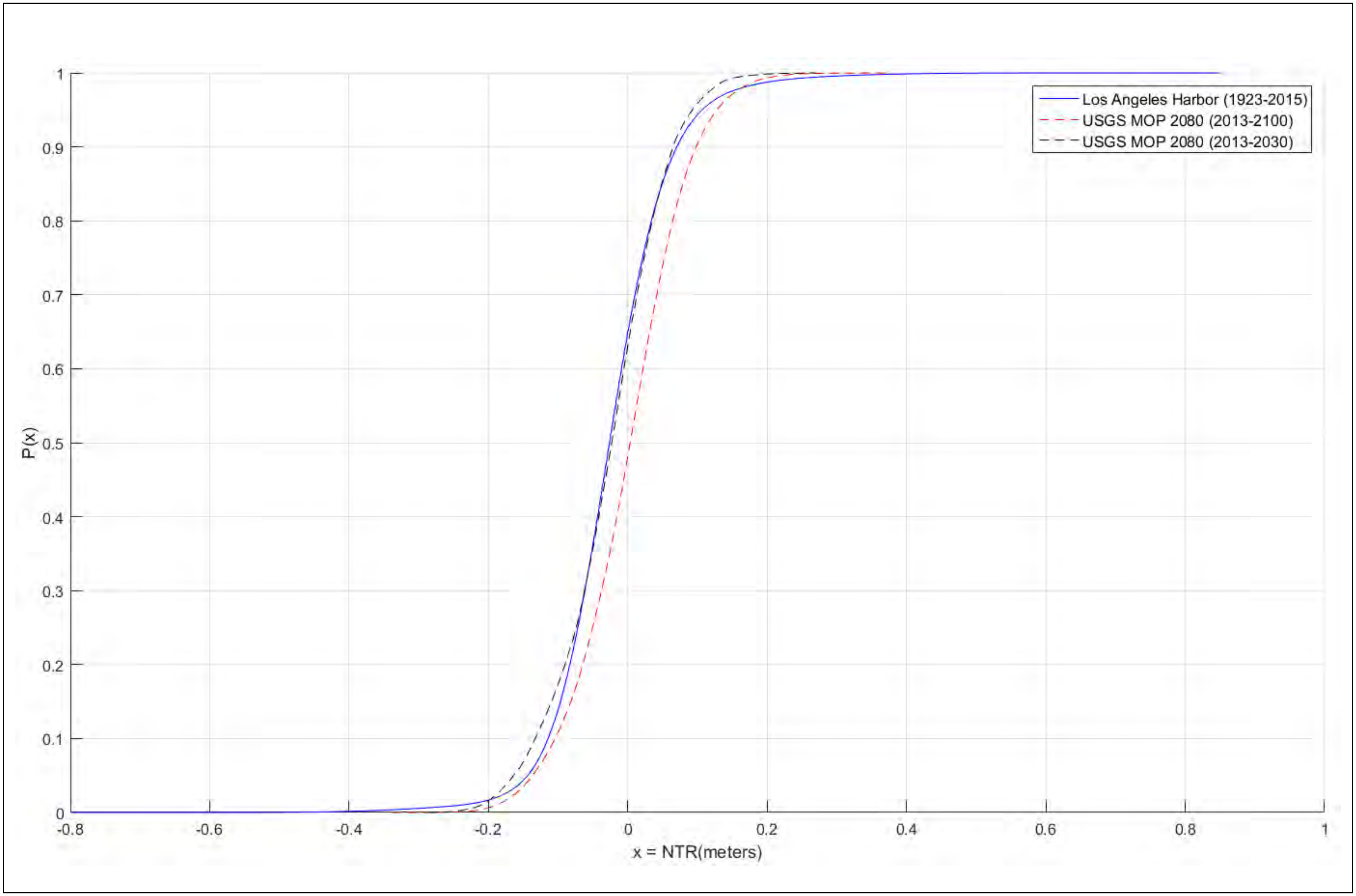
SOURCE: NDBC, 2014; USGS, 2015.

Figure 15
Wave roses for the Harvest gauge (real data) and the GCM output (synthetic data, from NAWC33)



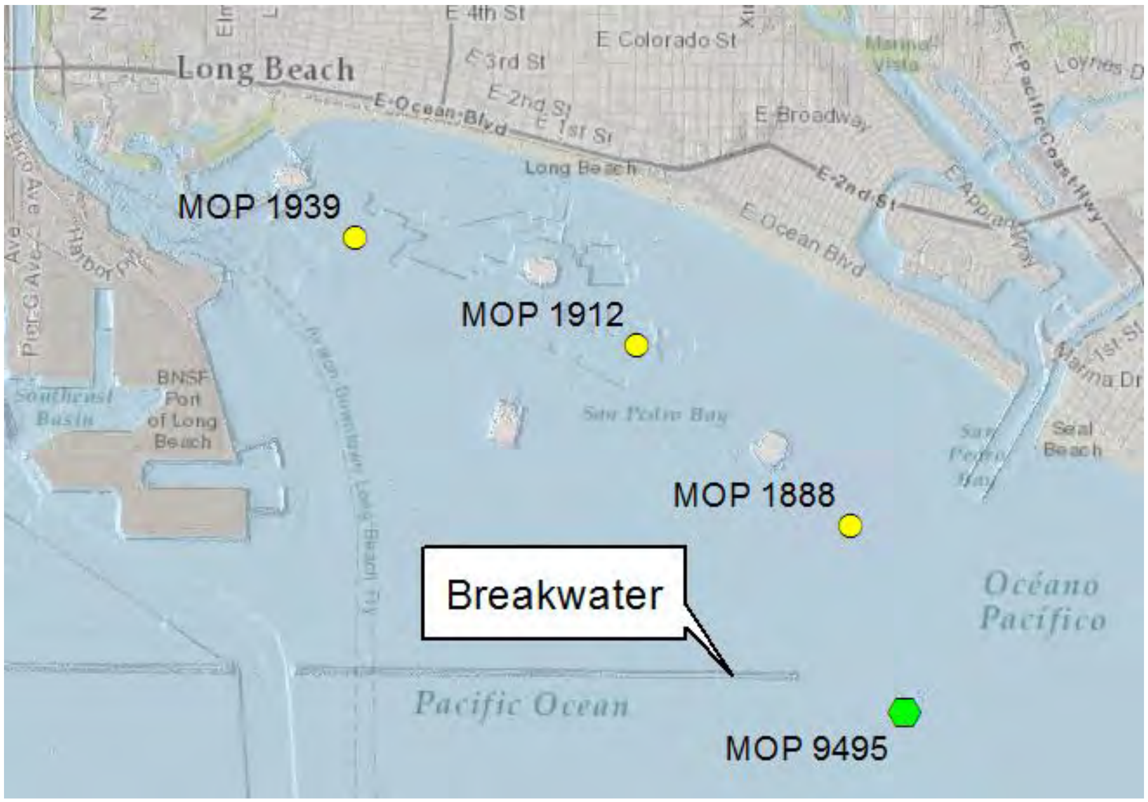
SOURCE: NOAA, 2015; USGS, 2015.

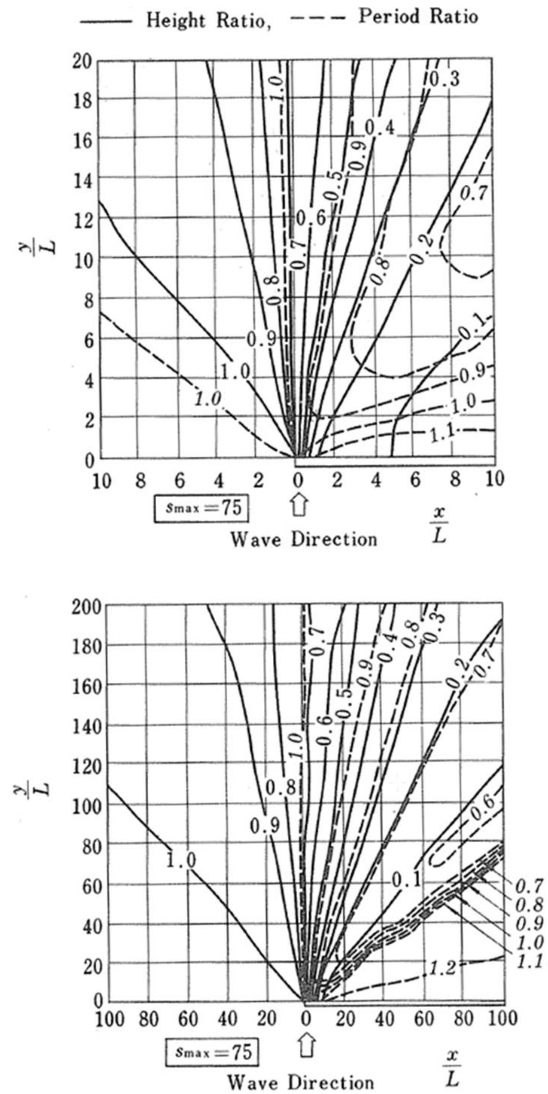
Figure 14
Synthetic water level non-tidal residuals from climate modeling compared with real data from LA Harbor tide gauge



SOURCE: NOAA, 2015; USGS, 2015.

Figure 15
Synthetic water level non-tidal residuals cumulative distribution compared against LA historic records





NOTE:. Diffraction diagrams are for a semi-infinite breakwater for random sea waves of normal incidence. Solid lines for wave height ration and dash lines for wave period ration. Diagrams reproduced from Goda 1978. Diagrams from Goda present a breakwater from right, so they were mirrored to represent the Long Beach breakwater (from the left).

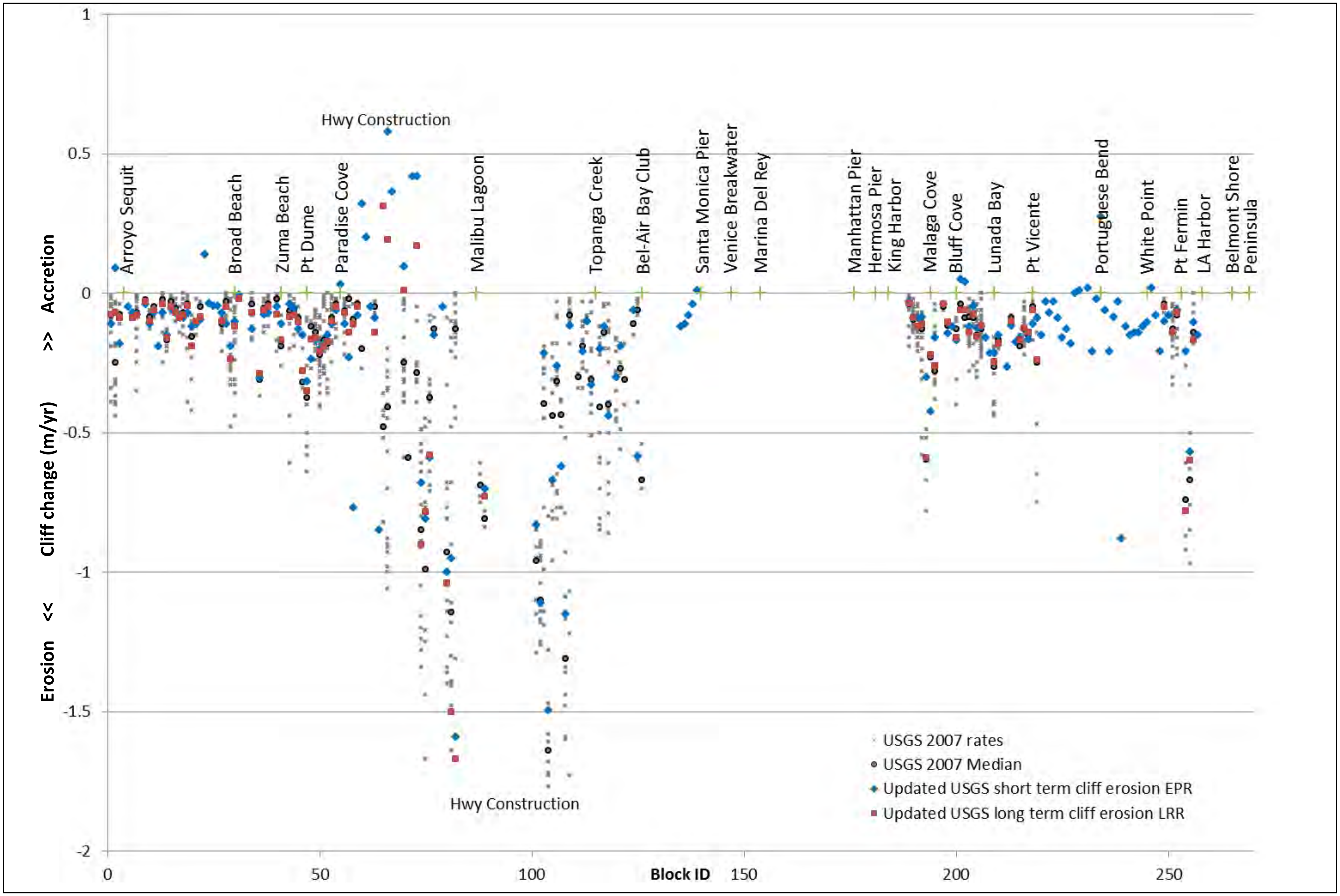
Figure 16

MOPs used in manual diffraction of waves within Long Beach Harbor and Shallow water diffraction diagram for straight, semi-infinite breakwater

NOTE: Negative values are erosion, positive values are accretion.

Figure 17

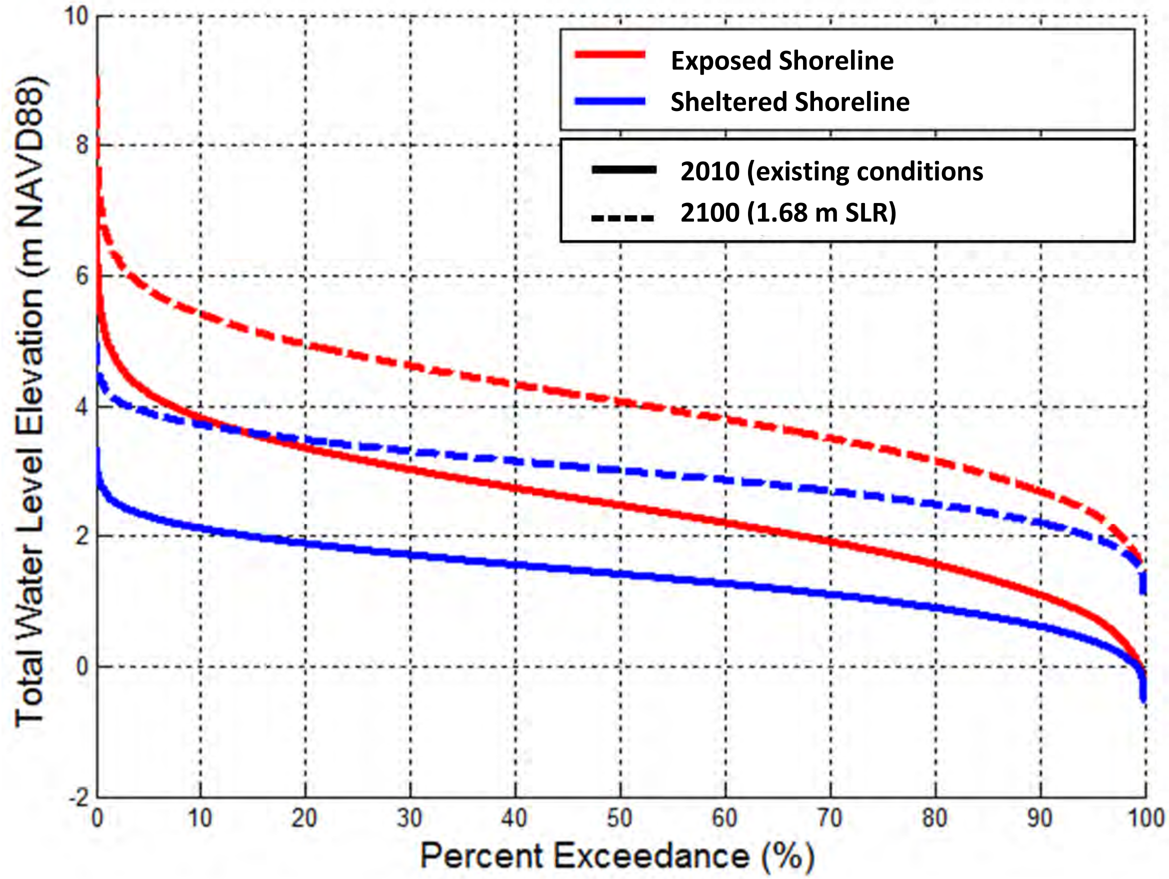
Historic sandy shoreline change rates in Los Angeles County



NOTE: Negative values are erosion, positive values are the result of Hwy 1 construction and other human activities.

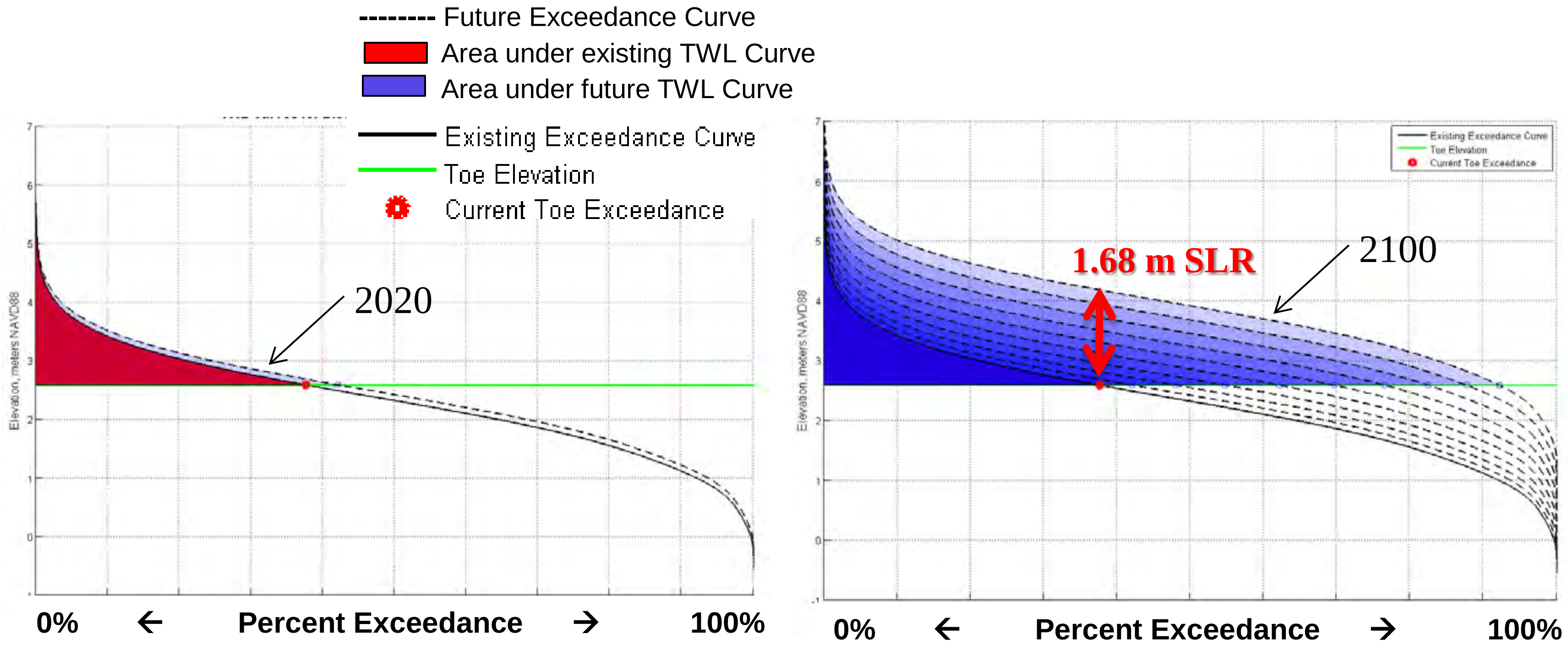
Figure 18

Historic cliff edge erosion rates in Los Angeles County



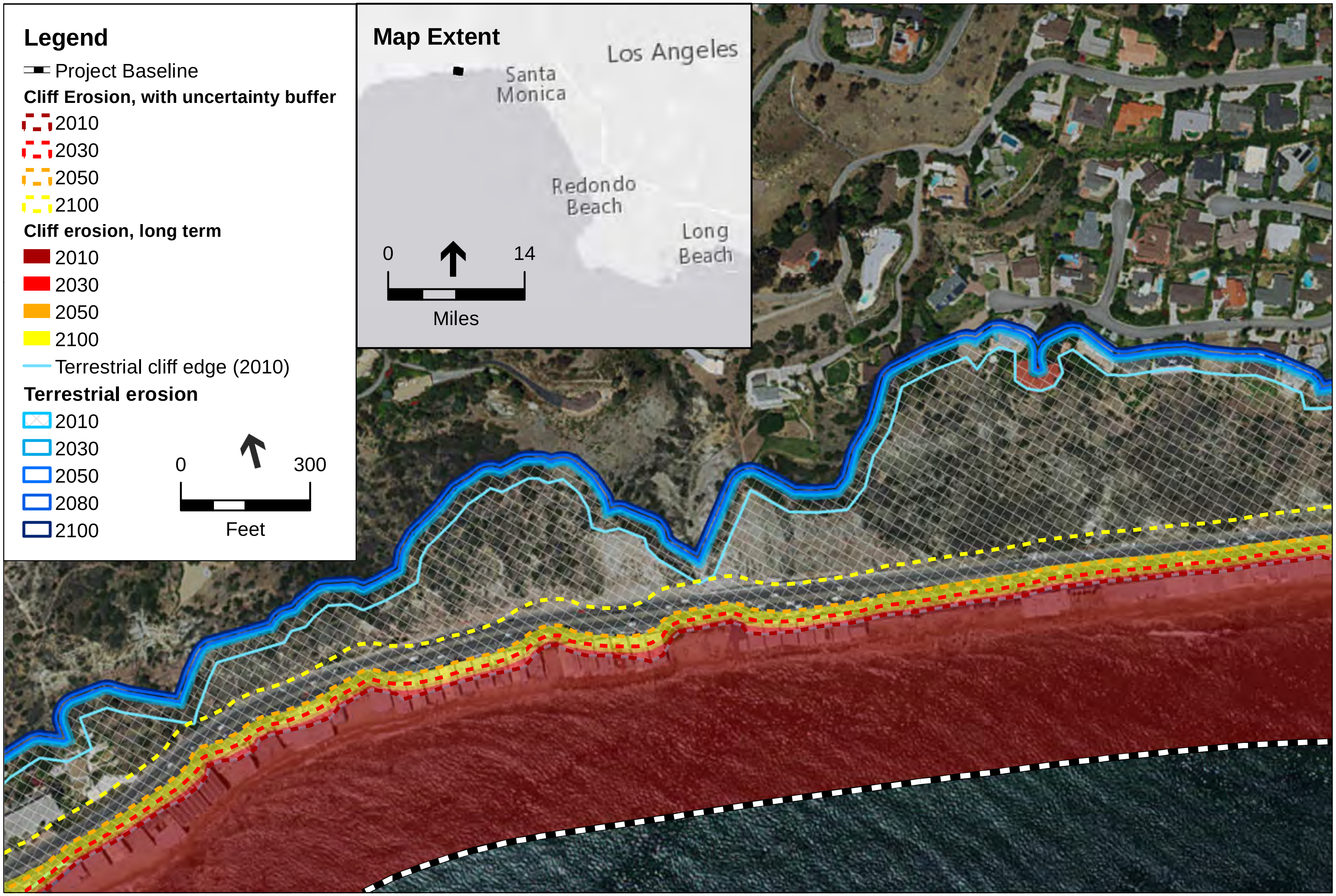
SOURCE: ESA, 2016.

Figure 19
Example of total water level exceedance curves



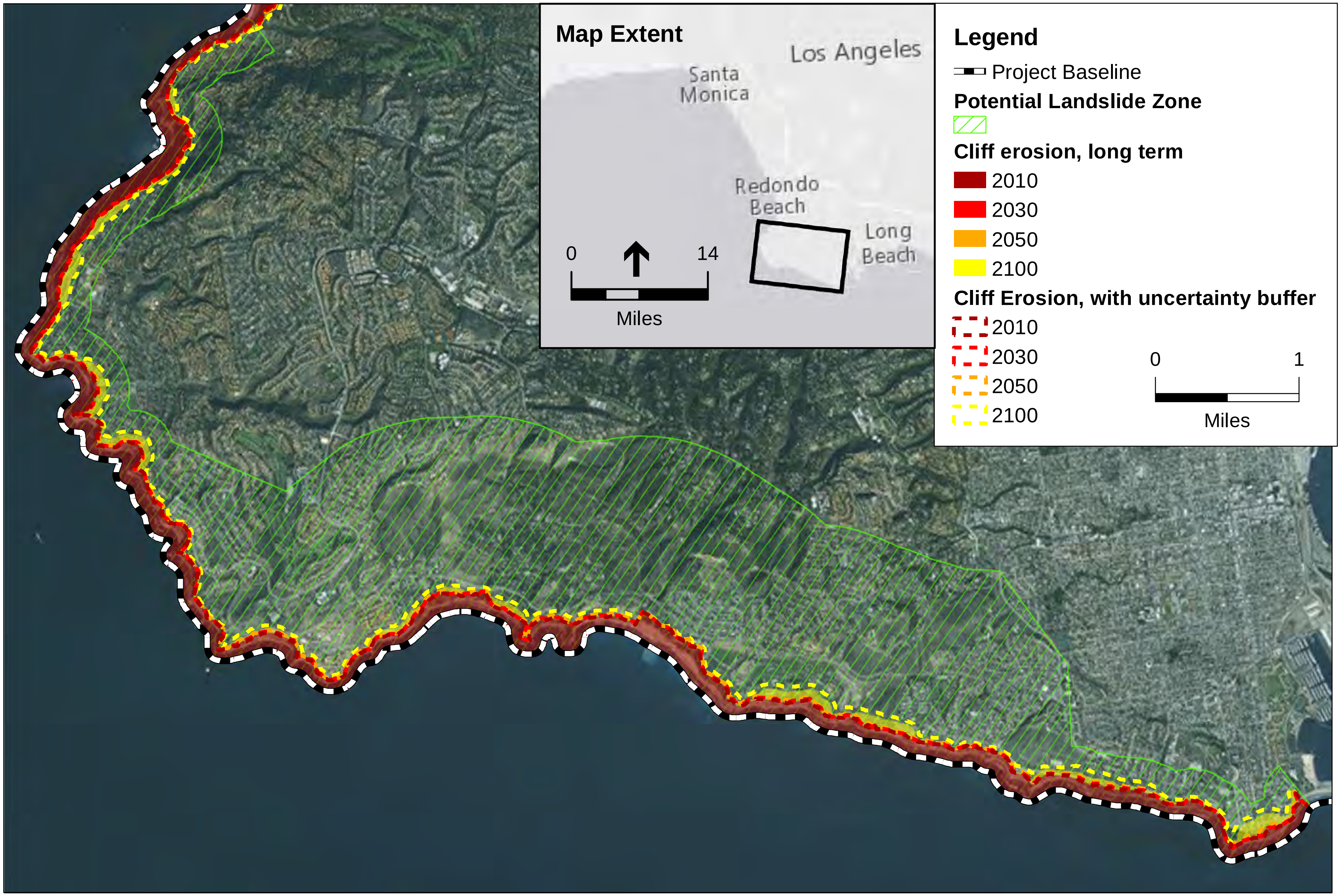
SOURCE: ESA

Figure 20
Cliff erosion methods



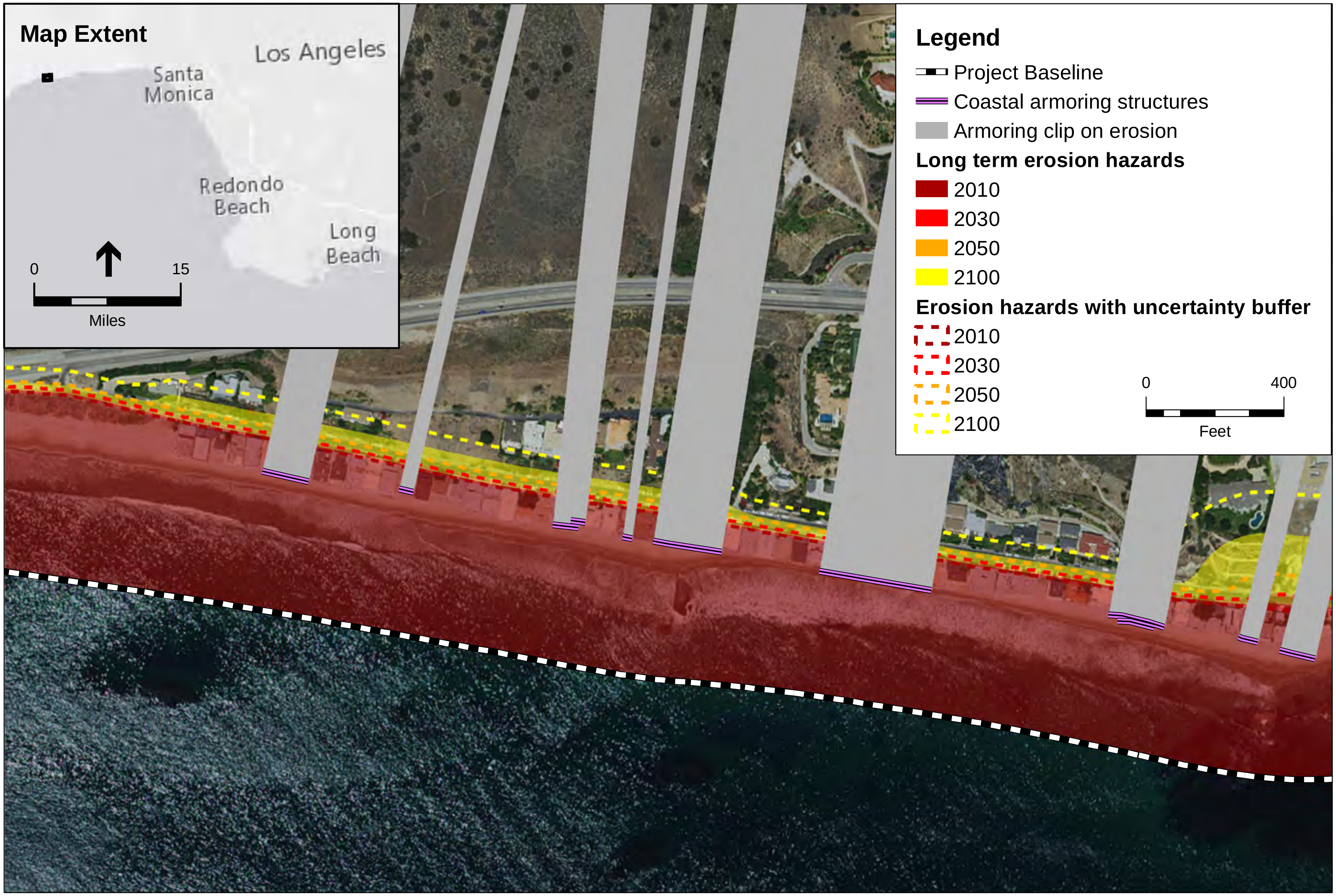
NOTE: The cliff erosion hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring. Terrestrial erosion zones do not depend on SLR.

Figure 21
Example of terrestrial erosion zones



NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring.

Figure 22
Potential landslide zone in Palos Verdes



NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010.

Figure 23

Example of coastal erosion armoring clip

SOURCE: USGS MOPs

LA County Coastal Hazard Modeling . 130524.00

Figure 24

Coastal Flooding Methods

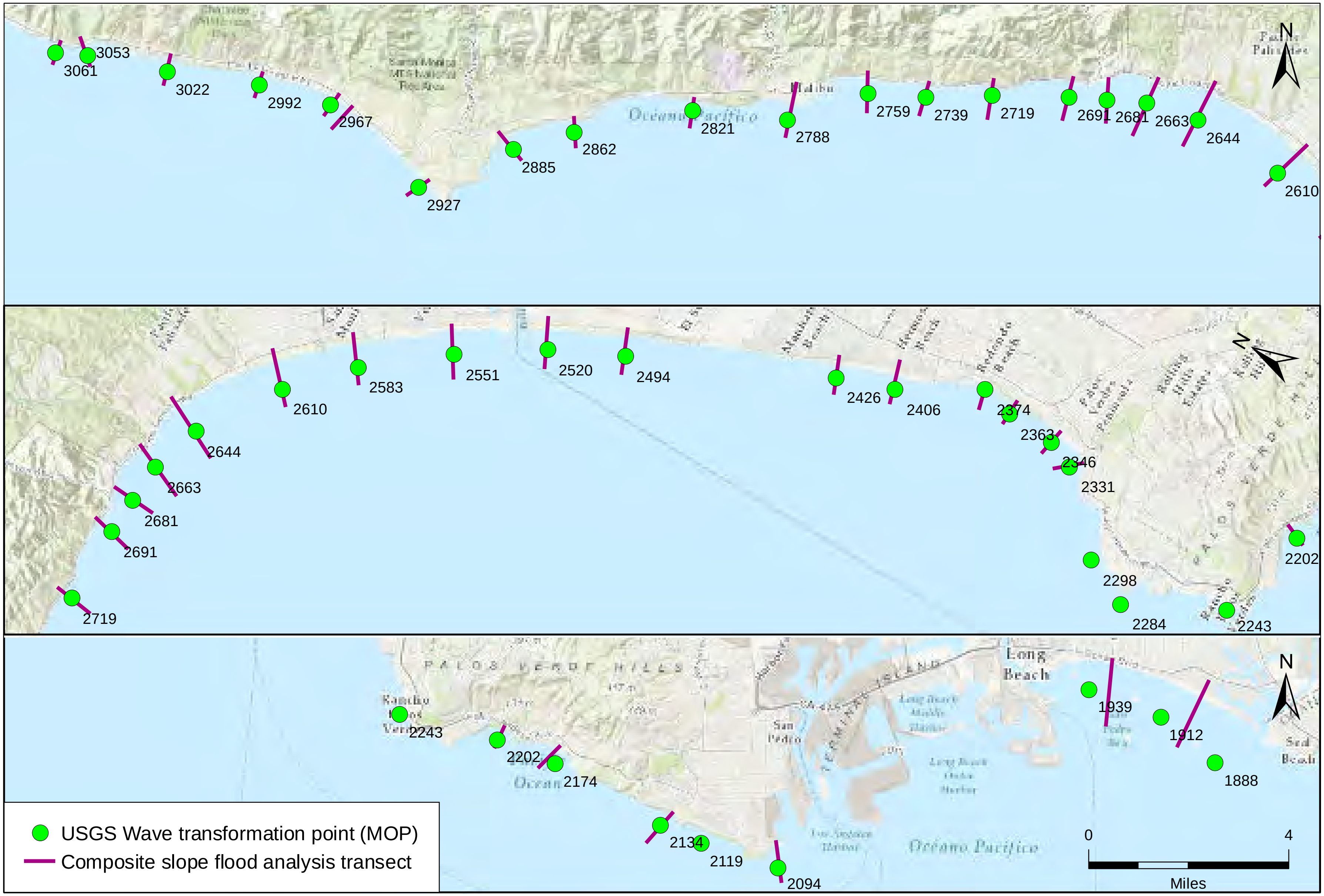
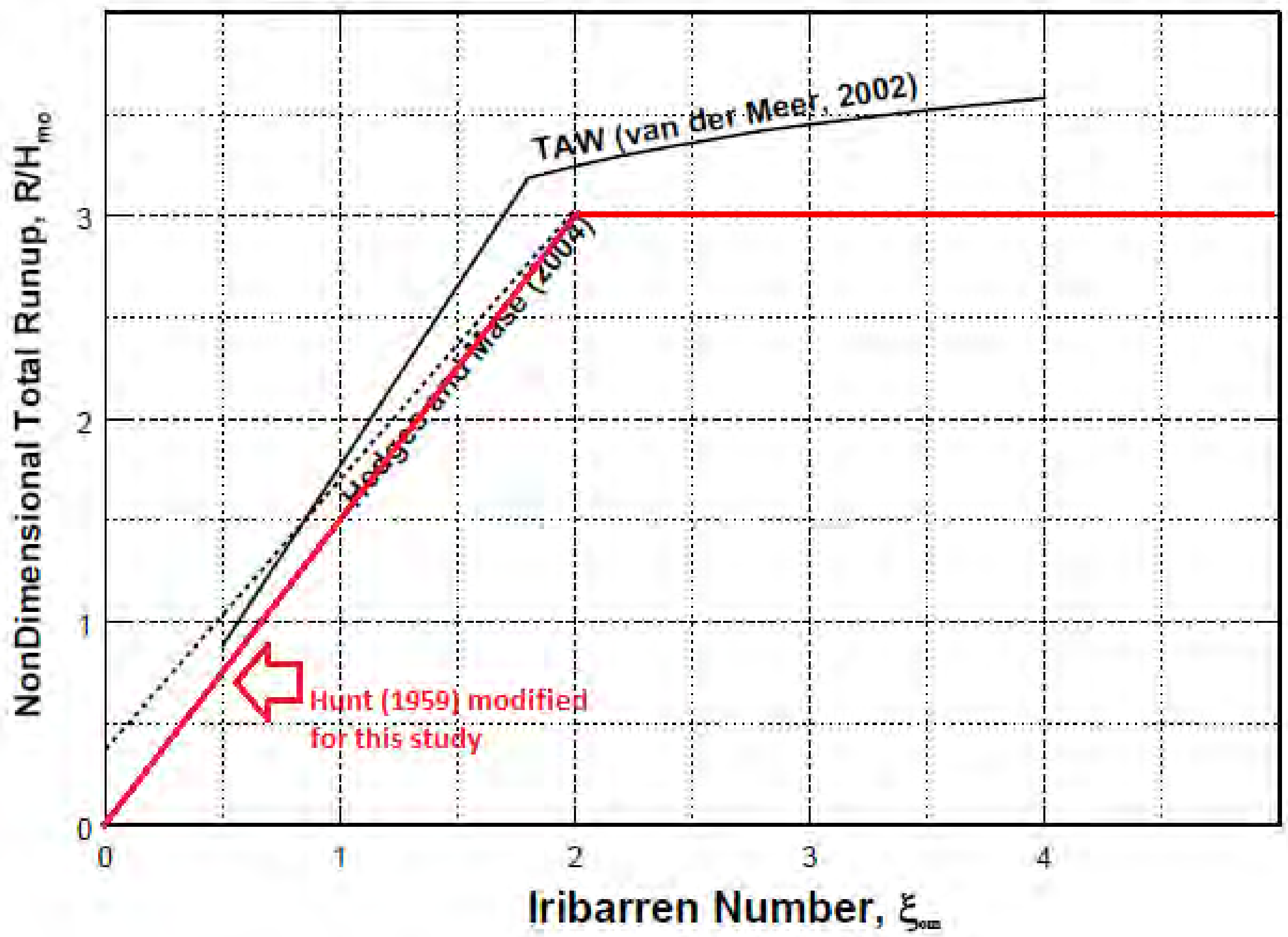


Figure 25
Composite slope profile locations

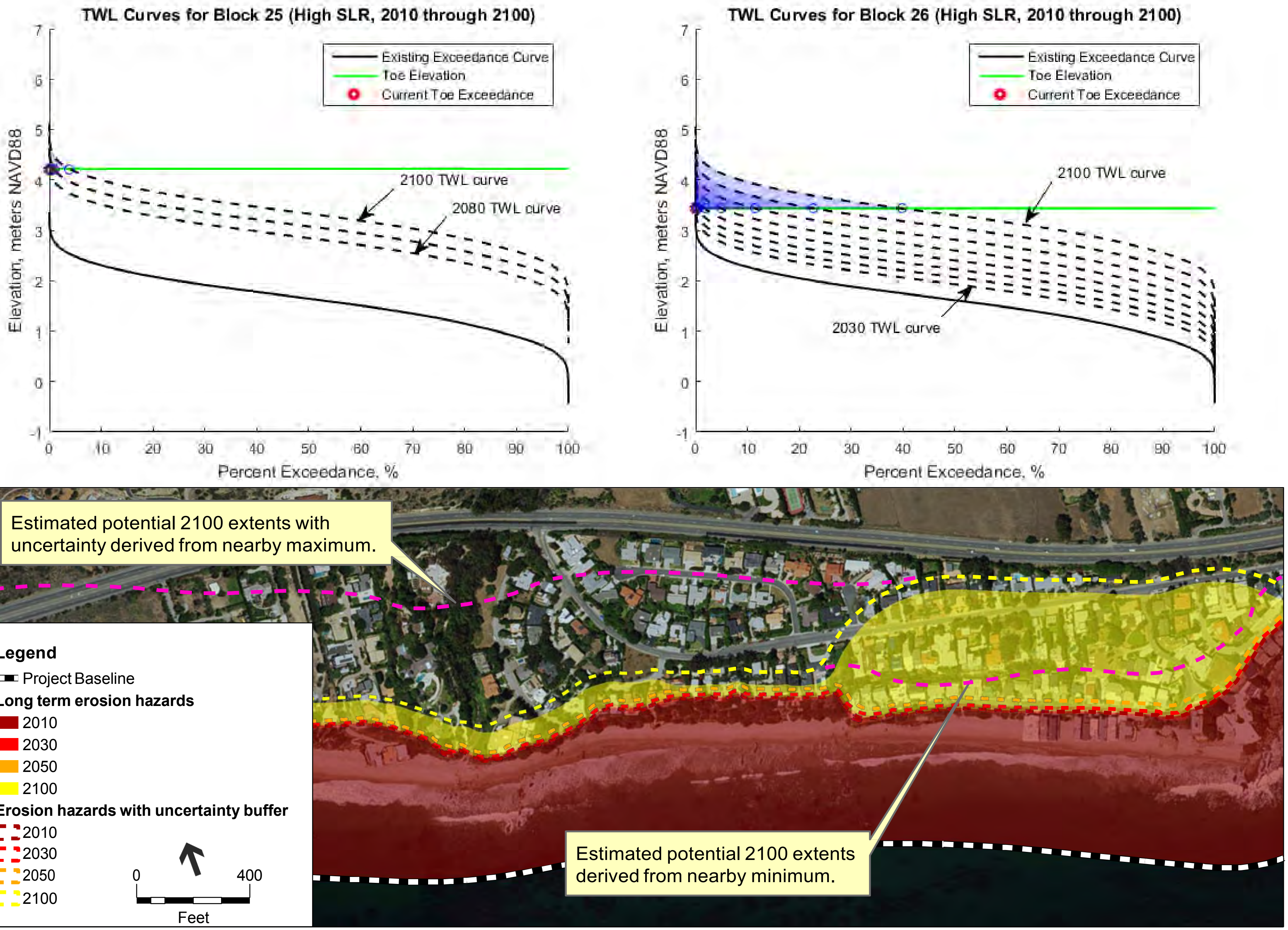


Wave run-up relative to wave height is modeled as being proportional to the Iribarren Number, also known as the Surf Similarity Parameter, which is the ratio of the beach slope to the square root of wave steepness (relative slope steepness). Note that the wave run-up is limited above a value of three times the incident wave height.

SOURCE: FEMA 2005a

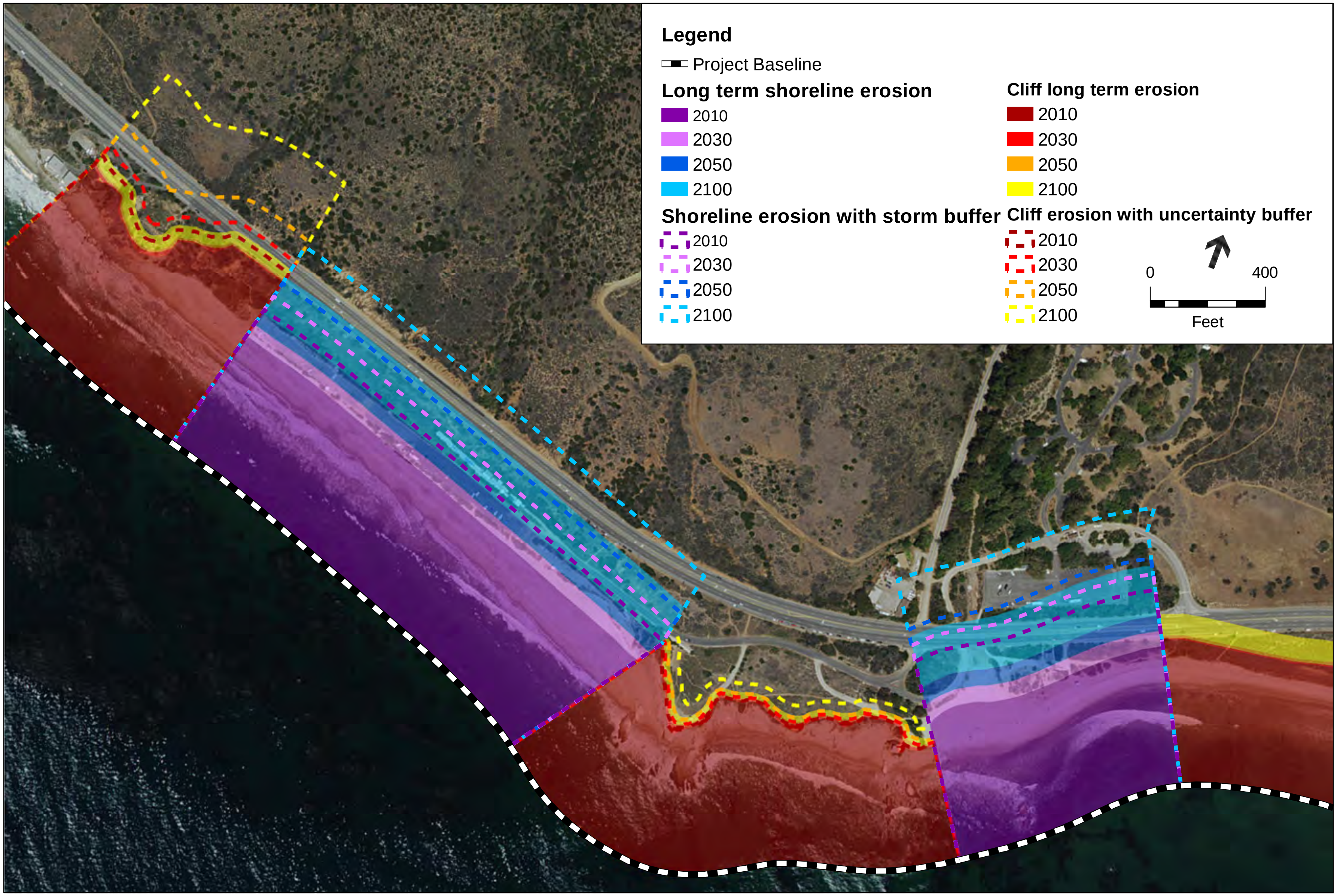
Figure 26

Non-dimensional total runup vs. Iribarren Number



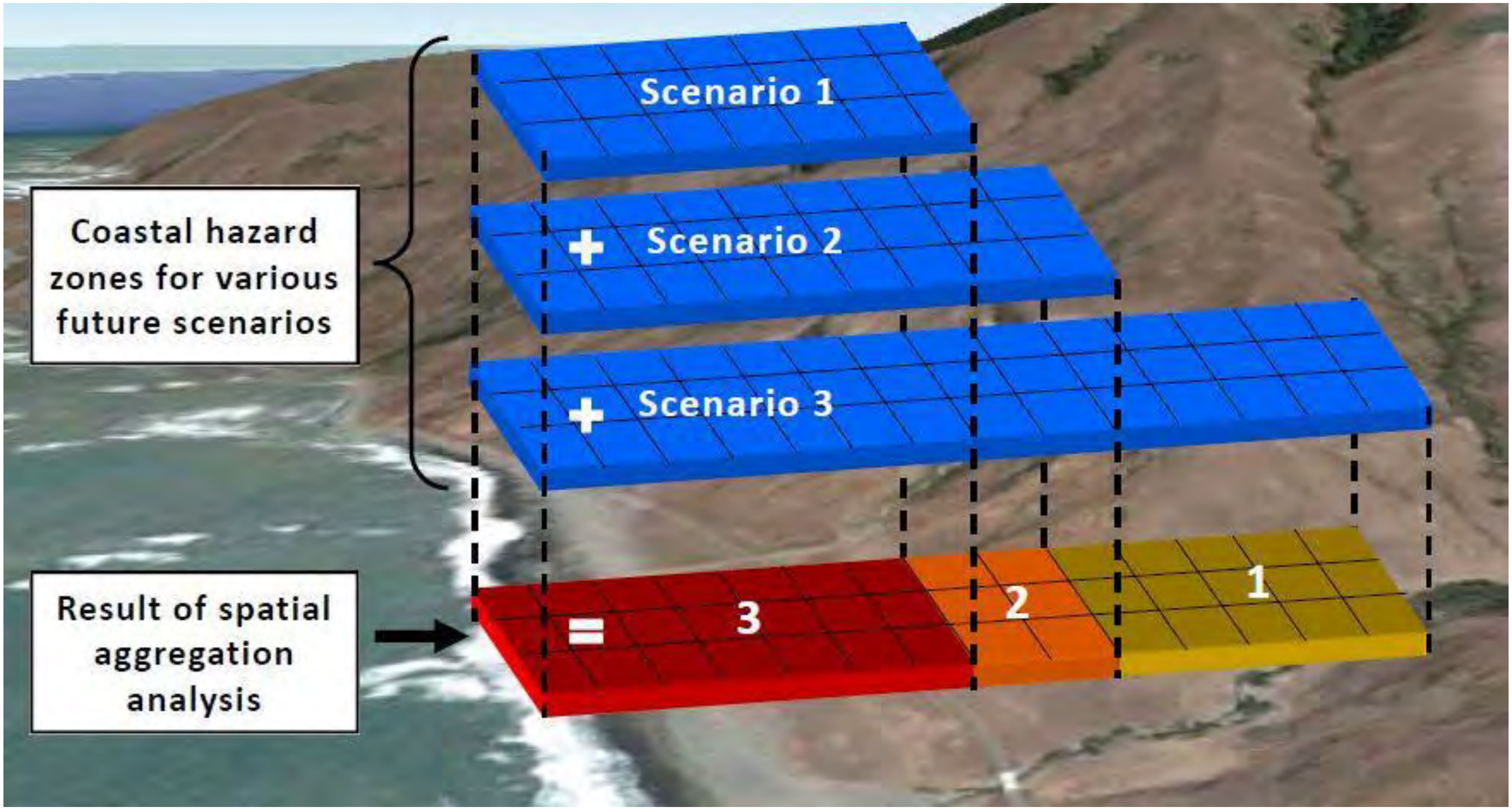
NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring. TWL curves are only shown for years were cliff toe is exceeded.

Figure 27
Model uncertainty example
Adjacent blocks of similar backshore type



NOTE: The hazards shown are for the "high sea level rise" scenario of 1.68 meters of SLR by 2100 relative to 2010. These hazard zones do not consider coastal armoring.

Figure 28
Model uncertainty example
Adjacent blocks of different backshore type



NOTE:. Spatially Aggregated Hazard maps for Los Angeles County Coastline are presented in Appendix 2.

Figure 29
Spatial Aggregation Schematic

APPENDIX 1. LIST OF LOS ANGELES COUNTY COASTAL HAZARD GIS FILES

File Naming Convention

The naming conventions for the GIS deliverables are based on hazard zone type, erosion projection type, sea level rise scenario, and planning horizon, as follows:

Shoreline and cliff erosion hazard zones:
Hazard zone type + _ + erosion projection type +_+ sea level rise scenario + planning horizon + armoring consideration

Flood hazard zones:
Hazard zone type + _ + sea level rise scenario + planning horizon

Hazard zone types:

coastal_erosion –	Coastal erosion hazard zone (shoreline and cliff together)
coastal_floodhz –	Coastal storm flood hazard zone
emhw –	Rising tide (Extreme Monthly High Water) inundation area
dep –	Inundation zone depth in areas with a definite connection to ocean tides

Erosion projection type (only applies to shoreline and cliff erosion hazard zones):

longterm –	A continuation of historic erosion with additional erosion caused by sea level rise. Does not include potential impacts of a large storm
event –	Includes long-term erosion and the potential erosion of a large storm event (e.g. 100-year storm) for shorelines and an uncertainty buffer of two standard deviations for cliffs

Armoring consideration (only applies to shoreline and cliff erosion hazard zones):

_Arm	Indicates whether coastal armoring structures were considered by stopping erosion at the limit of known existing structures.

Sea level rise scenarios (Section **Error! Reference source not found.**):
ec – Existing conditions (2010 water level)
s2 – Medium sea level rise (93 cm by 2100)
s3 – High sea level rise (167 cm by 2100)
s4 – Extreme sea level rise (167 cm at 2080 only)

Planning horizons (Section **Error! Reference source not found.**):
2010 (Existing conditions)
2030, 2050, 2100 (Future conditions)
2080 (Extreme Future conditions)

Example: The *long-term* coastal erosion hazard zone at *2100* with medium *sea level rise* (s2) that considers existing coastal armoring is named:

"coastal_erosion_longterm_s22100_Arm.shp"

Appendix 1. List of Los Angeles County Coastal Hazard GIS Files

File Name	Folder	File Type	Hazard Zone Type	Prefix	Projection Type	Sea Level Rise	Planning Horizon	Coastal Armor?
coastal erosion hazard zones								
coastal_erosion_hz_event_ec2010_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	ec	2010	Yes
coastal_erosion_hz_event_s22030_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2030	Yes
coastal_erosion_hz_event_s22050_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2050	Yes
coastal_erosion_hz_event_s22100_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2100	Yes
coastal_erosion_hz_event_s32030_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2030	Yes
coastal_erosion_hz_event_s32050_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2050	Yes
coastal_erosion_hz_event_s32100_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2100	Yes
coastal_erosion_hz_event_s42080_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s4	2080	Yes
coastal_erosion_hz_longterm_ec2010_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	ec	2010	Yes
coastal_erosion_hz_longterm_s22030_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2030	Yes
coastal_erosion_hz_longterm_s22050_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2050	Yes
coastal_erosion_hz_longterm_s22100_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2100	Yes
coastal_erosion_hz_longterm_s32030_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2030	Yes
coastal_erosion_hz_longterm_s32050_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2050	Yes
coastal_erosion_hz_longterm_s32100_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2100	Yes
coastal_erosion_hz_longterm_s42080_Arm.shp	/CoastalErosion/Armor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s4	2080	Yes
coastal_erosion_hz_event_ec2010.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	ec	2010	No
coastal_erosion_hz_event_s22030.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2030	No
coastal_erosion_hz_event_s22050.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2050	No
coastal_erosion_hz_event_s22100.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s2	2100	No
coastal_erosion_hz_event_s32030.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2030	No
coastal_erosion_hz_event_s32050.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2050	No
coastal_erosion_hz_event_s32100.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s3	2100	No
coastal_erosion_hz_event_s42080.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	event	s4	2080	No
coastal_erosion_hz_longterm_ec2010.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	ec	2010	No
coastal_erosion_hz_longterm_s22030.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2030	No
coastal_erosion_hz_longterm_s22050.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2050	No
coastal_erosion_hz_longterm_s22100.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s2	2100	No
coastal_erosion_hz_longterm_s32030.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2030	No
coastal_erosion_hz_longterm_s32050.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2050	No
coastal_erosion_hz_longterm_s32100.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s3	2100	No
coastal_erosion_hz_longterm_s42080.shp	/CoastalErosion/NoArmor	polygon shapefile	Coastal Erosion Hazard Zone	coastal_erosion_hz	longterm	s4	2080	No

Appendix 1. List of Los Angeles County Coastal Hazard GIS Files

File Name	Folder	File Type	Hazard Zone Type	Prefix	Projection Type	Sea Level Rise	Planning Horizon	Coastal Armor?
coastal storm flood hazard zones								
coastal_floodhz_ec2010_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	ec	2010	Yes
coastal_floodhz_s22030_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2030	Yes
coastal_floodhz_s22050_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2050	Yes
coastal_floodhz_s22100_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2100	Yes
coastal_floodhz_s32030_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2030	Yes
coastal_floodhz_s32050_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2050	Yes
coastal_floodhz_s32100_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2100	Yes
coastal_floodhz_s42080_Arm_cnnct.shp	/CoastalStormFlooding/Armor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s4	2080	Yes
coastal_floodhz_ec2010_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	ec	2010	No
coastal_floodhz_s22030_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2030	No
coastal_floodhz_s22050_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2050	No
coastal_floodhz_s22100_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s2	2100	No
coastal_floodhz_s32030_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2030	No
coastal_floodhz_s32050_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2050	No
coastal_floodhz_s32100_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s3	2100	No
coastal_floodhz_s42080_cnnct.shp	/CoastalStormFlooding/NoArmor	polygon shapefile	Coastal Storm Flood Hazard Area	coastal_floodhz	event	s4	2080	No
extreme monthly tides inundation zones, area								
EMHW__ec2010.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	ec	2010	No
EMHW__s22030.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s2	2030	No
EMHW__s22050.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s2	2050	No
EMHW__s22100.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s2	2100	No
EMHW__s32030.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s3	2030	No
EMHW__s32050.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s3	2050	No
EMHW__s32100.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s3	2100	No
EMHW__s42080.shp	/TidalFlooding_EMHW/Extents	polygon shapefile	EMHW Inundation Zone	EMHW	longterm	s4	2080	No
extreme monthly tides inundation zones, depth								
dep_ec2010	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	ec	2010	No
dep_s22030	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2030	No
dep_s22050	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2050	No
dep_s22100	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2100	No
dep_s32030	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2030	No
dep_s32050	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2050	No
dep_s32100	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2100	No
dep_s42080	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s4	2080	No
dep_l_ec2010	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	ec	2010	No
dep_l_s22030	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2030	No
dep_l_s22050	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2050	No
dep_l_s22100	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s2	2100	No
dep_l_s32030	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2030	No
dep_l_s32050	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2050	No
dep_l_s32100	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s3	2100	No
dep_l_s42080	/TidalFlooding_EMHW/Extents	raster	EMHW Inundation Zone	EMHW	longterm	s4	2080	No
non-coastal erosion hazards								
LandslideHazardZones.shp	/CoastalErosion/NonCoastalErosion	polygon shapefile	Non-Coastal Erosion Hazard Zone	N/A	event	N/A	N/A	No
TerrErZone_2010	/CoastalErosion/NonCoastalErosion/lalcp_TerrestrialErosionHZ.gdb	polygon feature class	Non-Coastal Erosion Hazard Zone	TerrErZone	event	N/A	2010	No
TerrErZone_2030	/CoastalErosion/NonCoastalErosion/lalcp_TerrestrialErosionHZ.gdb	polygon feature class	Non-Coastal Erosion Hazard Zone	TerrErZone	event	N/A	2030	No
TerrErZone_2050	/CoastalErosion/NonCoastalErosion/lalcp_TerrestrialErosionHZ.gdb	polygon feature class	Non-Coastal Erosion Hazard Zone	TerrErZone	event	N/A	2050	No
TerrErZone_2080	/CoastalErosion/NonCoastalErosion/lalcp_TerrestrialErosionHZ.gdb	polygon feature class	Non-Coastal Erosion Hazard Zone	TerrErZone	event	N/A	2080	No
TerrErZone_2100	/CoastalErosion/NonCoastalErosion/lalcp_TerrestrialErosionHZ.gdb	polygon feature class	Non-Coastal Erosion Hazard Zone	TerrErZone	event	N/A	2100	No