Sea Level Rise Vulnerability Study for the City of Los Angeles

Prepared by the
University of Southern California Sea Grant Program

Sea Grant
University of Southern California

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Funding
This publication has been produced with support from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA10OAR4170058.

The National Sea Grant Program is a network of 33 university-based programs in coastal and Great Lakes states involving more than 300 institutions nationwide in research, education and the transfer of technology regarding coastal, marine and Great Lakes issues.

Publication Number: USCSG-TR-05-2013

Report Citation
Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, M. Schulhof. (2013) *Sea Level Rise Vulnerability Study for the City of Los Angeles*. USCSG-TR-05-2013.

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Acknowledgments

USC Sea Grant is grateful to the key contributors to this study. Most importantly, we would like to acknowledge the authors who contributed the vulnerability assessments: Dr. Reinhard Flick, Mr. Brian Holland, Ms. Melissa Higbee, Dr. Julia Ekstrom, Dr. Susanne Moser, Dr. Dan Wei, and Dr. Sam Chatterjee. All of these authors are recognized locally, nationally, and internationally as experts in their respective fields of study. They worked to complete these assessments on a very tight timeline and with modest budgets. We would like to thank Dr. Patrick Barnard and his team at the U.S. Geological Survey for their invaluable work applying the coastal storm modeling system to Los Angeles. Dr. Flick, Ms. Lesley Ewing, Dr. Mark Gold and Dr. Guangyu Wang, as advisors to USC Sea Grant, provided valuable insight, advice and guidance on this study. Dr. Paul Bunje, Ms. Krista Kline, and Ms. Monica Gilchrist, as members of the Adaptation Planning Team, also played an enormous role in the development of the planning process and all the steps along the way. We would also like to thank the external reviewers of the vulnerability assessments for taking the time to review these studies and for providing insightful and helpful suggestions. We thank the City of Los Angeles for the opportunity to work with City officials to begin the important task of identifying the City's vulnerability to sea level rise.

Abstract

The City of Los Angeles (City of L.A. or the City) has initiated research to support planning for the impacts of climate change. The City, the University of Southern California Sea Grant Program (USC Sea Grant) and project partners developed a science-based and stakeholder-supported adaptation planning process to support research on the impacts of sea level rise on City assets, resources and communities. As a first step, this report, *Sea Level Rise Vulnerability Report for the City of Los Angeles*, is a summary of initial research on the potential impacts of sea level rise and associated flooding from storms for coastal communities in the City of L.A. The study concentrates on the City's three coastal regions: Pacific Palisades from Malibu to Santa Monica; Venice and Playa del Rey; and San Pedro, Wilmington and the Port of Los Angeles.

An interdisciplinary team of world-renowned experts was engaged to identify the City's potential exposure to sea level rise. A sophisticated model, developed by the U.S. Geological Survey (USGS), was used to examine the impacts from rising seas, as well as flood impacts from storms and high tides that could be exacerbated with those rising sea levels. The model is based on an *El Nino*-fueled storm that occurred in the Los Angeles region during January 2010, considered a moderately severe "10-year" storm (10% chance of occurring annually). As new data become available for the L.A. region, they can be applied to evaluate impacts of more severe storms, such as a 100-year event (1% chance of occurring annually).

In this study, we provide an initial report by Dr. Reinhard Flick focused on coastal vulnerabilities in locales within City boundaries, and provide recommendations for beach monitoring programs. We then highlight the findings of three vulnerability assessments that provide a preliminary examination of the physical, social, and economic impacts of sea level rise on the City's coastal assets, resources and communities, and include a summary discussion of ecological vulnerability at Ballona Wetlands. One of the next steps for the City will be to develop an Adaptation Plan. We help get this process started with a matrix of available adaptation measures the City can consider in planning for sea level rise as well as recommendations for moving forward with adaptation planning.

The summary of coastal issues and full texts of each vulnerability assessment are included as appendices to this report:

- Appendix 1 - *City of Los Angeles Coastal Issues Related to Future Mean Sea Level Rise*
- Appendix 2 - *Physical Vulnerability Assessment Findings for the City of Los Angeles*
- Appendix 3 - *Sea-Level Rise Impacts and Flooding Risks in the Context of Social Vulnerability: An Assessment for the City of Los Angeles*
- Appendix 4 - *Economic Impact of Sea Level Rise to the City of Los Angeles*

This report provides an initial and conservative assessment of the potential vulnerabilities the City may face due to rising sea levels. It draws attention to potentially vulnerable City assets (i.e. water and power infrastructure), possible building-related economic losses, and indicators of social vulnerability to begin to identify the most vulnerable communities in the City of L.A. It is not meant to be a comprehensive or regional review. It includes strategies the City may wish to consider; however this report in no way replaces the critical science and engineering studies that should be conducted as part of the development of any adaptation strategy or plan.

Executive Summary

Climate change is expected to usher in an era of higher temperatures, increased precipitation and/or severe drought, and increased rates of sea level rise around the world. According to the National Research Council (NRC), global sea level has risen at an increasing rate since the late 19th / early 20th Century, when global temperatures first started to rise. Climate researchers believe sea level rise will drive storm surge and wave run-up higher than current conditions, thereby causing more extensive and frequent coastal, storm-driven flooding.

Sea level rise in Los Angeles is expected to match global projections over the next century with an increase of 0.1 - 0.6 meters (m), or 0.3 - 2.0 feet (ft), from 2000 - 2050 and 0.4 - 1.7 m (or 1.3 - 5.6 ft) from 2000 - 2100 (NRC 2012). Tides, wave-driven run-up, and storm surge play critical roles in coastal flooding in Southern California, especially when big wave storms occur at or near peak high tides. Sea level rise will potentially exacerbate the damage from these events.

The City of Los Angeles (City of L.A. or the City) owns and maintains critical coastal infrastructure that includes two power plants and two wastewater treatment plants, and the Port of Los Angeles (Port), all of which are approximately 10 ft above sea level. Under current conditions, some of this infrastructure is vulnerable to flooding during high tide events and severe storms. This flooding is expected to worsen as sea level rise contributes to increased total water levels. The Port is among the busiest in the world, contributing more than $63 billion to the State of California, and more than $260 billion to the U.S. economy. More than 40% of all imports arriving in the U.S. comes through the Ports of Los Angeles and Long Beach, where it is loaded onto trucks and trains for overland shipping (Port of Los Angeles 2012).

Beyond these critical assets, a major component of Los Angeles' economy is dependent upon beach tourism. In 2012, the Los Angeles region attracted over 41 million tourists, who accounted for more than $16.5 billion in expenditures (Los Angeles Division of Tourism 2012).

The City recognizes that this is the time to begin planning for the impacts of climate change, not 20 or 30 years in the future when disruptions to business and damage to critical coastal infrastructure will prompt *ad hoc* and poorly coordinated responses. Because of the unprecedented degree of stakeholder collaboration and inter-agency cooperation required for large-scale regional adaptation, an extended timeframe for planning is critical.

The City of L.A. engaged the University of Southern California (USC) Sea Grant Program, along with the Los Angeles Regional Collaborative on Climate Action and Sustainability (LARC) and ICLEI – Local Governments for Sustainability, U.S.A. (ICLEI), to begin research into the impacts of sea level rise on the City's coastal assets, resources and communities. In December 2011, the City launched this project; a science-based and stakeholder-supported sea level rise adaptation planning effort. The methodology 1) supports the City in identifying the vulnerabilities of its coastal assets, resources and communities to sea level rise, 2) provides information for developing meaningful and effective adaptation strategies, and 3) builds on the City's ongoing environmental and climate policies.

Geographic Scope and Purpose of this Report

This report focuses on the potential impacts of sea level rise and associated coastal flooding for the coastal communities of the City of L.A. We highlight the findings of a coastal issues report; three vulnerability assessments that provide a preliminary examination of the physical, social, and economic impacts of sea level rise on the City of L. A.; and a discussion of ecological vulnerability at Ballona

Wetlands. We conclude the report with a set of guidelines for identifying and evaluating possible adaptation strategies and measures to address these potential vulnerabilities. This report is meant to provide a first glimpse into the vulnerabilities the City of L.A. may face under rising sea levels and to start building the capacity within the City to begin an adaptive approach to planning for sea level rise and other climate change impacts.

Sea Level Rise Exposure

For the vulnerability assessments, the City utilized a coastal impacts model developed by Dr. Patrick Barnard and colleagues at the United States Geological Survey (USGS). This model incorporates not only the impacts of rising sea levels, but also the impacts of waves and storm surge associated with coastal storms. The USGS model is based on a storm that occurred in the Los Angeles region during January 2010. The modelers applied two sea level rise scenarios using upper-end estimates of 0.5 meters (m) sea level rise between 2000 - 2050 and 1.4 m sea level rise between 2000 - 2100 (scenarios based on Rahmstorf 2007). The scenarios were added to the tide, wave and wind conditions of the January 2010 storm to project what could be expected for a similar type of storm event under conditions related to rising seas. While there are a number of sea level rise and coastal impact models available for use, it was determined at the time of this analysis that the USGS model provided the best available science.

Major Findings

Coastal and Shoreline Assets[1]

This section summarizes a preliminary report on coastal vulnerabilities for those beaches located within City boundaries, and provides recommendations for monitoring programs. This report provides a first glimpse into potential strategies the City may wish to consider, however this report in no way replaces the critical engineering studies that should be conducted before committing to any strategy or plan.

Physical Vulnerability Assessment[2]

The physical vulnerability assessment considers areas where important structural community assets are susceptible to and/or unable to accommodate adverse effects of sea level rise. The major findings include:

- The City's roads and water systems (wastewater, stormwater, potable water) are vulnerable to impacts from sea level rise and associated storm surge.

- The City's cultural assets are vulnerable to sea level rise. Museums and cultural centers are considered to be highly vulnerable because of the damages that can result to the physical buildings and resources. Parks and open space, while in vulnerable locations, are less vulnerable to flooding impacts since they can be restored relatively quickly.

- The Port and the City energy facilities have relatively low vulnerability to sea level rise.

Under current conditions, City assets are already vulnerable to damages that could occur during concurrent high tide and large storm events. Highlighting future possible vulnerabilities allows the City to start planning now on how to better address the potentially increasing frequency and severity of these events in the future.

It is also important to highlight that some agencies within the City have already begun planning for sea

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1. This report, funded by the City of L.A., was developed by Dr. Reinhard Flick (see Appendix 1).
2. This study, funded by the City of L.A., was conducted by ICLEI (see Appendix 2).

level rise, even prior to the initiation of this study. For instance, the Bureau of Sanitation has recognized that climate change effects may impact assets and operations and has developed strategic planning goals and outcomes to mitigate these impacts. The Bureau has commissioned engineering studies to plan for potential flooding at several critical locations. Since 2011, the Port has been working with the RAND Corporation to conduct a sea level rise vulnerability study. Similarly, in 2010, the Department of Water and Power conducted a tsunami study. Analyses from all of these studies have been incorporated in the sea level rise vulnerability study we discuss here.

Social Vulnerability Assessment[3]

The social vulnerability assessment describes the impacts that sea level rise and its associated effects may pose to the City's coastal residents. Demographic overviews of the three coastal areas within the City of L.A. that will experience direct impacts of sea level rise are followed by a description of population characteristics that help predict the degree of social vulnerability for certain segments of communities vulnerable to flooding. The characteristics examined in this assessment include: income, poverty, education, females as head of household, race, linguistic isolation, age, housing type and age, and physical and mental illnesses and disabilities. These characteristics are associated with higher sensitivity and/or lower adaptive capacity to flooding and sea level rise, and thus can be used to inform adaptation planning. Major findings include:

- Low-lying San Pedro and Wilmington, communities around the Port of Los Angeles, are more vulnerable to the impacts of sea level rise, due to lower per capita income, lower education levels and linguistic isolation.

- Venice, and low-lying San Pedro and Wilmington may also have reduced capacity to adapt to the impacts of sea level rise because of an older housing stock and a high percentage of renters.

- The Social Vulnerability Index (developed by Cutter et al. 2003), which calculates a vulnerability index based on a combination of 32 census-based population characteristics, corroborates findings that communities in Venice, San Pedro and Wilmington are the most socially vulnerable coastal communities in the City.

This assessment allows the City to begin identifying adaptation and communication strategies that target vulnerable populations. Strategies may include: documenting where vulnerable populations reside so first responders understand the extent of the need and can direct assistance appropriately when the time comes; conducting workshops and preparing other public outreach materials for non-English speakers; and, given low education and high poverty levels, using alternative educational/informational methods that do not require literacy or internet access.

Economic Vulnerability Assessment[4]

The economic impacts analyzed in this study include both property damage losses and direct and indirect business interruption losses due to sea level rise and associated storm surge. These findings present a "worst case" assumption if the City takes no action to plan for the potential impacts from these events.

Major findings include:

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3. This study, funded by the City of L.A., was conducted by Dr. Julie Ekstrom and Dr. Susanne Moser (see Appendix 3).
4. This study, funded by USC Sea Grant, was conducted by Dr. Dan Wei and Dr. Sam Chatterjee (see Appendix 4).

- For a 10-year flood event, the direct building losses are estimated to be $410.3 million with 0.5 m sea level rise, and nearly doubled with 1.4 m sea level rise. Losses to residential buildings comprise about 50% of the total losses. The other 50% of losses are split evenly between the commercial buildings and industrial buildings in most simulated scenarios.

- Business interruption losses are relatively small compared with the building stock losses. For a 10-year flood event, the total output losses in the City are expected to be $5.8 million to $9.1 million under the two simulated sea level rise scenarios.

- Simulations show that the transportation system and the utility system in the City would suffer very limited damages from flooding in the limited scenarios evaluated in this study.

Impacts caused by long-term and permanent coastal erosion and beach area losses of sea level rise are not covered in this study. The potential economic impacts of sea level rise to the City in this analysis should be considered to be conservative estimates. Further economic studies to assess potential impacts on tourism, transportation systems, goods movement, and the regional economy would help to elucidate a more robust picture of potential impacts. Identifying these vulnerabilities allows the City to identify where it should focus its adaptation efforts with respect to sea level rise to minimize the losses due to damage to its building stock and to minimize business interruption losses and the ensuing ripple effects.

Ecological Vulnerability Assessment

Most of the City's coastal zone is highly urbanized. The vulnerability of the less urbanized areas such as City beaches, open space areas, parks or recreation centers, was assessed in the physical vulnerability assessment conducted by ICLEI (Appendix 2). We do highlight one important ecological asset located within City boundaries: the Ballona Wetlands Ecological Reserve. This wetland provides a plethora of ecosystem services including, but not limited to, biological productivity energy flow, nutrient cycling, foraging, nursery, sheltering, and resting places for wildlife, sediment accretion, and wave attenuation.

We cite results from a recent sea level rise study conducted by researchers from Loyola Marymount University and the Santa Monica Bay Restoration Foundation, which indicate that Ballona is vulnerable to sea level rise and associated storm surge impacts (Bergquist et al. 2012). Even though the City does not manage Ballona Wetlands, it provides important ecosystem functions for the City, and therefore we suggest that it is in the interest of the City to participate in the development of sea level rise adaptation strategies and plans for this important ecological resource.

Moving Forward: Considerations for Identifying Appropriate Adaptation Strategies

In the final section, we identify a suite of adaptation measures the City can consider utilizing in planning for sea level rise. We also provide several recommendations for moving forward. These recommendations include:

- Continue the "adaptive adaptation planning" process that reassesses the City's vulnerabilities as scientific information and further vulnerability assessments evolve;

- Invest in a strong foundation for climate adaptation;

- Define clear adaptation goals;

- Develop clear prioritization and selection criteria for choosing among possible adaptation strategies;

- Expand partnerships in developing adaptation options, both within the City itself, as well as in the regional context;

- Invest in scientific and engineering studies and coastal monitoring efforts to clearly delineate the necessary modifications in physical assets and infrastructure, determine the time frame for responses, and begin constructing an estimate of financial needs; and,

- Conduct robust and thorough risk analyses.

Regional Stakeholder Participation

Stakeholder input is an invaluable part of the public process when planning for a future with potentially significant impacts on the public. A Regional Stakeholder Working Group (RSWG) was appointed early in the process. The group includes representatives from the Los Angeles City Council, Los Angeles County, State of California, the private sector, government associations, and non-governmental organizations. Through formal meetings and a review and comment process, the Regional Stakeholder Working Group (RSWG) provided critical input to the process and the final version of this study. RSWG members commented on the sea level rise report by providing suggestions on how to move forward in adaptation planning, expand this study in future iterations, and communicate the findings to wider audiences. While some comments were out of the scope and intent of this initial study, it is important to capture comments to assist the City as it moves to the next milestones of the process and updates this study as new science and information become available.

City Leadership Already Underway

Already, the City adaptation process is well underway to meeting, and exceeding, some of the recommendations listed above. The City has demonstrated proactive leadership in developing the process and undertaking this study to identify its potential vulnerabilities to sea level rise and associated flood impacts from storms. The City has engaged a team of world renowned experts to identify its potential exposure to sea level rise, using a sophisticated model that examines both the impacts from rising seas, as well as flood impacts from storms and high tides, which could be exacerbated with those rising sea levels. It has identified its potential vulnerabilities in order to begin planning now and not in 20 or 30 years.

Prior even to the recommendations of this study, agencies within the City were already commissioning studies to understand the impacts of sea level rise on critical infrastructure, as well as other climate change impacts. LARC commissioned a simulation of climate change by Dr. Alex Hall at the University of California, Los Angeles, to examine localized impacts such as temperature change, urban heat islands, fresh water supply, increased fire frequency, and human health impacts to the greater L.A. metropolis. Further results describing changes in precipitation, cloud cover, snowpack, winds, storms, and other patterns will be released in 2013 and 2014. Equally, the best adaptation strategy is mitigation, or the reduction of greenhouse gas (GHG) emissions. The City of L.A. has emerged as a leader in its varied and numerous mitigation strategies. Adaptation to current and potential impacts is the next important phase in tackling climate change head-on.

Sea Level Rise in Southern California

The Global Picture of Climate Change

Aside from a warmer planet, climate change is expected to usher in an era of higher winds, flooding and/or severe drought, and increased rates of sea level rise around the world. Caused by both the thermal expansion of seawater and the melting of land-based ice, global sea level rise is expected to accelerate due to increasing rates of ice cap and glacier melting and transfers of more heat from the atmosphere to the oceans. According to a recent report by the National Research Council (NRC) (NRC 2012), based on tide gage measurements from around the world, global sea level rose an average of 0.17 cm (or 0.07 in) per year, for a total of about 18 cm (7 in) over the entire 20th century. In comparison, global rates for 1993–2003 were almost double at 0.31 cm (or 0.12 inches) per year, based on precise satellite altimetry measurements and confirmed by tide gage records (Nicholls et al. 2011; NRC 2012). The most recent NRC report (2012) reports estimates global sea level will rise by as much as 8 - 23 cm (3 - 9 in) by 2030 relative to 2000; 18 - 48 cm (7 - 19 in) by 2050; and 50-140 cm (20-55 in) by 2100.

Many argue that we are already seeing evidence of this change. The fall of 2012, for example, witnessed "Superstorm Sandy" along the Eastern Seaboard of the U.S. The 14-foot storm surge at its peak washed away dozens of homes and destroyed entire neighborhoods; flooded streets, subways and other infrastructure, including a main substation of the power grid. Approximately 8.5 million people were without power, many without heat, refrigeration and communication for almost three weeks. All told, Sandy cost 159 lives and resulted in $65 billion in damages and economic loss, including significant business interruption (Hurricane Sandy Rebuilding Task Force 2013). While there is no definitive evidence that Sandy was a direct consequence of climate change, she left behind a path of devastation that demonstrates the damage that can accrue from major storms.

The Local Picture of Sea Level Rise

Although it is occurring around the globe, sea level rise is not uniform; it varies from place to place (NRC 2012). Along the West Coast, sea level is influenced by a number of regional factors, such as decadal (or about a 10 year cycle) ocean and atmospheric circulation patterns (Bromirski et al., 2011) and shorter-term heating and cooling effects, such as *El Niños* in the Pacific Ocean, as well as plate tectonics (NRC 2012).

Sea level rise in Los Angeles is expected to match global projections over the next century, despite the fact that local sea level has been relatively static for the past decade. For the Los Angeles region, the NRC report projects sea level rise of an increase of 0.1 - 0.6 m (or, 0.3 - 2.0 ft), from 2000 - 2050 and 0.4 - 1.7 m (or 1.3 - 5.6 ft) from 2000 - 2100 (NRC 2012).

Image of the Hyperion Wastewater Treatment Plant and the Scattergood Generating Plant, two coastal assets in the City of Los Angeles. (Photo credit: Kenneth & Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org).

Tides, wave-driven run-up, and storms play the most critical roles in coastal flooding in Southern California, especially when big wave storms occur at or near peak high tides. Sea level rise slowly but inexorably exacerbates these effects by making the occurrence of extreme total high water levels more and more frequent over time.

As a result, climate researchers believe storms will impact the West Coast more powerfully in the future because sea level rise will raise wave run-up (or maximum vertical extent of wave up-rush on a beach) and storm surge, thereby causing more erosion and more extensive and frequent flooding and damages.

The Need for Sea Level Rise Adaptation Planning in Los Angeles

The City of L.A. owns and maintains critical coastal infrastructure that includes two power plants and two wastewater treatment plants that are approximately 10 feet above mean sea level. Under current conditions, some of this infrastructure is already vulnerable to flooding during high tide events and severe storms. This flooding is expected to worsen as sea level rise contributes to increased total extreme water levels.

Beyond these critical assets, beaches and beach tourism are major contributions to Los Angeles' economy. L.A. County attracted almost 27 million tourists who accounted for more than $15 billion in expenditures, and more than $8 billion in tax revenues in 2011, climbing to over 41 million tourists and $16.5 billion in expenditures in 2012 (Los Angeles Division of Tourism, 2011 and 2012). Many of these visitors were attracted to the region's wide sandy beaches and other attractions that make coastal communities special, such as piers, boardwalks and marinas.

Among the most famous of these beach communities in Los Angeles is Venice, whose natural beach has been altered significantly by coastal engineering and advantageous sand placement. Over the last five decades, sand has already been replenished at a cost of millions of dollars (Flick 2012). Like Venice, other coastal communities such as Pacific Palisades, Santa Monica and Malibu, are dependent upon their wide sandy beaches and other coastal assets for tourism and economic development. As sea level rise accelerates, more will have to be done to expand and stabilize beaches, perhaps including sand and dune replenishment and the construction of groins, jetties, and breakwaters to safeguard these world-famous tourist destinations for future generations.

Los Angeles Harbor/San Pedro and the Port of Los Angeles are two important economic engines for the City of Los Angeles. (Photo Credit Top to Bottom: California Coastal Records; Jim Fawcett).

South of Venice, on the southern side of the Palos Verdes Peninsula, the Port of Los Angeles is one of the busiest in the world, contributing more than $63 billion to the State of California, and more than $230 billion to the U.S. economy (Port of Los Angeles 2012). In fact, more than 40 percent of all imports arriving in the U.S. comes through the Ports of Los Angeles and Long Beach, where it is loaded onto trucks and trains for overland shipping.

These and other invaluable coastal assets and resources are all threatened by climate change and sea level rise. A recent study by King et al. (2011) modeled the economic impacts of 100-year floods (e.g., flooding, upland erosion and beach erosion) on five coastal California communities using baseline conditions compared to sea level rise scenarios of 1.0 m and 1.4 m. For iconic Venice Beach, King's study indicates that a 100-year storm under current conditions with no sea level rise would cause an estimated $7 million in damages. By contrast, a 100-year storm with a 1.4 m rise in sea level (projected by 2100) could potentially cause $15.1 million in damages, more than doubling the economic impact. In our study, we provide revised estimates of expected economic impacts through our Economic Vulnerability Assessment (Appendix 4).

Mitigation and Adaptation Planning Ongoing in Los Angeles

More than half of the world's population lives in urban areas, and as a result, cities have taken on the mantle of being the "first responders" to the coming climate crisis. As one of the largest cities in the world, Los Angeles has become a model for the rest of the global community in planning for climate change.

In 2007, then-Mayor Antonio Villaraigosa released *GreenLA: An Action Plan to Lead the Nation in Fighting Global Warming*, a mitigation strategy that laid out standards for reducing greenhouse gas emissions by restricting energy and land use. Among other objectives, the plan set forth a goal of reducing greenhouse gas emissions to 35 percent below 1990 levels by 2030, one of the most aggressive climate goals put forth by any city in the country. The voluntary plan identifies more than 50 action items, grouped into focus areas, to reduce emissions. ClimateLA is the implementation program that provides detailed information about each action item discussed in the GreenLA framework. Action items include harnessing wind power to generate electricity, retrofitting City buildings to make them more energy efficient, and converting the City's fleet vehicles to cleaner models.

In 2008, the City began conducting research on adaptation planning, working with the Los Angeles Regional Collaborative for Climate Action and Sustainability (LARC), the University of Southern California (USC) Sea Grant Program, and the University of California, Los Angeles (UCLA). Adaptation planning, in contrast to mitigation, focuses on planning for the projected impacts of climate change to minimize harm. Together, mitigation strategies and adaptation planning are tools that help to ensure community resilience.[5]

Through a federal Energy and Efficiency Community Block Grant to the City of L.A., LARC commissioned a simulation of climate change in Greater L.A. UCLA's Dr. Alex Hall, a leading climate scientist and member of the Intergovernmental Panel on Climate Change, is using the most scientifically advanced models in the world to simulate the impacts of climate change at an extremely high resolution. These climate change simulations will allow the City of L.A. and LARC to plan for adaptation to such impacts as temperature change, urban heat islands, increased fire frequency, and human health impacts. The research is also informative about the potential for development of local renewable energy resources that would also lead to GHG reductions. The first results of these models, describing possible temperature changes in communities across Southern California by mid-century, were released in June of 2012. Further results describing changes in precipitation, cloud cover, snowpack, winds, storms, and other patterns will be released in 2013 and 2014.

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5. Resilience can be defined as the ability of a system to absorb some amount of change, including shocks from extreme events, bounce back and recover from that change, and, if necessary, transform itself to continue to be able to function and provide essential services and amenities that it has been designed to provide (California Natural Resources Agency, 2009).

Geographic Scope of this Study

The configuration of municipal boundaries in the City of L.A. reflects the history of the City as a collection of what were once separate municipalities. As a result, the City's coastal boundaries are discontiguous; and each region displays a variety of geomorphological and demographic traits. This plan focuses on the City's three coastal reaches: Pacific Palisades from Malibu to Santa Monica; Venice, Playa Del Rey and LAX; and San Pedro, Wilmington, and the Port of Los Angeles (Figure 1).

In the north, the coastal boundary of the City of L.A. begins in the hillside community of Pacific Palisades, an area distinguished by coastal canyons and high bluffs above a narrow coastal shelf. The Pacific Coast Highway runs along the narrow margin between Santa Monica Bay and already eroding coastal bluffs.

The community of Venice lies at low elevation along the Santa Monica Bay coastline, adjacent to the L.A. County enclave of Marina del Rey. A renowned beach destination, Venice occupies the northern side of the former Los Angeles River basin as it makes its way to the ocean.

The Playa del Rey and Playa Vista communities occupy a broad coastal plain, the former riverbed and delta of the Los Angeles River, now channelized 15 miles east and redirected to San Pedro Bay. Further south along the coast, LAX, and the community of Westchester occupy a coastal bluff bounded by wide beaches that have received significant sand nourishment during the last half century.

In the south, the coast has an east-west orientation, with south-facing beaches fronting San Pedro Bay, and a hillside community built on the eastern side of the Palos Verdes promontory. The Port of Los Angeles is built at its base and extends onto the western side of Terminal Island, a human-made island whose eastern half is part of the City of Long Beach. Wilmington lies on the north side of the Port of Los Angeles. Wilmington is a lower-income neighborhood, many of whose residents work in harbor-related businesses. To the west of Wilmington is the Harbor City community, a business area serving San Pedro and Wilmington.

Coastal Regions in the City of Los Angeles

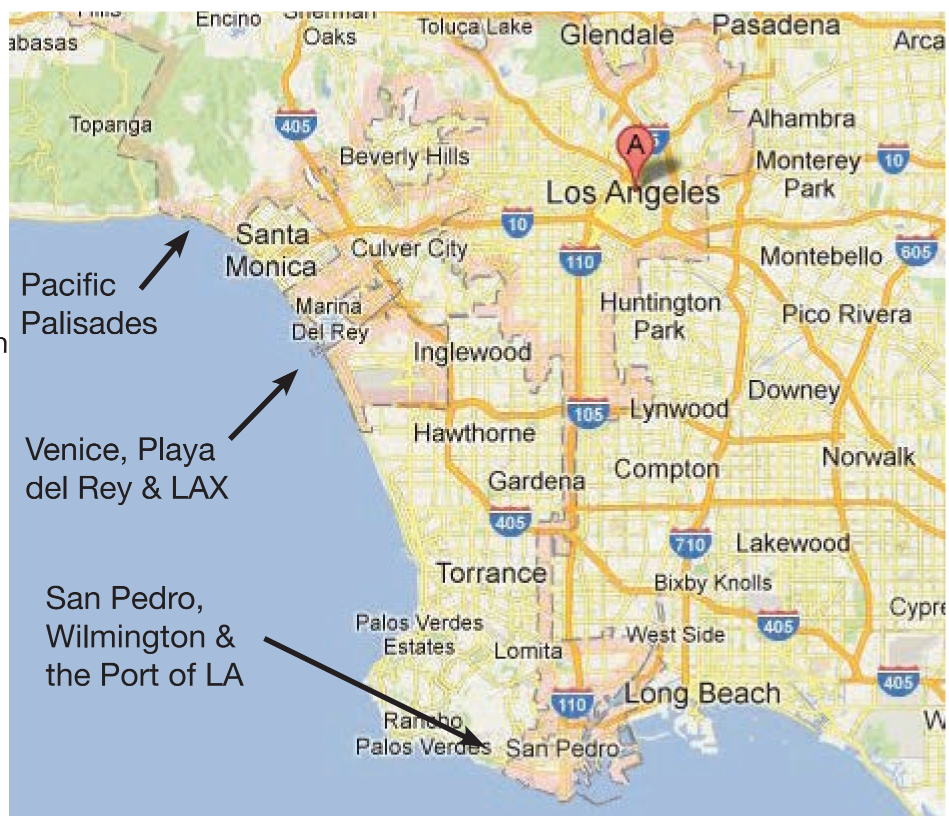


Figure 1: Google Maps image showing the boundaries of the City of Los Angeles with the major coastal regions indicated.

Adaptation Planning Process

The time to begin planning for the impacts of climate change is now, not 20 or 30 years in the future when these effects will already have begun to disrupt business and damage critical coastal infrastructure, prompting *ad hoc* and poorly coordinated responses. Because of the unprecedented degree of stakeholder collaboration and inter-agency cooperation required for regional-scale planning, an extended time frame for taking action is critical. Understanding this urgency, the City of L.A. has decided to commence proactive planning now.

The USC Sea Grant Program worked with the City, LARC and ICLEI - Local Governments for Sustainability, USA (ICLEI), to develop an adaptation planning process. This process is collaborative, science-based, and participatory. It provides a methodology to help the City identify the vulnerabilities to sea level rise of its assets, resources and communities, and establish mechanisms for moving forward with developing adaptation strategies. This methodology draws heavily from a variety of adaptation planning guides and resources (NRC 2010, Snover et al. 2007, Russell and Griggs, 2012), as well as the considerable on-the-ground experience of the project partners.

The project began with the development of three teams, which will be key to its long-term success: an Adaptation Planning Team; the City Adaptation Leadership Team (CAL); and a Regional Stakeholder Working Group (RSWG).

The Adaptation Planning Team is comprised of Mayor's office staff and representatives from USC Sea Grant, LARC, and ICLEI. This group oversees and coordinates the process.

The CAL brings together City department principals who will be at the forefront of facing the impacts of accelerating sea level rise. Departments include: Department of Water and Power; Department of Public Works; Bureau of Sanitation; Harbor Department; Planning Department; Department of Recreation and Parks; and Emergency Management Services.

City Adaptation Leadership members at a meeting to discuss current known vulnerabilities. (Photo credit: Marika Schulhof).

The RSWG includes Los Angeles City Council staff, Los Angeles County representatives, State of California representatives, business, industry, government associations, and non-governmental organizations. The City maintains close relationships with L.A. County, which manages several important facilities in its jurisdiction (i.e., waste treatment facilities, numerous roads, the 800-acre yacht harbor and residential enclave at Marina del Rey, and County-managed beaches), and neighboring cities such as Santa Monica, Malibu, and the South Bay beach cities of Manhattan Beach, Hermosa Beach and Redondo Beach. These communities are represented in the RSWG.

There are four major milestones in the process for sea level rise adaptation planning:

1. *Identification of Current Observed Vulnerabilities*: This entails identifying City assets, resources and communities located in the coastal zone. Since many of the impacts the City will feel from sea level rise are ones the City already experiences, effort was placed towards identifying current vulnerabilities and impacts from coastal storms and extreme high tides (e.g. flooding of major infrastructure).

2. *Sea Level Rise Vulnerability Assessments*: A sea level rise vulnerability assessment evaluates the degree to which important community assets are susceptible to, and unable to accommodate, the adverse effects of climate change. In this effort, partners have examined the physical, social, economic and ecological vulnerabilities the City may face under sea level rise.

3. *Identification of Sea Level Rise Adaptation Measures*: Once vulnerabilities are understood, the City can then begin to assess how best to manage the expected impacts. There are a number of tools available for the City to consider.

4. *Development of Sea Level Rise Adaptation Plan*: This is a long-term milestone that entails the development of a sea level rise adaptation plan that is approved by the Mayor and City Council. Using the strategies and guidance put forth in this study, the City can move forward with developing site-specific adaptation and financial strategies for implementation.

While the milestones above describe a linear process that culminates in an adaptation plan, adaptation planning is indeed far from complete once a plan has been developed and approved. Scientific information is always being updated and improved and this new information should be called upon to reassess the City's vulnerabilities, plans and actions. Moreover, any action to provide adaptation will trigger other changes and will require monitoring of effectiveness. We refer to this notion as "adaptive adaptation planning." The model has been developed with this concept in mind (Figure 2).

Sea level rise is one of many climate change impacts to be addressed using this iterative and adaptive planning process. It is hoped that the process developed for sea level rise will be useful in planning for other impacts of climate change, and that the City of L.A. will be a model for the region, as well as the rest of the country, in developing climate change adaptation strategies. The City looks to LARC to transfer the knowledge gained and lessons learned from this pilot sea level rise effort within the City.

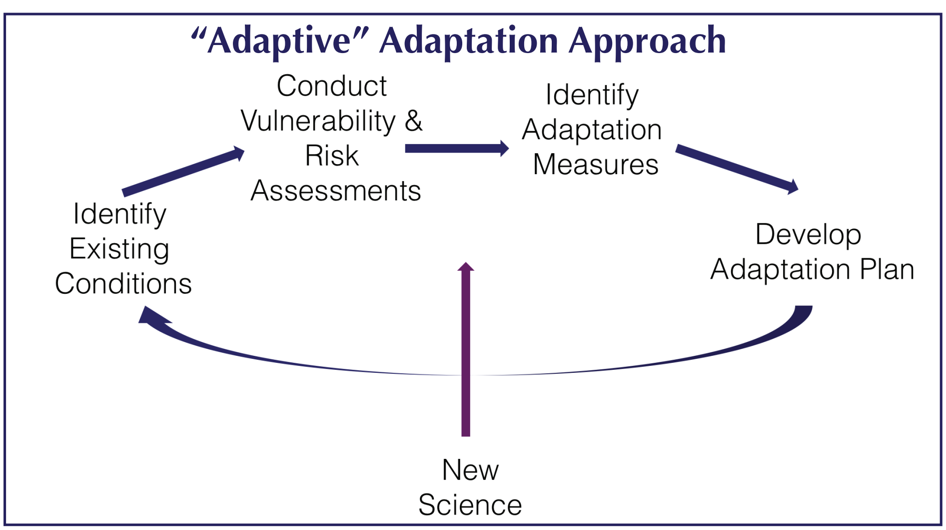


Figure 2: This schematic describes the "adaptive" adaptation planning approach. The four milestones do not describe a linear process, but rather, an iterative process that incorporates new science and information as it becomes available.

Regional Stakeholder Working Group Participation and Review

Stakeholder input is an invaluable part of the public process and particularly so when planning for a future with potentially significant impacts on the public. A Regional Stakeholder Working Group (RSWG)[1] was appointed early in the process. Through formal meetings and a review and comment process, the RSWG provided critical input to the draft and final versions of this study. RSWG members commented on the sea level rise report by providing suggestions on how to move forward in adaptation planning, expand this study in future iterations, and communicate the findings to wider audiences. While some comments were out of the scope and intent of this initial study, it is important to capture comments to assist the City as it moves to the next milestones of the process and updates this study as new science and information become available.

Comments from the RSWG include:

- It is important to look at how the methodology could be applied to regional or statewide efforts. Lessons learned would be valuable for other cities or regions undergoing vulnerability assessments.

- It may be disadvantageous to assume that the 10-year storm of the last fifty years will be the 10-year storm of the future. It is important to examine changes in strength and frequency of storm events.

- While not directly managed by the City, certain assets and resources should be closely examined and considered for further engineering studies. A few mentioned include: critical roads (i.e. PCH); seawater barriers in the County; breakwaters; piers (i.e. Santa Monica); and current or pending construction (i.e. the City's Temescal Canyon Park stormwater project).

- Consider conducting a full ecological vulnerability assessment to include all ecological resources in the City such as beaches, wetlands, open spaces and other coastal habitats.

- Consider including the impact to tourist resources and other indirect economic impacts in the analysis of economic vulnerability.

- Recommend including business continuity planning, insurance industry, risk management, emergency planning, and building design groups among groups to communicate study results and consider involving representatives in the planning process.

- An important next step would be to conduct a quantitative physical vulnerability and risk assessment to go beyond the qualitative assessment conducted in this study.

Climate Change Planning is Already Underway in the City of L.A.

By commissioning this study and by initiating this participatory process, the City of L.A. has shown tremendous leadership in proactively confronting climate change, rather than responding reactively. This study is part of a series of efforts on different aspects of climate change – heat, fresh water, fires, and human health impacts.

This preliminary sea level rise vulnerability assessment provides a first glimpse into the challenges the City may expect due to sea level rise (and other associated impacts) on its infrastructure assets, resources, and communities. The City has engaged a team of world renowned experts to identify its potential exposure to sea level rise, using a sophisticated model that examines both the impacts from rising seas, as well as flood impacts from storms and high tides, which could be exacerbated with

[6.] Members are listed on page 65.

rising sea levels. It has identified its potential vulnerabilities in order to begin planning now. Due to the participatory nature of the planning process, the City recognizes the importance of community stakeholders in identifying appropriate adaptation measures to increase its resilience and is actively engaging them in their planning process.

Prior even to the recommendations of this study, agencies within the City were already commissioning studies to understand the impacts of sea level rise on critical infrastructure. For instance, the Bureau of Sanitation, the Port of Los Angeles and the Department of Water and Power have already commissioned independent studies to assess their vulnerability to sea level rise, climate change, and tsunami risks. These studies will serve to bolster the resilience already built into many of the agencies' operations and planning.

An important adaptation strategy is mitigation through the reduction of greenhouse gas (GHG) emissions. In any sea level rise, or climate change, model, much of the uncertainty lies in not knowing which way society as a whole will move with respect to limiting its GHG emissions. Under business as usual scenarios in which we continue to emit greenhouse gases at current rates, climate change impacts will be far more severe than if we work to limit our emissions. Through its GreenLA and ClimateLA plans, the City of L.A. has emerged as a leader in its varied and numerous mitigation strategies.

The Purpose of this Document

This report contains the results of the coastal vulnerabilities report, the current observed vulnerabilities identification exercise and the physical, social and economic vulnerability assessment studies that were commissioned by the City and USC Sea Grant. In addition, a discussion of the ecological vulnerability of Ballona Creek, the City's major remaining natural coastal feature, is included. This report is meant to inform policymaking by identifying the systems and sectors most likely to be affected by sea level rise, and by furthering an understanding of each sector's vulnerabilities. Understanding these vulnerabilities will enable the City to develop strategies that increase its resilience to accelerated sea level rise and other impacts of coastal change. In the final section of the report, we identify a broad range of adaptation strategies that can serve as a foundation for future adaptation planning.

This document is one of the first tangible products of the adaptation planning effort. It represents a preliminary and first step in an ongoing process to assess the City's vulnerability and work to increase its resilience to climate change impacts. Because the science of climate change is advancing so rapidly, it is vitally important to build flexibility into the City's efforts. The result is this living document that must be continually updated to integrate new science; iterative and collaborative "adaptive adaptation planning" process is as important as the document itself.

Coastal and Shoreline Assets

Dr. Reinhard Flick, Scripps Institution of Oceanography, has developed a preliminary review of the major geographic regions within the City of L.A. and provides a brief overview of the potential adaptation strategies and next steps the City can consider in planning for sea level rise (see Appendix 1 for full report). Dr. Flick's report provides a first glimpse into potential strategies the City may wish to consider; however this report in no way replaces the critical engineering studies that should be conducted before committing to any strategy or plan. We summarize some of the key recommendations from that report below.

Pacific Palisades (Topanga Canyon Boulevard to Santa Monica)

This reach, or section of coastline, presents mainly major geotechnical and coastal engineering challenges, as well as complex societal and legal issues. The inland stretch along PCH is heavily developed with few or no good options for retreat of the highway. Since PCH is not likely to be moved, continued and improved armoring is the most realistic choice for avoiding undermining the roadway by wave-driven erosion. This seems to be the most vulnerable part of the entire City shoreline. Heavily-used PCH has occasionally been undermined in some spots and has required attention since it was first constructed, and will continue to do so in the future. L.A. City, County, and Caltrans highway engineers are aware of these problems, and are in the best position to suggest solutions once the future vulnerabilities are better defined. Careful quantification of the times, locations, and extent of future overtopping; ocean flooding; and undermining of PCH and other infrastructure due to erosion can eventually form the basis for a phased and ongoing plan to address geotechnical needs.

As sea level rise accelerates, it would be wise to initiate a storm watch and notification program using standard available weather and wave forecast products to provide warnings several days in advance of dangerous wave and tide combination conditions. This would facilitate traffic management, increase safety, and provide engineering data that will be useful once adaptation measures become necessary.

Beaches show a typical configuration with wave-driven sand transport predominantly to the east; that is, they are narrow or non-existent upcoast (west) where headlands block the flow of sand or divert it offshore, and widen downcoast, reaching maximum width just west of the next headland. At least annual monitoring beach widths will eventually provide the history that will be necessary to address the issues of stabilization with groins or other measures, and periodic nourishment that will almost certainly be needed in the future to maintain a sandy beach.

Will Rogers State Beach is highly instructive in that it illustrates successful and relatively unobtrusive groin beach width stabilization structures that will almost certainly become increasingly necessary if area beaches are to be preserved in the future. Everts Coastal (2002) provides quantitative assessments of major shoreline sand retention structures and guidelines that will be helpful for engineers planning future structures. As with the beaches to the west, at least annual systematic monitoring of beach width should be conducted.

Google Earth image of Will Rogers State Beach with effective groin beach stabilization.

Venice-Marina Peninsula-Playa Del Rey-LAX

This reach is a central part of Santa Monica Bay's iconic "Bay Watch" beach system that extends from Malibu to Redondo Beach and provides major economic benefits from recreation, boating, utility siting, and tourism. It has mostly wide to very wide beaches that were largely created by sand supplied as a by-product of coastal construction activity, including LAX, Marina Del Rey, and the Hyperion Wastewater Treatment Plant (Flick 1993; Leidersdorf and Woodell 1993, 1994).

View south of iconic beaches of central Santa Monica Bay: from Venice (pier, lower right) past Marina Del Rey jetties and west end of LAX runways, toward Redondo Beach (Wikimedia Commons photo, 2007).

While these beaches have been wide and stable for many decades, gradual retreat is already in progress. The main concern for the future is that sand is not being provided at nearly the rate it was up until the 1960s. As sea level rise accelerates in the future, these iconic L.A. beaches will undoubtedly narrow at an even faster rate. It is unlikely that any storm-wave driven flooding or property damage will occur in the foreseeable future, but if sea level rise takes one of the higher trajectories, problems would become evident around mid-century.

To maintain the property protection and recreational benefits of these beaches, sand nourishment will be necessary at some point in the future. To enable sound engineering benefit/cost analyses for these inevitable projects, it will be necessary to monitor the beach width going forward, in a manner similar to that discussed in the context of the beaches in the Pacific Palisades reach. The Venice-Marina Peninsula-Playa Del Rey-LAX reach is ripe for wave- and sea level rise-driven beach retreat modeling, since a wealth of historical beach profile, shoreline position, and wave data already exists. Such work could help to narrow the uncertainty of future rates of beach loss due to sea level rise using empirical models currently under development. This is of course a regional, and in fact a state-wide necessity, and not only a City of L.A. concern. However, the City can play a vital role in highlighting the need for monitoring and coordination of local, regional, state, and federal constituencies.

San Pedro-Wilmington-Terminal Island-L.A. Harbor Exposed Coast

The San Pedro part of L.A. has a south-facing exposed open-coast portion, and an east-facing section sheltered behind the L.A.-Long Beach outer breakwater. Both sections are heavily suburbanized atop a flat coastal terrace that has a 35 m (115 ft) high sea cliff at its seaward edge. The geology suggests relatively resistant formations at sea level near Cabrillo Point, but more erodible material to the west toward Point Fermin. As sea level rise accelerates, the weaker cliff sections will be subject to more undermining from wave action and eventual collapse than the more resistant sections. Ongoing — at least annual — monitoring of cliff retreat is recommended.

Inspection of aerial photos (Google Earth) shows that about 25% of the cliff edge in San Pedro is occupied by park or other open space, which minimizes the vulnerability of property loss from cliff failure. Cliff-top development on the other 75% of the exposed western end of San Pedro has substantial setback from the edge of the cliff. Therefore, few if any developments will be immediately threatened. However, several areas of geotechnical instability are evident, especially related to land sliding. Some residential development on the cliff top at the eastern end of the exposed section of San Pedro has little setback and may be threatened if cliff retreat resumes or accelerates in response to sea level rise.

L.A. Harbor

The L.A.-Long Beach outer breakwater starts at Cabrillo Beach and protects everything behind it (to the north) from wave attack. Components of harbor infrastructure and Port of Los Angeles operations may be vulnerable to sea level rise. But this again presents mostly a major harbor engineering project that will have to be undertaken in stages as problems become apparent. For example, the outer breakwater is highly effective at sheltering the harbor and adjacent coast from wave action, but it is frequently overtopped during high wave events coinciding with high tides. If wave climate becomes more severe, more damage to the breakwater itself is likely and may require elevation.

View north over L.A.-Long beach outer breakwater Angel's Gate toward Port of Los Angeles and Terminal Island (lower right) Wilmington is visible in the distance (Port of Los Angeles photo).

Anecdotal evidence suggests that the Port infrastructure can accommodate even mid-to high-range sea level rise scenarios by periodically being raised during major refitting construction projects. A study by the RAND Corporation was conducted to determine the Port's vulnerabilities and what accommodation and adaptation strategies will be needed (Lempert et al. 2012).

Immediate Sea Level Rise Adaptation Actions

Each coastal community within the City of L.A. will require its own specific adaptation strategies. In the cases of the need for geoengineering solutions, these strategies will require the accompanying engineering and geotechnical studies. There are, however, several important actions that can be taken immediately, requiring minimal financial expenditures, that would serve to advance the City's efforts to prepare for the impacts of sea level rise. These include:

- Storm watch and notification;
- Semi-annual beach width monitoring;
- Annual monitoring of cliff retreat;
- Use of historical beach profiles and existing wave data to develop predictions; and
- Coordination with local, regional, state and federal agencies, especially Los Angeles County (Public Works and the Department of Beaches and Harbors) and the U.S. Army Corps of Engineers.

Current Observed Vulnerabilities and Physical Vulnerability Assessment

This section provides an overview of current observed vulnerabilities conducted by USC Sea Grant and the physical vulnerability assessment survey conducted by ICLEI – Local Governments for Sustainability, U.S.A. (ICLEI). The ICLEI report is presented in its entirety in Appendix 2. All of the information on the City's assets is presented in a series of matrices in this section that include a description of the asset, an overview of current observed vulnerabilities to storms and high tide events, and a description of its potential physical vulnerabilities due to rising sea levels as described by ICLEI.

Current Observed Vulnerabilities

The first step in the adaptation planning process, conducted during the winter of 2012, was to work with City staff from the City Adaptation Leadership team (CAL) to identify and examine current observed vulnerabilities and existing conditions. Members of the CAL were asked to:

- Identify their major assets within the coastal zone;
- Provide a brief description of the asset; and,
- Provide a description of the current known vulnerabilities and environmental issues related to maintenance and functioning of these assets.

The assets and observed conditions were identified in a two-fold process. First, we developed a series of maps on which City officials identified coastal assets and known vulnerabilities. This was followed by a worksheet in which officials provided more detailed information about the asset and its current vulnerabilities. We also include a replacement value, where that information is available, for some of the City assets. It should be noted that these replacement values were not derived from the economic study described in Appendix 4, but rather were self-reported by City agency officials. Information gathered during this exercise is summarized in the asset matrices presented at the end of this section (pages 20-48).


Members of the CAL during a mapping exercise in which members were asked to identify coastal assets and their current vulnerabilities. (Photo credit: Marika Schulhof).

Physical Vulnerability Assessment

Overview on Physical Vulnerability Assessments

A sea level rise physical vulnerability assessment considers areas where important community assets are susceptible to, and unable to accommodate, the adverse effects of sea level rise. Four factors are generally considered in vulnerability assessments: *exposure*, *sensitivity*, *adaptive capacity* and *consequences*.

Exposure is defined as the nature and degree to which a system experiences a stress or hazard. In the case of sea level rise, this would entail identifying which assets, resources or communities may be vulnerable to impacts from sea level rise. This includes examining both flooding (defined as land that was once dry that becomes *temporarily* wet either periodically or episodically) and inundation (defined as land that was once dry that becomes *permanently* wet or underwater), (Flick et al. 2012).

Sensitivity is defined as the degree to which exposed assets would be impaired by sea level rise. Assets that are greatly impaired by sea level rise have a *high* sensitivity, whereas assets that are minimally impaired by the same change in sea level have a *low* sensitivity.

Adaptive capacity is the ability of an asset to make adjustments in response to a climate impact to maintain its primary functions. This does not mean that the asset must look the same as before the impact, but it must provide the same services and functions as it did before the impact occurred.

Consequences are the adverse effects that occur as a result of an asset being impaired by a climate impact. City officials were asked to describe consequences for the economy, environment, and communities and populations. They were also asked to consider the magnitude of the consequence, such as a size of the population, land area, or resources that would be affected.

Identifying the City's Exposure

While the exercise conducted to identify current observed vulnerabilities served as guidance for preliminary analysis, it was imperative to use the best available science when focusing in on the City's potential vulnerabilities to sea level rise. This was determined to be a coastal impacts model developed by Dr. Patrick Barnard and colleagues from the U.S. Geological Survey (USGS). This model incorporates not only the impacts of a rising sea, but also the impacts of tides, and extreme waves and storm surge associated with severe coastal storms.

Image of flooding in San Pedro (5th St. and Pacific Ave.) during the January 2010 storm. (Photo credit: Robert Casillas, http://lapd.com/news/headlines/torrential_rains_pound_san_pedro/).

The USGS model is based on a storm that occurred in the Los Angeles region during January 2010. This El Niño-fueled storm produced large waves (with a maximum wave height offshore of Los Angeles of 7.5 m, or 25 ft) that remained elevated for a week, producing some of the most extreme coastal erosion observed for several decades in Southern California and causing severe flooding in some coastal communities.

Once the model appropriately recreated, or hindcast, the impacts from this 2010 storm, the modelers applied two sea level rise

Components of Total Water Predictions

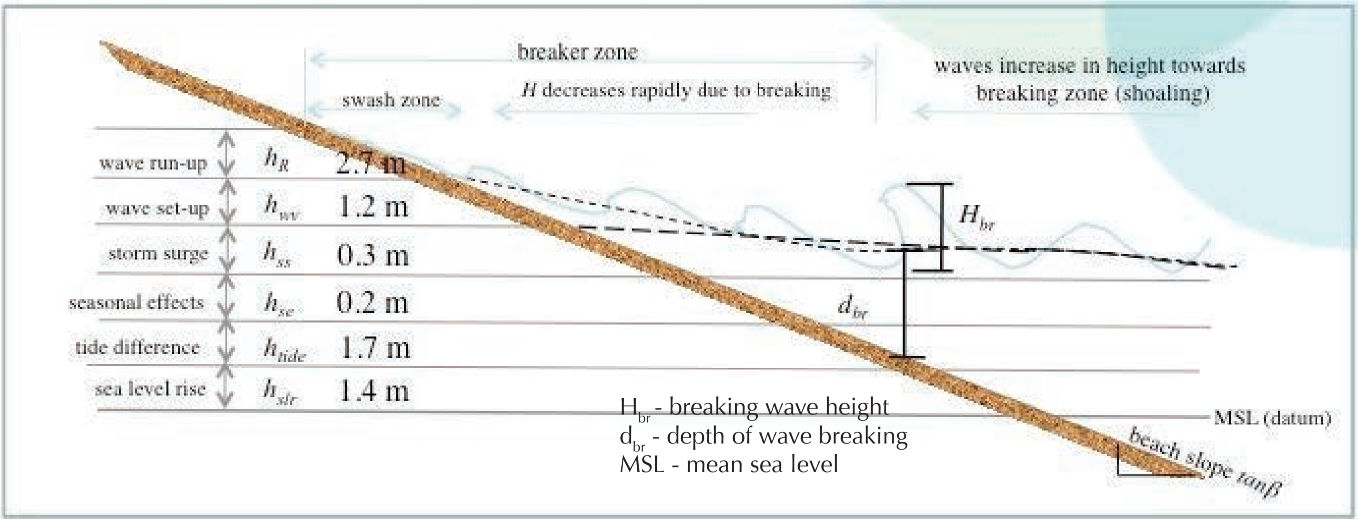


Figure 3: This diagram depicts the total coastal water level components caused by both sea level rise and storms driven by climate change that are used in the coastal impacts model to predict coastal flooding. The diagram includes the upper-end sea level rise scenario predicted between 2000-2100 and the wave height, surge and tidal ranges predicted for Southern California under a 10-year storm scenario. (Source: Patrick Barnard, USGS).

scenarios using the upper-end sea level rise scenarios of 0.5 m (1.6 ft) between 2000 - 2050 and 1.4 m (4.6 ft) between 2000 - 2100 based on Rahmstorf (2007). These sea levels were added to the tide, wave, and wind conditions of the January 2010 storm to project the potential for increased flooding that could result from various sea level rise scenarios under a similar storm event (Figure 3).

The City used these scenarios to identify the exposure of its assets to sea level rise. The maps used by the City to assess vulnerability are presented in subsequent pages of this report (Figures 4-6, pages 17 - 19).

While there are a number of coastal impact and sea level rise models available for use, it was determined at the time of this analysis that the USGS model provides the best scientific description of what could be expected from the combination of sea level rise and a moderately severe winter storm. However, there are two important caveats that should be noted:

- The January 2010 storm is considered a moderately severe “10-year” storm, which means it has a 10% chance of occurring on a yearly basis. Most planning departments and insurance estimates base their analyses on the “100-year” storm, or a storm that has a 1% chance of occurring in a single year. This model therefore provides a conservative estimate of flooding.

- As the science advances, sea level rise scenarios and the ranges and average rates of sea level rise associated with those scenarios will continue to be updated and modified. For this report, the USGS model used sea level rise scenarios based on a highly-respected and cited report published in 2007 (Rahmstorf 2007). Since then, a study by the NRC has refined these scenarios specifically for the West Coast of the U.S. This new study suggests that Southern California should plan for a range of sea level rise of 0.1 - 0.6 m between 2000 - 2050 and 0.4 – 1.7 m between 2000 - 2100. The difference in these scenarios (recent NRC study vs. Rahmstorf’s estimates) does not invalidate the results of our preliminary vulnerability assessment, but rather underscores the need to continually reassess vulnerabilities based on the best available science. Sea level rise, and climate change, vulnerability assessment is an iterative process and it is critical to allow for the “adaptive adaptation planning” approach we advocate in this report. We strongly recommend that as more information becomes available, the City incorporate this new information and reassess their assets’ vulnerabilities.

Analysis of the City's Assets Exposure

Based on the exposure of City assets identified by the USGS model, ICLEI employed a qualitative and participatory methodology to gauge the sensitivity and adaptive capacity of the systems addressed in this report. Specifically, ICLEI developed a detailed survey that required respondents to consider a system's sensitivity, adaptive capacity, and consequences of not protecting these assets from accelerated sea level rise. The vulnerabilities for each asset were determined using answers to the survey and subsequent follow-up conversations with City staff.

The ICLEI report revealed vulnerabilities in wastewater management, stormwater management, potable water systems, and roads. Within the City's wastewater management system, collection systems in low-lying areas are particularly vulnerable to flooding, tidal and groundwater inflow, which cause wastewater to discharge into the ocean. Wastewater treatment plants also are vulnerable to inundation and flooding, which could damage systems and impact operations, and also result in wastewater being discharged into the ocean.

The ICLEI report found that the City's stormwater management system is vulnerable to flooding and inundation, potentially causing flooding in low-lying areas. Likewise, the potable water system is vulnerable to flooding, inundation and groundwater intrusion, making access to underground infrastructure difficult and thereby posing a risk to public health. The City's roads are also vulnerable to flooding, inundation, and groundwater inflow, potentially putting access to transportation and emergency services at risk. Coastal buildings, especially in Venice, which is near sea level, are vulnerable to flooding and inundation.

In contrast, the ICLEI report revealed that the Port and City energy facilities have relatively low vulnerability to sea level rise. The Port, although susceptible to flooding and inundation because of its low elevation, was found to have a high capacity to adapt, as it plans to build future infrastructure at higher elevations. However, the vulnerability of roadways surrounding the Port needs to be a consideration in future assessments due to the potential to interrupt the movement of goods. Energy systems have low vulnerability because of replacement schedules and built-in system redundancies.

A sand dune protects a L.A. power generation plant while residents enjoy coastal recreation. (Photo credit: Marika Schulhof)

City parks and open areas were determined to have moderate vulnerability to flooding because they can be restored relatively quickly. On the other hand, museums and other structures have higher vulnerability because of the damage that would be incurred by flooding or inundation.

Identifying components of the City's infrastructure that are at risk is the first step toward building future resilience for sensitive assets. It also helps educate the public about potential risks and opportunities to manage those risks. Proactive planning at this relatively early juncture will increase the City and region's capacity for building the Los Angeles of the future.

It is important to highlight, however, that many of the City's agencies had already begun planning for climate change prior to the initiation of this study. For instance, the Bureau of Sanitation (BOS) has recognized that climate change effects may impact assets and operations and has developed strategic planning goals and outcomes to lessen these impacts. Additionally, the BOS includes capabilities for upgrades and replacement of equipment, facilities and infrastructure in its planning and capital improvement programs. They have already commissioned engineering studies to address potential flooding at several critical locations. Since 2011, the Port has been working with the RAND Corporation to conduct a sea level rise vulnerability study. Similarly, in 2010, the Department of Water and Power conducted a tsunami study. While tsunamis are not directly related to sea level rise and climate change, wave run-up and surge from a tsunami provide a good, if extreme, corollary to what could be expected in the future with higher sea levels and a major storm. Analyses from all of these studies have been incorporated in the sea level rise vulnerability study we discuss here.

Sea Level Rise Exposure Maps
Pacific Palisades Area

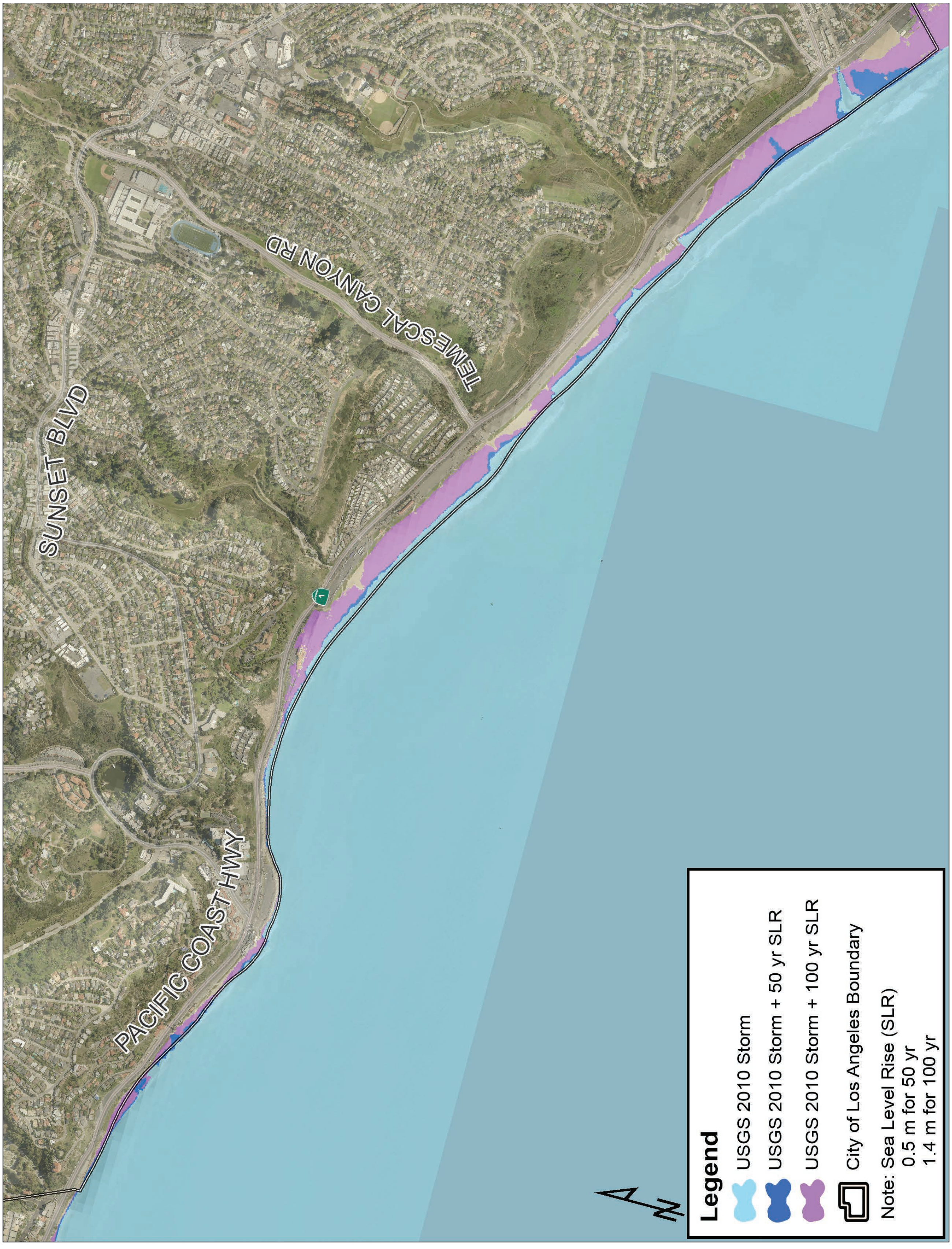


Figure 4

Sea Level Rise Exposure Maps
Venice Area

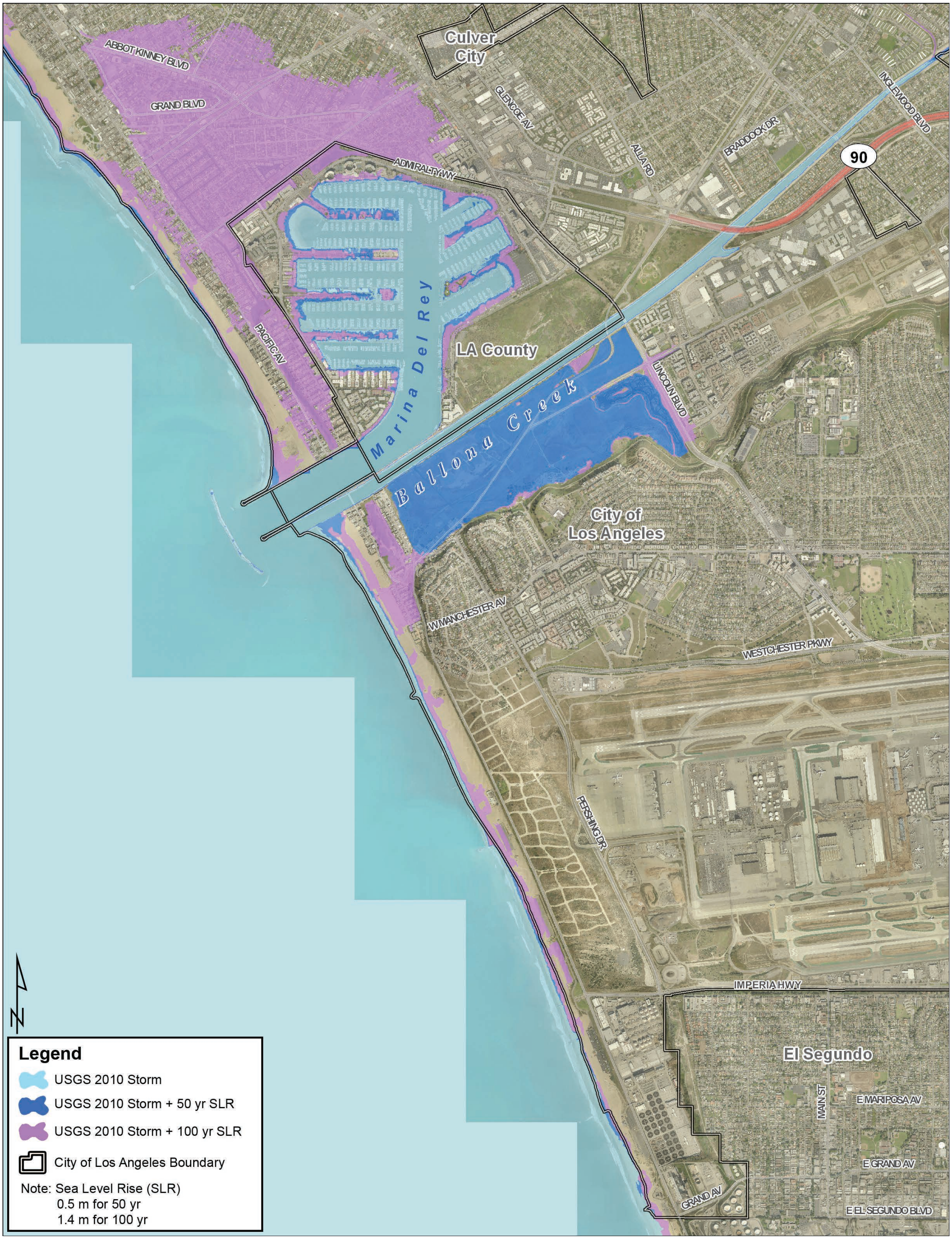


Figure 5

Sea Level Rise Exposure Maps
Harbor Area

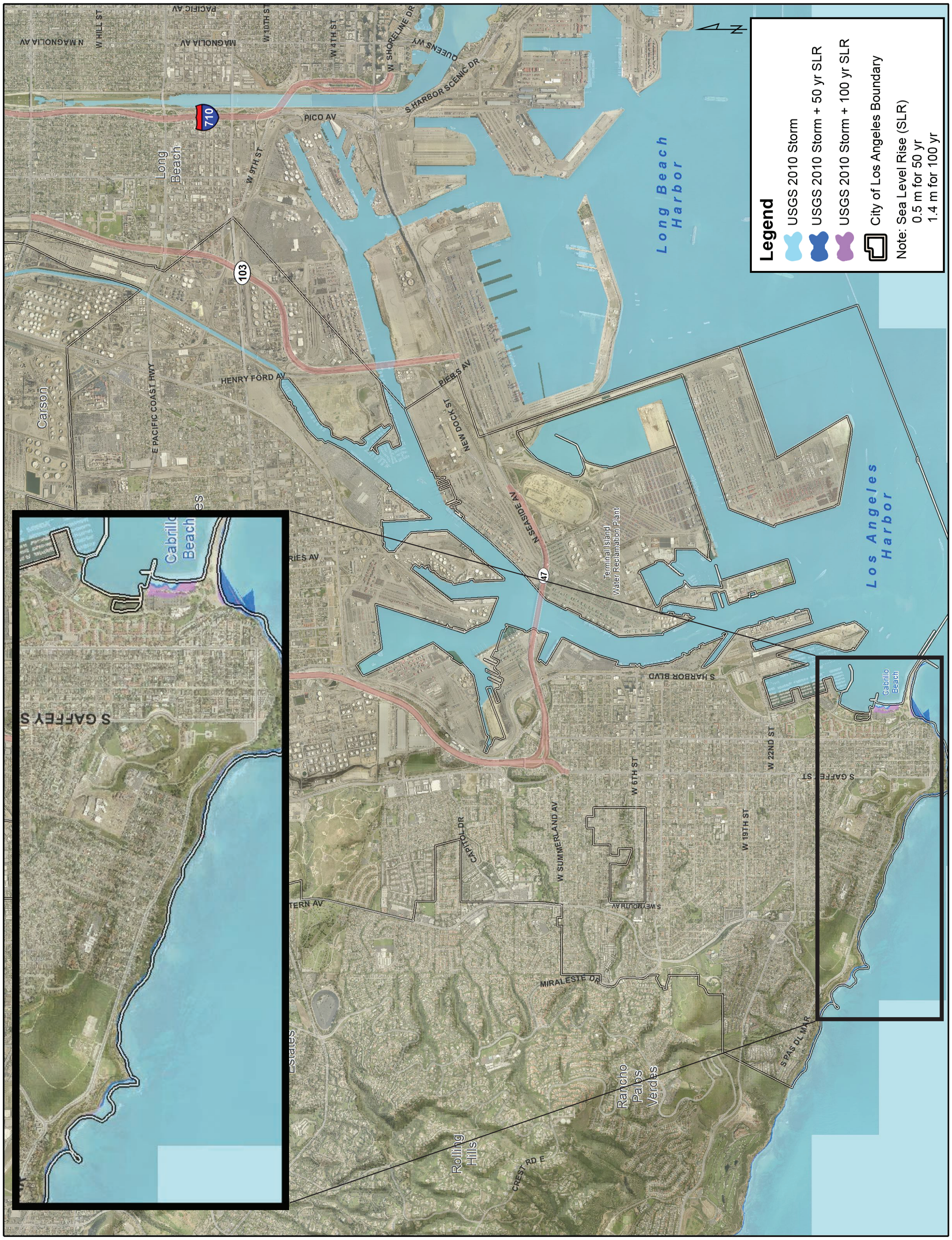


Figure 6

City Asset Matrices: Current Observed and Expected Physical Vulnerabilities

In the subsequent pages, we provide matrices for each asset by City sector. These matrices provide:

1. An overview of the asset that describes the function of the asset, the responsible City department/ point of contact, the associated regulatory oversight and a description of the asset;

2. Current, known vulnerabilities (e.g., does the asset currently flood under extreme high tides or severe storms?);

3. A summary of the asset's sensitivity and adaptive capacity in response to sea level rise associated impacts, along with the consequences of inaction; and,

4. An estimate of replacement value. It should be noted that these values are self-reported by the responsible City department and are not correlated with the economic vulnerability assessment described below (see also Appendix 4).

In some of the matrices, a unique asset is described (e.g., Hyperion Wastewater Treatment Plant). For these, exposure maps are included that demonstrate the potential flooding due to both 0.5 m and 1.4 m sea level rise. In other instances, assets are grouped by type (e.g., fire hydrants). In these matrices, maps are not included because the assets cover too broad of a geographic region. The number of assets for each sub-region (Pacific Palisades, Venice/LAX, and San Pedro/Harbor) are included.

Hyperion Wastewater Treatment Plant (HTP)
12000 Vista Del Mar Blvd
Playa Del Rey, CA 90293

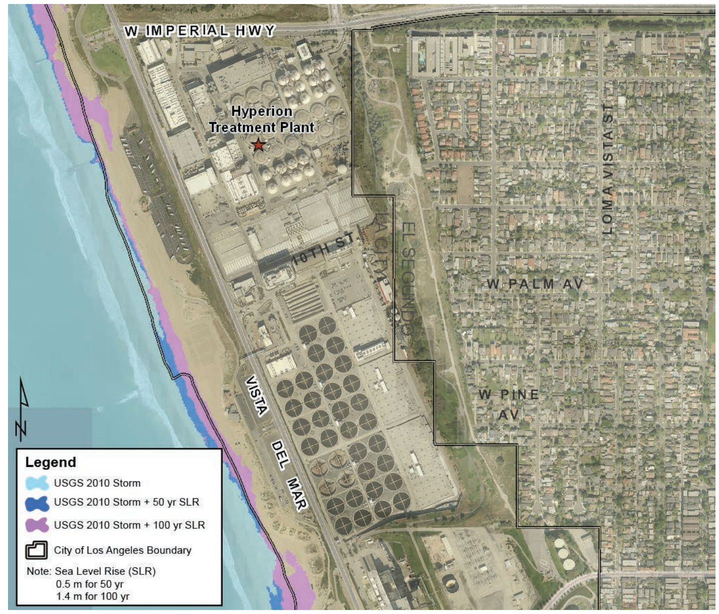
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Public Works, Bureau of Sanitation

Regulatory Oversight:
Regional Water Quality Control Board
State Water Resources Control Board
Environmental Protection Agency
South Coast Air Quality Management District

Summary of Asset:
HTP is located next to Dockweiler State Beach at approximately 32 feet above sea level. The major treatment processes at this plant include screening, grit removal, primary sedimentation, and secondary treatment. After secondary treatment, the wastewater is discharged into Santa Monica Bay through the five-mile submerged outfall.



Current Observed Vulnerabilities

Localized flooding and damage to equipment and structure of facility is possible due to extreme wet weather, if there are failure(s) to critical individual unit processes (facilities), failure of effluent pumping, or failure of influent bypass pumping of influent sewer flow. Damage to process control operations (secondary treatment) is possible from extreme wet weather washout.

Possible structural damage from seismic or tsunami events, combined with extreme wet weather, could result in failure of critical plant process equipment and/or inability to transport biosolids to reuse sites, due to restricted local road and interstate highway access.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
HTP is sensitive to storm-related flooding which could cause equipment and operations failures due to damage of electrical pumps and panels from exposure to water. A dramatic increase in sea level could reduce the plant's efficiency in the discharge of effluent, because the pumped flow would be met with more water pressure. While erosion could result in some loss of the beach in front of the plant, the plant itself is not very sensitive to erosion or interaction with the groundwater because it is built on top of a large cement catacomb.	The plant's ability to continue to function if it is partially disabled depends on the severity of the impact. The plant maintains additional flow capacity, so if one part of it becomes impaired, the plant will continue to treat and handle the quantity of wastewater entering the plant. The plant is equipped with pumps that could remove water relatively quickly and has a redundant 1-mile outfall. Emergency generators have been placed at all critical facilities. The Bureau of Sanitation is securing an on-site renewable energy power source to maintain service in case of grid failure.	The primary economic consequences would be repairing the plant. Impacts to individual pieces of equipment would cost significantly less than the loss of the entire facility. The primary environmental consequence would be the discharge of partially treated wastewater into Santa Monica Bay which would be temporary in nature and therefore may impact habitat and wildlife.

Replacement value (i.e., cost of inaction):	$3 billion

Terminal Island Water Reclamation Plant (TIWRP)
445 Ferry Street, San Pedro, CA 90731

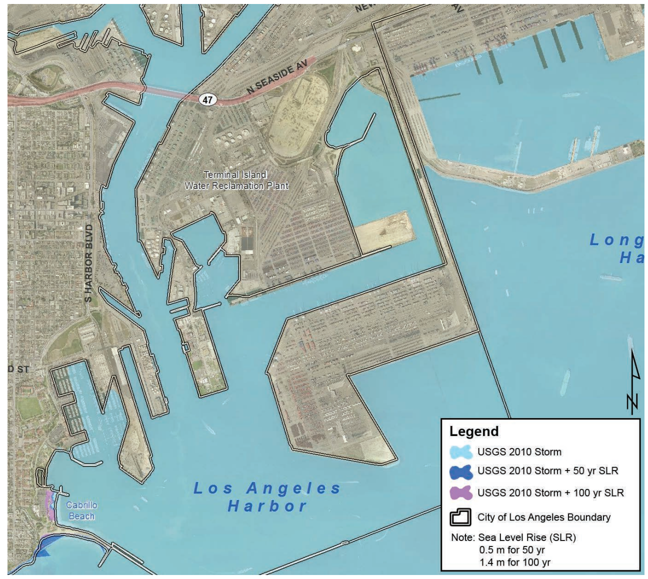
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Public Works, Bureau of Sanitation

Regulatory Oversight:
Regional Water Quality Control Board
State Water Resources Control Board
Environmental Protection Agency
South Coast Air Quality Management District

Summary of Asset:
TIWRP is a tertiary/advanced water reclamation plant that treats municipal and industrial wastewater. It is located on Terminal Island, and is situated on a 19.8-acre site, parts of which are located below sea level. Raw wastewater reaches the plant through a series of pumping plants and force mains. The plant provides preliminary, primary, secondary, tertiary, advanced and solids handling and treatment facilities. The TIWRP currently discharges tertiary effluent to the Los Angeles Harbor.



Current Observed Vulnerabilities

Localized flooding and damage to equipment and structure of facility is possible due to extreme wet weather, possibly resulting in failure(s) to critical individual unit processes (facilities), failure of effluent pumping, or failure of influent bypass pumping of influent sewer flow. Damage may occur to process control operations (secondary treatment) from extreme wet weather washout and gallery flooding.

Possible structural damage from seismic or tsunami events, combined with extreme wet weather, could result in failure of critical plant process equipment and/or inability to transport biosolids to reuse sites, due to weather related road closures and interstate highway access.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (MEDIUM)	Consequences (MEDIUM)
Terminal Island Reclamation Plant is sensitive to storm-related and tidal flooding, which could cause equipment damage and operations failures. The property is impacted by extreme high tides during which it pumps out seawater. With sea level rise, king high tides could pass through the gates at the rear of the plant, inundating some facilities. A storm-related event could exceed the design capacity of the plant, flooding galleries and damaging equipment. As a result, partially treated wastewater could be discharged into the Los Angeles Harbor.	The plant would continue to function if partially disabled. At the current flow of 15 MGD the plant has some additional capacity to handle increased flow during storm events. Depending on the equipment damage caused by a storm event, the plant may be temporarily or partially disabled and may require emergency generators or pumps to be used to ensure that wastewater continues to be discharged to the outfall. Engineering studies that include assumptions about flood depth and duration would help to refine an evaluation of adaptive capacity.	The economic consequences of impairment of TIWRP are medium. If the pumps fail, emergency response actions would be needed to remove the water to return the plant to service. Impacts to individual pieces of equipment would cost significantly less than the loss of the entire facility. Damage to processes could result in partially treated wastewater discharges, with public health impacts and environmental consequences that would be localized and temporary. Partially treated wastewater could spill into the San Pedro Harbor, affecting fishing communities, recreational opportunities and habitat.

Replacement value (i.e., cost of inaction):	None provided

Venice Collection System
Coastal Interceptor Sewer runs along the coastline; the south end begins at the Hyperion Treatment Plant.

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Public Works, Bureau of Sanitation

Regulatory Oversight:
Regional Water Quality Control Board
State Water Resources Control Board
Environmental Protection Agency

Summary of Asset:
The Venice Collection System is part of the Coastal Interceptor Sewer, which runs along the coast from West Los Angeles to the Hyperion Treatment Plant.

Current Observed Vulnerabilities

Structural damage possible from seismic or tsunami, combined with Extreme Wet Weather, could result in failure of critical conveyance equipment.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
The Venice collection system is sensitive to interaction with groundwater, storm-related and tidal flooding, because water entering the collection system reduces its capacity. Erosion could also potentially damage the pipes.	The collection system can continue to function if partially disabled, because it will continue to convey wastewater into the Hyperion Treatment plant at reduced capacity. The BOS is upgrading the system to be more resilient to storm-related flooding through proactive maintenance and functional improvements and has emergency response plans to control overflows and maintain the integrity of the collection system.	The economic consequences of impairment of this asset include the costs of repairing the system. Damage to the system could also cause wastewater spills in the Santa Monica Bay, which would have environmental, public health and economic impacts.

Replacement value (i.e., cost of inaction):	None provided

Venice Storm Water / Urban Runoff Pumping Plant (VSPP)
1600 Main Street
Venice, CA 90291

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Public Works, Bureau of Sanitation

Regulatory Oversight:
Regional Water Quality Control Board
State Water Resources Control Board
Environmental Protection Agency

Summary of Asset:
The Venice Storm Water / Urban Runoff Pumping plant is a low flow diversion pump designed to move urban runoff and, in the wet season, stormwater flows from a lower elevation up to a higher one, so that it can be transported through pipelines by gravity for eventual processing at a treatment plant during low flows and discharge into the ocean during storm flows.

Current Observed Vulnerabilities

Pumping plant may be damaged if an extreme wet weather event floods electrical components. It is in the Tsunami Warning Area. Severe tidal condition could flood the plant.

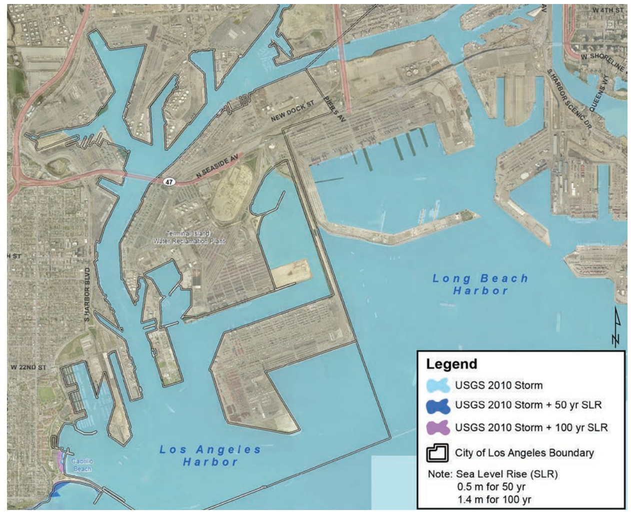
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (LOW)
The VSPP is not sensitive to storm-related flooding, tidal flooding, and erosion. Discharge during each storm season continues as designed and does not impact pumping capacity. The pump does not operate during rain events and the flow is conveyed to the discharge locations by gravity. The plant is located between the beach and a channel, so the plant could potentially be inundated by sea level rise from both sides.	The plant has been identified as an asset that is functioning as intended. Any flooding would not be related to function of the low flow pump. The BOS is evaluating the need to make the plant more resilient to storm-related flooding through functional and reliability improvements. The BOS has emergency plans in place to restore function. A study to better understand the impacts of groundwater and seawater intrusion into the VSPP is underway.	Any localized flooding would not be related to function of the low flow urban runoff diversion pump. Flooding would have high social consequences including displacement and public health concerns. The replacement value of the plant itself is ten million dollars however impacts to individual pieces of equipment would cost significantly less than the loss of the entire facility.

Replacement value (e.g., cost of inaction):	$10 million

San Pedro Storm Water Collection System
San Pedro Storm Drain Network
Harbor Area, Terminal Island Basin

Asset Overview
Owner: City of Los Angeles
City Department and Point of Contact: Department of Public Works, Bureau of Sanitation
Regulatory Oversight: Regional Water Quality Control Board State Water Resources Control Board Environmental Protection Agency
Summary of Asset: The San Pedro storm water collection system includes the storm drain network in the San Pedro area. Many lines are located below sea level.



Current Observed Vulnerabilities

The stormwater management system is vulnerable to extreme weather, flooding, and inundation, which could exacerbate flooding in low-lying areas.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (MEDIUM)	Consequences (MEDIUM)
This system is sensitive to storm-related and tidal flooding. Large amounts of water may enter the system, either through storm-water or high tides, exceeding the capacity of the system and causing neighborhoods to flood.	The system is able to function if partially disabled and will continue to convey storm water at a reduced capacity. The ability of the system to be quickly restored depends on the severity of the storm and the functionality of other connected facilities in the system. This system has been impacted by storm-related flooding and the Department of Public Works was able to reroute, relocate and resize the pipes, as well as remove some turns which had constrained the flow to eliminate the localized flooding.	The consequences of an impaired system are medium related to the economic impacts of flooded homes and streets.

Replacement value (e.g., cost of inaction):	None provided

Wastewater Pumping Plants

Asset Overview

Location and Number of Assets*

Pacific Palisades Sub-Region:	Venice/LAX Sub-Region:	San Pedro/Harbor Sub-Region:
Pacific Palisades (4)	Los Angeles (1) Venice (1) Playa del Rey (1)	Wilmington (6) Terminal Island (4) San Pedro (6)

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Public Works, Bureau of Sanitation

Regulatory Oversight:
Regional Water Quality Control Board
State Water Resources Control Board
Environmental Protection Agency

Description of Assets:
Wastewater pumping plants are located underground and move wastewater from a lower elevation up to a higher one, so that it can be transported through municipal sewer lines for eventual processing at a treatment plant. There are approximately 21 plants located in the exposure zone.

Current Observed Vulnerabilities

Pumping plants may be damaged if an extreme wet weather event floods electrical components and there is no emergency generator on site. The pumping plants are located in a Tsunami Warning Area. Severe tidal conditions could flood plants causing a wastewater spill.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
The wastewater pumping plants are taxed by storm-related flooding and the impacts of sea level rise would only exacerbate those problems. Storm-related and daily tidal flooding could cause electrical equipment to fail or flood the plant.	Many locations have backup generators on site. The BOS has plans to be able to get to these plants so they could be quickly and easily restored if impaired. This depends on the severity of the event. The BOS is undertaking efforts to make these plants more resilient to flooding.	Impairment of these plants would have significant economic consequences. Each of these 21 plants has an approximate two million dollar replacement value. In addition, damage to these plants could result in wastewater spills resulting in negative economic and environmental impacts.

Replacement value (e.g., cost of inaction)	$2 million/per plant (21 plants in exposure zone)

* Please refer to subregional maps on pages 17-19.

Low Flow Diversion Pumps

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: Pacific Palisades (3)	Venice/LAX Sub-Region: Venice (1)	San Pedro/Harbor Sub-Region: none in coastal zone
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Public Works, Bureau of Sanitation		
Regulatory Oversight: Regional Water Quality Control Board State Water Resources Control Board Environmental Protection Agency		
Description of Assets: There are four low flow diversion pumping plants located in the exposure zone, and they are designed to move water during low flow periods from lower to higher elevation, so it can be transported through pipes by gravity for eventual processing and cleaning at a treatment plant. They do not usually operate during storm events.		
Current Observed Vulnerabilities		
Pumping plant may be damaged if extreme wet weather event floods electrical components. Located in a Tsunami Warning Area. Severe tidal condition could flood the plant causing inability to divert storm water. Severe tidal condition could flood the plant causing wastewater spill.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (LOW)
Discharge during each storm season continues as designed and does not impact pumping capacity as the pump does not operate during rain events and the flow is conveyed to the discharge locations by gravity.	The pumps can be restored to operation prior to the dry season if they are impaired by storm-related flooding.	The primary economic consequence would be repair or replacement of the plants, which have a million dollar replacement value each.
Replacement value (e.g., cost of inaction)	$1 million/per plant (4 plants in exposure zone)	

* Please refer to subregional maps on pages 17-19.

Harbor Generating Station
161 N Island Ave
Wilmington, CA 90744

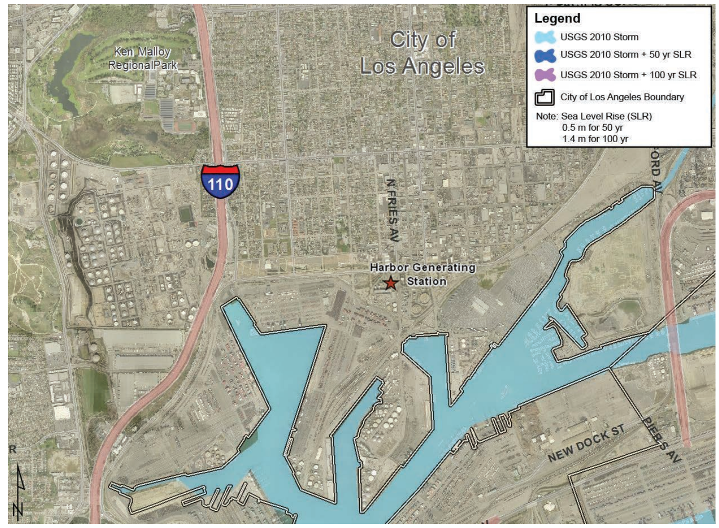
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Water and Power

Regulatory Oversight:
North American Electric Reliability Corporation (NERC), Western Electricity Coordination Council (WECC), Southern California Air Quality Management District (SCAQMD)

Summary of Asset:
The Harbor Generation Station is a natural gas fired steam electric generating facility located in the Wilmington area. The facility's total capacity is 472 megawatts and it occupies approximately 20 acres.



Current Observed Vulnerabilities

Energy facilities have low vulnerability to the impacts of sea level rise, because all coastal assets were designed to withstand exposure to water. In addition, replacement schedules and system redundancies reduce vulnerability.

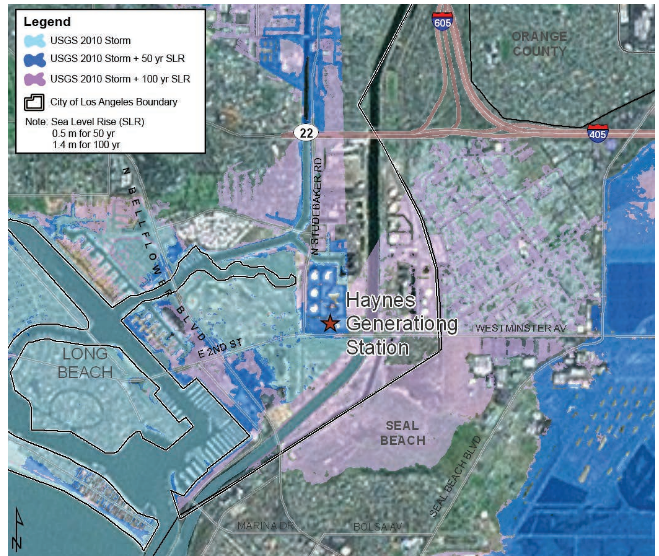
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
The Harbor Generation Station is not sensitive to the impacts of sea level rise, such as storm-related flooding, tidal flooding, erosion, and interaction with groundwater, because, as a coastal asset, it was designed to be able to cope with these impacts.	This asset can continue to function if partially disabled and its functionality can be restored quickly if impaired. Outdoor components are designed for water resistance and exposure. Indoor components are designed for water to drain into sumps and are also equipped with pumps to quickly remove the water from the sumps.	Impacts would be equally distributed to the immediate area.

Replacement value (e.g., cost of inaction):	None provided

Haynes Generating Station
6801 E 2nd Street
Long Beach CA 90803

Asset Overview
Owner: City of Los Angeles
City Department and Point of Contact: Department of Water and Power
Regulatory Oversight: North American Electric Reliability Corporation (NERC), Western Electricity Coordination Council (WECC), Southern California Air Quality Management District (SCAQMD), California State Water Resources Control Board (SWRCB)
Summary of Asset: Haynes Generation Station is a natural gas fired power plant located in the Long Beach area with a capacity of 1556 megawatts.



Current Observed Vulnerabilities
Energy facilities have low vulnerability to the impacts of sea level rise, because all coastal assets were designed to withstand exposure to water. In addition, replacement schedules and system redundancies reduce vulnerability.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
This asset is not sensitive to the impacts of sea level rise, such as storm-related flooding, tidal flooding, erosion, and interaction with groundwater because, as a coastal asset, it was designed to be able to cope with these impacts.	This asset can continue to function if partially disabled and its functionality can be restored quickly, because outdoor assets are designed for water resistance and exposure. Indoor assets are designed for water to drain into sumps and are also equipped with pumps to quickly remove the water from the sumps.	Impairment of Haynes would have moderate economic consequences, because clean-up could take time, potentially affecting the power supply to other parts of Los Angeles. The disruption of power supply could have environmental consequences, because it could impact power supply to waste water treatment plants, potentially resulting in sewage spills.

Replacement value (e.g., cost of inaction):	None provided

Receiving Station Q (RSQ)
150 N Island Ave
Wilmington, CA 90744

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Water and Power

Regulatory Oversight:
North American Electric Reliability Corporation (NERC) and Western Electricity Coordination Council (WECC) Reliability Standards. California Public Utilities Commission (CPUC) claims jurisdiction over matters of safety.

Summary of Asset:
Receiving Station (RS) Q is located in the Wilmington area and is comprised of equipment that receives power from generation, transforms the voltage, and distributes the power out again into the distribution network. Specifically, it has underground transmission connections to RS-C and Harbor Generation stations and connection to distribution stations that serve the San Pedro and Wilmington areas.

Current Observed Vulnerabilities

Energy facilities have low vulnerability to the impacts of sea level rise, because all coastal assets were designed to withstand exposure to water. In addition, replacement schedules and system redundancies reduce vulnerability.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
This asset is not sensitive to the impacts of sea level rise, such as storm-related flooding, tidal flooding, erosion, and interaction with groundwater, because as a coastal asset, it was designed to be able to cope with these impacts.	This asset can continue to function if partially disabled and its functionality can be restored quickly, because outdoor assets are designed for water resistance and exposure. Indoor assets are designed for water to drain into sumps and are also equipped with pumps to quickly evacuate the water from the sumps.	The DWP reports minor economic consequences from the potential impairment of RS-Q, because impacts would be distributed equally in the immediate area. Impairment of RS-Q could have moderate environmental consequences, however, because it could impact power supply to wastewater treatment plants, potentially resulting in a sewage spill.

Replacement value (e.g., cost of inaction):	None provided

230 KV Scattergood-Olympic Cable Dockweiler Beach/Venice Area

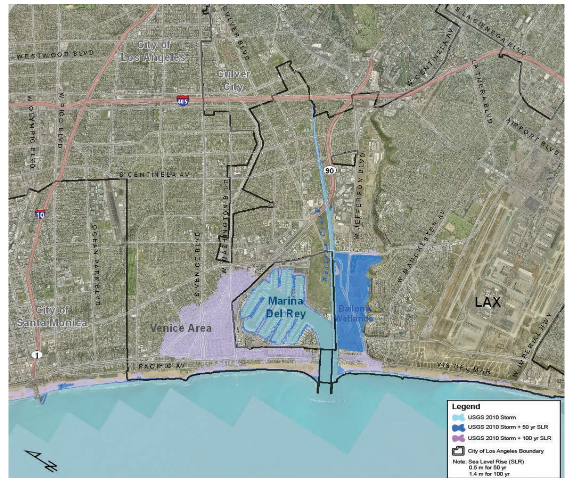
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Water and Power

Regulatory Oversight:
North American Electric Reliability Corporation (NERC) and Western Electricity Coordination Council (WECC) Reliability Standards.

Summary of Asset:
This is an underground cable in the Dockweiler Beach/Venice area that connects to a high voltage interstate line.



Current Observed Vulnerabilities

None identified

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
This asset is potentially sensitive to daily tidal flooding, because flooding of low-lying areas around the cable could make maintenance and repair difficult.	This asset can continue to function if partially disabled. Outdoor assets are designed for water resistance and exterior exposure. Their function can also be restored quickly.	The DWP reports minor consequences from the potential impairment of this asset, because impacts would be distributed equally in the immediate area.

Replacement value (e.g., cost of inaction):	None provided

Electrode Vault
17300 Pacific Coast Highway
Pacific Palisades, 90272

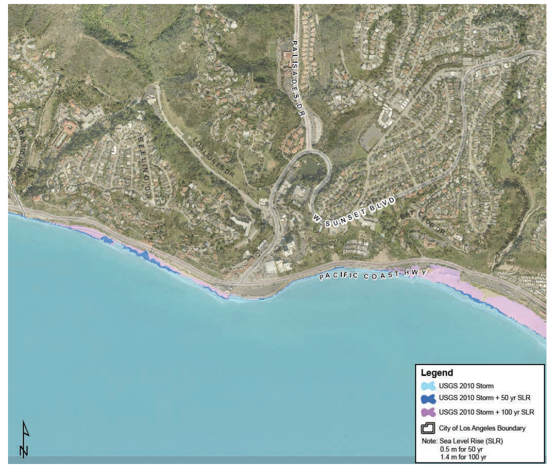
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Water and Power

Regulatory Oversight:
California Public Utilities Commission (CPUC) claims jurisdiction over power equipment based on safety matters.

Summary of Asset:
This is an underground vault. It is currently being redesigned and moved for reasons unrelated to sea level rise.



Current Observed Vulnerabilities

Energy facilities have low vulnerability to the impacts of sea level rise, because all coastal assets were designed to withstand exposure to water. In addition, replacement schedules and system redundancies reduce vulnerability.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
This asset is not sensitive to the impacts of sea level rise, such as storm-related flooding, tidal flooding, erosion, and interaction with groundwater, because, as a coastal asset, it was designed to deal with these impacts.	This asset can continue to function if partially disabled. Outdoor assets are designed for water resistance and exterior exposure. Their function can also be restored quickly.	The DWP reports minor consequences from the potential impairment of this asset, because impacts would be distributed equally in the immediate area.

Replacement value (i.e., cost of inaction):	None provided

Local Electricity Distribution Assets

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: Poles (multiple) Transformers (multiple) Wires (multiple)	Venice/LAX Sub-Region: Poles (multiple) Transformers (multiple) Wires (multiple)	San Pedro/Harbor Sub-Region: Distribution Stations (3) Poles (multiple) Transformers (multiple) Wires (multiple)
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Water and Power		
Regulatory Oversight: California Public Utilities Commission (CPUC) claims jurisdiction over power equipment based on safety matters.		
Description of Assets: Local electricity distribution assets include three distribution stations, poles, transformers, wires, vaults, and cables. These assets help deliver electricity at relatively low voltages to customers.		
Current Observed Vulnerabilities		
Energy facilities have low vulnerability to the impacts of sea level rise, because all coastal assets were designed to withstand exposure to water. In addition, replacement schedules and system redundancies reduce vulnerability.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (LOW)	Adaptive Capacity (HIGH)	Consequences (MEDIUM)
These assets are not sensitive to the impacts of sea level rise, such as storm-related flooding, tidal flooding, erosion, and interaction with groundwater, because, as coastal assets, they were designed to be able to cope with these impacts.	These assets can continue to function if partially disabled. Outdoor assets are designed for water resistance and exterior exposure. Indoor assets are designed for water to drain into sumps and are also equipped with pumps to quickly evacuate the water from the sumps. In addition, assets are laid out in a manner that is easily reparable and their function can also be restored quickly. Lastly, if needed, power can be re-routed to other parts of the network.	The DWP reports minor consequences from the potential impairment of these assets, because impacts would be distributed equally in the immediate area.
Replacement value (e.g., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

Water Pipes

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: 1919 feet	Venice/LAX Sub-Region: 186,961 feet	San Pedro/Harbor Sub-Region: 10,632 feet
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Water and Power		
Regulatory Oversight: Los Angeles Department of Water and Power, California Department of Public Health (CDPH), U.S. Environmental Protection Agency (USEPA)		
Summary of Asset: LADWP's water infrastructure distributes water supply to 676,000 active service connections through a distribution network of over 7,200 miles of pipelines. About 500 miles of pipe in the distribution system is 24 inches or larger in diameter (trunkline). The remaining pipes have a diameter of less than 24 inches (mainline). There are approximately 199,512 feet of pipe in the exposure zone. Pipes carry water through the distribution system to customers.		
Current Observed Vulnerabilities		
The potable water system is vulnerable to storm-related flooding, daily tidal flooding, and interaction with groundwater, which makes accessing underground assets, such as pipes, extremely challenging and raise public health concerns. Erosion could also damage many of the assets.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (MEDIUM)
Pipes are sensitive to storm-related flooding, tidal flooding, and interaction with groundwater because the water makes it difficult for crews to access the buried pipes, thus impairing construction and maintenance. The pipes are also sensitive to erosion, because the loss of ground stability could damage or break the pipes, thus impairing operation.	By pumping water out from flooded areas, the pipes could continue to function even if partially disabled. Crews can also limit construction and maintenance to low tide periods. Lastly, because the pipes are part of a networked system, LADWP could potentially bypass an impaired section of the network. The functionality of the pipes, however, might not be quickly or easily restored, because major excavation and construction is required to restore operations. There are no current efforts in place to make the pipes more resilient to these impacts.	Impairment of pipes from sea level rise impacts would have high economic consequences because it affects construction and reduces the life span of the pipes. In addition, there are public health concerns regarding salt water, groundwater, or other substances potentially infiltrating the potable water system. Lastly, pipe failure could potentially exacerbate flooding in flat areas with poor drainage.
Replacement value (e.g., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

Water Services

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: 9	Venice/LAX Sub-Region: 4,208	San Pedro/Harbor Sub-Region: 11
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Water and Power		
Regulatory Oversight: Los Angeles Department of Water and Power, California Department of Public Health (CDPH), U.S. Environmental Protection Agency (USEPA)		
Summary of Asset: Approximately 4,228 water services in the exposure area connect water mains to customers. This asset includes connections between the water main and the meter, the meters, and meter boxes.		
Current Observed Vulnerabilities		
The potable water system is vulnerable to storm-related flooding, daily tidal flooding, and interaction with groundwater, which makes accessing underground assets, such as pipes, extremely challenging and raise public health concerns. Erosion could also damage many of the assets.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (MEDIUM)
Many water services are located below ground. Thus, if they were submerged in water, such as from storm-related flooding, daily tidal flooding, or interaction with groundwater, the water would need to be pumped out before the asset could be placed back into operation. These impacts could impair construction, maintenance, and operation of water services.	By removing the water to a minimum level needed for operations, the water services could continue to function even if they were partially disabled. In addition, there is some redundancy and flexibility in the system, which provides some resilience, but this is highly dependent on the location. If impaired, however, the functionality of water services might not easily or quickly restore. The DWP has undertaken some efforts to make water services more resilient by installing some of the larger services above ground.	These impacts have high economic consequences because they affect construction and reduce the life span of these assets. In addition, there are public health concerns resulting from salt water, groundwater, and/or other substances potentially infiltrating the potable water system. Lastly, failure could exacerbate flooding in flat areas with poor drainage.
Replacement value (i.e., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

Fire Hydrants

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: 0	Venice/LAX Sub-Region: 248	San Pedro/Harbor Sub-Region: 1
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Water and Power		
Regulatory Oversight: Los Angeles Department of Water and Power, California Department of Public Health (CDPH), U.S. Environmental Protection Agency (USEPA)		
Description of Assets: There are approximately 249 fire hydrants in the exposure area that provide high pressure water for fire fighting efforts and temporary water services.		
Current Observed Vulnerabilities		
None identified.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (HIGH)	Adaptive Capacity (LOW)	Consequences (MEDIUM)
Fire hydrants are sensitive to storm related and tidal flooding, because if the hydrants are submerged in water, firefighting personnel will not be able to access or operate them. Fire hydrants are also sensitive to erosion, because the loss of ground stability could damage the fire hydrant and render it inoperable.	Fire hydrants can function if partially disabled, because they will continue to work in semi-submerged conditions. The function, however, cannot be restored quickly or easily if impaired and there are no current efforts in place to make hydrants more resilient to these impacts.	Flooding, inundation, and groundwater have high economic consequences because they impact the construction and lifespan of the asset. In addition, there are public health concerns regarding salt water, groundwater, or other substances potentially infiltrating the potable water system, since fire hydrants are connected to the potable water system. Lastly, failure of fire hydrants could exacerbate flooding in flat areas with poor drainage because water at high pressure could spill from a broken hydrant.
Replacement value (i.e., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

Cultural Facilities

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: None in coastal zone	Venice/LAX Sub-Region: None in coastal zone	San Pedro/Harbor Sub-Region: LA Maritime Museum
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Recreation and Parks		
Regulatory Oversight: No Regulatory Oversight		
Description of Assets: The L.A. Maritime Museum is located in the coastal zone, in the 1941 Municipal Ferry Terminal, and is on the National Register of Historic Places.		
Current Observed Vulnerabilities		
Structures like recreation centers and museums are highly vulnerable to flooding and inundation, because the structures would be damaged, inoperable, and/or inaccessible.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (HIGH)	Adaptive Capacity (LOW)	Consequences (MEDIUM)
The museum is sensitive to storm-related flooding, tidal flooding, and erosion. These impacts would cause damage to the structure and/or content of the building and would cause the facility to close to the public.	This facility cannot function if it is partially impaired and cannot be quickly or easily restored if impaired. There are no current efforts in place to make the museum more resilient to the impacts of sea level rise.	The greatest consequence would be the economic impact of a storm-related flood, because this could cause damage to the valuable artifacts within the museum. In addition, closure of the Maritime Museum would be a cultural loss for the local community and greater City of Los Angeles, as this site attracts visitors from around the region.
Replacement value (e.g., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

Cabrillo Beach
3720 Stephen M. White Dr.
San Pedro, CA 90731

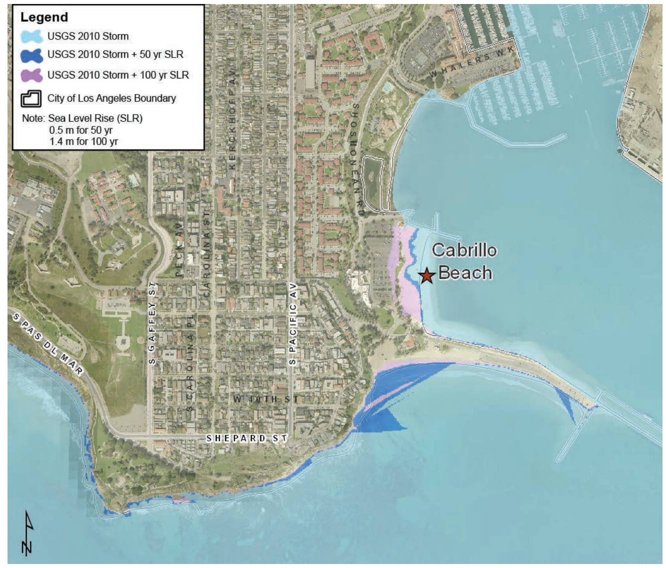
Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Recreation and Parks

Regulatory Oversight:
No Regulatory Oversight

Summary of Asset:
Cabrillo Beach includes a public beach, a marine aquarium, a recreation center, and a fishing pier.



Current Observed Vulnerabilities

Currently has poor water quality; sand has been replaced twice already.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
The public beach is sensitive to storm-related flooding, daily tidal flooding, erosion, and interaction with groundwater. The public beach could potentially be lost to erosion. In fact, in 2007, a large storm washed away the sand and the outer beach was exposed down to rocks. The sand was replaced naturally over time, but with higher sea level, it is uncertain if the sand would return naturally following a storm event. Storm-related flooding, tidal flooding, and groundwater could damage the recreation center and aquarium.	The public beach could potentially continue to function if partially impaired. For example, if the beach is flooded only during high tides, visitors could potentially use the beach during low tides. Also, it could potentially continue to function if impaired by storm-related flooding. After previous storm events, some of the beach sand still remained, but with a two- to three-foot berm that visitors had to navigate to access the water. On the other hand, partial impairment of the aquarium and recreation center would render them non-functional. Also, these facilities could not be quickly or easily restored if impaired. Flooding in the parking lot or road would result in a loss of access for visitors. There are no current efforts in place to make the facilities at Cabrillo Beach more resilient to the impacts of sea level rise.	Impairment of this asset would have high economic consequences, because the beach and aquarium attract visitors from all over Southern California. The local communities of Wilmington, San Pedro, and Harbor City also use the beach and the recreation center, and the impairment of these assets would be a loss of open space and recreation opportunities for these park-poor communities.

Replacement value (e.g., cost of inaction):	None provided

Parks and Open Space

<table>
<tr><th colspan="3">Asset Overview</th></tr>
<tr><td colspan="3">Location and Number of Assets*</td></tr>
<tr><td>Pacific Palisades Sub-Region:
None in coastal zone</td><td>Venice/LAX Sub-Region:
Playa del Rey:
Del Rey Lagoon Park (Playa del Rey)**
Venice:
Canal Park/Linnie Canal (Venice)**
Westminster Park (Venice)
Triangle Park (Marr Park)
Culver City:
Titmouse Park (Culver City)**</td><td>San Pedro/Harbor Sub-Region:
San Pedro:
John S. Gibson Jr. Park</td></tr>
<tr><td colspan="3">Owner:
City of Los Angeles</td></tr>
<tr><td colspan="3">City Department and Point of Contact:
Department of Recreation and Parks</td></tr>
<tr><td colspan="3">Regulatory Oversight:
No Regulatory Oversight</td></tr>
<tr><td colspan="3">Description of Assets:
Neighborhood Parks located in the sea level rise exposure zone include Del Rey Lagoon Park, Canal Park, and Titmouse Park. Del Rey Lagoon features a tidal basin, children's play area, a ball field, and restroom facility. Canal Park is a pocket park located along the Venice canals and it includes grass and a children's play area. Titmouse Park is a small park located near Ballona Creek consisting of native plants that provide habitat for birds.</td></tr>
<tr><th colspan="3">Current Observed Vulnerabilities</th></tr>
<tr><td colspan="3">Parks and other open spaces are generally fairly resilient assets. They can be restored relatively quickly or they can change to cope with new environmental conditions. For example, different landscaping can be introduced to deal with periodic flooding without significantly changing the function of the park. Built structures, such as recreational buildings and museums are much less resilient, because damage takes longer to repair and they cannot function if partially impaired.

The consequences of impairment of these facilities are highly dependent on the location. Some facilities, like the Venice Beach Boardwalk, are iconic destinations and their impairment could have significant economic consequences. Some parks are unique because they provide habitat for rare plants and animals. Other parks and recreation centers are highly valued and used by the local communities, especially in the San Pedro/Harbor area, because few other parks exists in the area.</td></tr>
<tr><th colspan="3">Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis</th></tr>
<tr><th>Sensitivity (HIGH)</th><th>Adaptive Capacity (MEDIUM)</th><th>Consequences (LOW)</th></tr>
<tr><td>These parks are sensitive to storm-related flooding, daily tidal flooding, and erosion which could damage the park facilities and make the park unusable an inaccessible.</td><td>The parks could function if partially impaired. For example, if only a small part of the park experiences tidal flooding, other parts of the park could be used. The park could be quickly restored depending on how fast storm water recedes. The landscape and vegetation of the parks could change given these impacts and still be useful as habitat for plants and animals.</td><td>The consequences of impairment of these parks would be relatively minor given their small size. There would be a loss of recreational opportunities for residents and habitat for plants and animals.</td></tr>
<tr><th>Replacement value (e.g., cost of inaction)</th><td colspan="2">None provided</td></tr>
</table>

* Please refer to subregional maps on pages 17-19.
**The physical vulnerability assessment only considers the impacts to these parks.

Recreation Centers

Asset Overview		
Location and Number of Assets*		
Pacific Palisades Sub-Region: None in exposure zone	Venice/LAX Sub-Region: Venice Beach Recreation Center** San Juan Garage	San Pedro/Harbor Sub-Region: None in exposure zone
Owner: City of Los Angeles		
City Department and Point of Contact: Department of Recreation and Parks		
Regulatory Oversight: No Regulatory Oversight		
Description of Assets: Recreation Centers located in the exposure zone include the Venice Beach Recreation Center and San Juan Garage. The Venice Beach Recreation Center consists of a boardwalk, fishing pier, picnic areas, skateboard arena and athletic courts.		
Current Observed Vulnerabilities		
Structures like recreation centers and museums are highly vulnerable to flooding and inundation, because the structures would be damaged, inoperable, and/or inaccessible.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (HIGH)	Adaptive Capacity (LOW)	Consequences (HIGH)
This asset is sensitive to storm-related and daily tidal flooding, which could damage the various elements of the recreation center and render them unusable by the public. The pier already has some structural weakness and it could be further damaged by these impacts. Erosion could also weaken the structural stability of the pier and the boardwalk.	This asset cannot function if partially impaired. The boardwalk and athletic courts could be quickly restored if impaired, but the pier would take considerably longer to restore if damaged. Recreation and Parks is currently working on a plan to reinforce the pier to better withstand current impacts, but the plan does not explicitly take the impacts of sea level rise into consideration.	Impairment of these iconic facilities, particularly the boardwalk, would have high economic consequences, because of their cultural, recreational, and tourist value. They draw visitors from around the region and even from around the world. The boardwalk also includes spaces for about 200 vendors, who would have to seek other locations to sell their goods.
Replacement value (e.g., cost of inaction)	None provided	

* Please refer to subregional maps on pages 17-19.

**The physical vulnerability assessment only considers the impacts to the Venice Beach Recreation Center.

Building Stock and Roads - Venice Area

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Planning

Regulatory Oversight:
US Army Corps of Engineers (USACE)*
Los Angeles County Department of Water and Power (LACDWP)*
City of Los Angeles Bureau of Engineering (BOE)*
California Coastal Commission*
City of Los Angeles Ordinance (No. 172,081)**

Description of Assets:
None provided.

Current Observed Vulnerabilities

Roads are vulnerable to flooding, inundation, erosion, and groundwater, which could result in reduced access for residents and impaired regional transport. The building stock is most vulnerable to flooding and inundation in Venice, where it is located very near sea level and there are many older structures.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
The building stock and roads in the Venice area are sensitive to storm-related flooding, tidal flooding, and erosion. The impacts of sea level rise could lead to damaged and/or uninhabitable homes, businesses, schools, and public buildings. Many structures are built at, or very near, sea level. In addition, many of the structures were built before the 1970s, which means they are more sensitive to flooding. In fact, some residents already experience flooded basements during storm events. Damage to roads from the impacts of sea level rise could also result in a lack of access for residents and emergency services.	The ability of the roads and building stock in Venice to continue to function if partially disabled depends on the extent of damage. The functionality of these assets could not be restored very quickly or easily. The City Planning department, in collaboration with the Departments of Building and Safety, Public Works, and Transportation can identify an adaptation strategy for these assets during the next update of the Venice Community Plan.	The economic and social consequences of the impairment of these assets would be high due to the displacement of residents and businesses. In particular, the displacement of low-income residents in the Venice Beach area would have significant social consequences. In addition, flooding in this area could cause damage to the Ballona wetlands, which provides habitat for plants and animals and helps filter groundwater.

Replacement value (e.g., cost of inaction)	None provided

*Flood Protection in the region is managed by 3 agencies: 1) United States Army Corps of Engineers (USACE); 2) Los Angeles County Department of Public Works (LACDPW); and 3) City of Los Angeles Bureau of Engineering (BOE). The USACE oversees projects associated with navigable bodies of water, including ocean harbors. The LACDPW oversees county flood control drainage facilities to reduce the impacts of 100- and 500- year storms. The BOE oversees the City's storm drainage system, which is designed to reduce the impacts of 50-year magnitude storms. Various city agencies implement development permit and slope stability permits. The California Coastal Commission also has permit responsibility in the coastal zone located in San Pedro and the Port of Los Angeles.

**The City of Los Angeles has an ordinance governing permit review and mitigation procedures for issuance of development permits in areas prone to flooding, mudflow, or coastal inundation. The Ordinance (No. 172,081) specifies mitigation measures, which include relocation of structures within a property, increased base elevation, additional structural reinforcement, anchoring, and installation of protective barriers.

Building Stock and Roads - San Pedro/Harbor Area

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Planning

Regulatory Oversight:
U.S. Army Corps of Engineers (USACE)*
Los Angeles County Department of Water and Power (LACDWP)*
City of Los Angeles Bureau of Engineering (BOE)*
California Coastal Commission*
City of Los Angeles Ordinance (No. 172,081)**

Description of Assets:
The San Pedro and Harbor area are served by a circulation system of highways (freeways or high capacity roadways), arterials (moderate capacity roadways), collector streets and local streets. Paseo Del Mar, in the southern portion of San Pedro runs in an east-west direction along the coastline. Harbor Boulevard runs in a north-south direction along the harbor shoreline. Being located on a peninsula, San Pedro and the harbor area are limited in the number of through routes.

Current Observed Vulnerabilities

Roads are vulnerable to flooding, inundation, erosion, and groundwater, which could result in reduced access for residents and impaired regional transport.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
The building stock and roads in the San Pedro/Harbor Area are sensitive to storm-related flooding, tidal flooding, and erosion. Not many residential buildings will be exposed to sea level rise because they are terraced up on the hillside, but there are some people that live on boats in the marina. Roads could be damaged by these impacts.	The City Planning department is uncertain if this asset could continue to function if partially disabled, because it depends upon the extent of the damage. The City Planning department, in collaboration with the Departments of Building and Safety, Public Works, and Transportation can identify an adaptation strategy for these assets during the next update of the San Pedro Community Plan.	Impairment of roads would have significant economic consequences because they are important for regional goods movement due to their proximity to the Port of Los Angeles. Damage to roads could also limit access to neighborhoods. Damage to building stock could displace businesses and low-income residents.

Replacement value (e.g., cost of inaction)	None provided

*Flood Protection in the region is managed by 3 agencies: 1) United States Army Corps of Engineers (USACE); 2) Los Angeles County Department of Public Works (LACDPW); and 3) City of Los Angeles Bureau of Engineering (BOE). The USACE oversees projects associated with navigable bodies of water, including ocean harbors. The LACDPW oversees county flood control drainage facilities to reduce the impacts of 100- and 500- year storms. The BOE oversees the City's storm drainage system, which is designed to reduce the impacts of 50-year magnitude storms. Various city agencies implement development permit and slope stability permits. The California Coastal Commission also has permit responsibility in the coastal zone located in San Pedro and the Port of Los Angeles.

**The City of Los Angeles has an ordinance governing permit review and mitigation procedures for issuance of development permits in areas prone to flooding, mudflow, or coastal inundation. The Ordinance (No. 172,081) specifies mitigation measures, which include relocation of structures within a property, increased base elevation, additional structural reinforcement, anchoring, and installation of protective barriers.

Pacific Coast Highway (PCH) - Pacific Palisades Area

Asset Overview

Owner:
City of Los Angeles

City Department and Point of Contact:
Department of Planning

Regulatory Oversight:
U.S. Army Corps of Engineers (USACE)*
Los Angeles County Department of Water and Power (LACDWP)*
City of Los Angeles Bureau of Engineering (BOE)*
California Coastal Commission*
City of Los Angeles Ordinance (No. 172,081)**

Summary of Asset:
This asset consists of approximately 2.5 miles of PCH from Sunset Boulevard to Entrada Drive. The highway in this stretch generally has six lanes and runs near the ocean, separated from the sea by sandy beaches and some coastal armoring. California Department of Transportation has jurisdiction over PCH, but it provides a critical connection to coastal communities.

Current Observed Vulnerabilities

Roads are vulnerable to flooding, inundation, erosion, and groundwater, which could result in reduced access for residents and impaired regional transport

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (HIGH)	Adaptive Capacity (MEDIUM)	Consequences (HIGH)
This asset is sensitive to storm-related flooding, tidal flooding, and erosion. All of these impacts could result in damage to the highway, potentially causing frequent closures and even structural failure.	It is uncertain if PCH could continue to function if partially disabled, because it would depend on decision-making by Caltrans regarding keeping the highway open with a reduced number of lanes.	Impairment of PCH would have significant economic consequences, because it is an important transportation connection in the region. In addition, it would have adverse consequences for communities living in Pacific Palisades who could have difficulty accessing their homes or be less accessible to emergency services.

Replacement value (e.g., cost of inaction)	None provided

*Flood Protection in the region is managed by 3 agencies: 1) United States Army Corps of Engineers (USACE); 2) Los Angeles County Department of Public Works (LACDPW); and 3) City of Los Angeles Bureau of Engineering (BOE). The USACE oversees projects associated with navigable bodies of water, including ocean harbors. The LACDPW oversees county flood control drainage facilities to reduce the impacts of 100- and 500- year storms. The BOE oversees the City's storm drainage system, which is designed to reduce the impacts of 50-year magnitude storms. Various city agencies implement development permit and slope stability permits. The California Coastal Commission also has permit responsibility in the coastal zone located in San Pedro and the Port of Los Angeles.

**The City of Los Angeles has an ordinance governing permit review and mitigation procedures for issuance of development permits in areas prone to flooding, mudflow, or coastal inundation. The Ordinance (No. 172,081) specifies mitigation measures, which include relocation of structures within a property, increased base elevation, additional structural reinforcement, anchoring, and installation of protective barriers.

Port of Los Angeles
Container Terminals
425 South Palos Verdes Street
San Pedro California 90731

Asset Overview

Owner:
Port of Los Angeles

City Department and Point of Contact:
Harbor

Regulatory Oversight:
No description provided.

Description of Assets:
Container terminals are the facilities where cranes load cargo containers to and from ships and onto trucks or trains for onward transportation. These facilities also provide storage for containers in stacks while awaiting transport.

Current Observed Vulnerabilities

Although the Port's assets are highly sensitive to flooding and inundation, the port has low vulnerability because of its high capacity to adapt by building future infrastructure at a higher elevation.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (HIGH)	Consequences (HIGH)
Container terminals will be sensitive to storm-related flooding during high tide events in the later years of this study. This flooding could render the terminals inaccessible and non-operational with unsecured containers and no power supply for equipment.	In the short-term, container terminals have low adaptive capacity, because they cannot continue to function if partially disabled and their functionality cannot be restored quickly after suffering damage. However, in the long-term the terminals could be redesigned and re-built at higher elevations.	The economic consequences of impaired container terminals are very significant. They are the port's highest revenue generating resource and they have a $2.85 billion replacement value. Furthermore, the economic impacts would ripple through the economy as shipments would be delayed or re-routed. Quantifying the economic consequences of impaired container terminals is extremely difficult because it depends on a variety of factors. According to the National Oceanic and Atmospheric Administration 2008-2017 Strategic Plan, the cost of a shutdown of the POLA/POLB would cost $1 billion per day in regional economic losses.

Replacement value (i.e., cost of inaction)	$2.85 billion replacement value, $1 billion per day cost of shut down of POLA/POLB

Port of Los Angeles
Electrical Infrastructure
425 South Palos Verdes Street
San Pedro California 90731

Asset Overview		
Owner: Port of Los Angeles		
City Department and Point of Contact: Harbor		
Regulatory Oversight: Los Angeles Department of Building and Safety (LADBS)		
Description of Assets: Electrical infrastructure for container handling and lighting.		
Current Observed Vulnerabilities		
Although the Port's assets are highly sensitive to flooding and inundation, the port has low vulnerability because of its high capacity to adapt by building future infrastructure at a higher elevation.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (MEDIUM)	Adaptive Capacity (HIGH)	Consequences (HIGH)
The Port's electrical infrastructure could be severely damaged by regular storm-related flooding in the later years of the study, as it is not designed to be flooded or inundated.	In the short term, this asset has low adaptive capacity, because it cannot function if partially disabled and the functionality is not quickly or easily restored if impaired. However, in the long-term, the electrical infrastructure could be redesigned at higher elevations.	This infrastructure is vital to port operations and impairment would cause equipment, such as cranes, to be non-operational. This could cause delays and disruptions in cargo loading and offloading. This asset has a $350 million replacement value.
Replacement value (e.g., cost of inaction)	$350 million	

Port of Los Angeles
Breakwater
425 South Palos Verdes Street
San Pedro California 90731

Asset Overview

Owner:
Port of Los Angeles

City Department and Point of Contact:
Harbor

Regulatory Oversight:
Army Corps of Engineers

Description of Assets:
The breakwater is an 8.5-mile rock structure that prevents waves from entering the harbor. It has two openings to allow ships to enter the port areas behind it.

Current Observed Vulnerabilities

Although the Port's assets are highly sensitive to flooding and inundation, the port has low vulnerability because of its high capacity to adapt by building future infrastructure at a higher elevation.

Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis

Sensitivity (MEDIUM)	Adaptive Capacity (HIGH)	Consequences (HIGH)
The breakwater would be sensitive to overtopping and storm surge damage during the later years of the study. This would impact its ability to shelter harbor facilities.	The breakwater could potentially function if partially impaired. For example, if a portion of the breakwater is eroded, the rest of the structure would continue to block waves. Also, if the breakwater is flooded only during high tide, it would continue to function during low tide.	An impaired breakwater would have high economic consequences because it could cause damage to the port, rendering shipping terminals unusable and interrupting flow of cargo. There could also be environmental damage to the shallow water habitat adjacent to breakwater, which is a built ecosystem that supports eelgrass, fish, and bird life. The breakwater has a $500 million replacement value and is managed by the Army Corps of Engineers.

Replacement value (e.g., cost of inaction)	$500 million

Port of Los Angeles
Transportation
425 South Palos Verdes Street
San Pedro California 90731

Asset Overview		
Owner: Port of Los Angeles		
City Department and Point of Contact: Harbor		
Regulatory Oversight: Los Angeles Department of Transportation (LADOT), Metropolitan Transportation Authority (MTA), California Department of Transportation (Caltrans), Public Utilities Commission (PUC)		
Description of Assets: Transportation assets include roads, rails, and grade separations that help move cargo to and from the Port.		
Current Observed Vulnerabilities		
Although the Port's assets are highly sensitive to flooding and inundation, the port has low vulnerability because of its high capacity to adapt by building future infrastructure at a higher elevation.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (MEDIUM)	**Adaptive Capacity (HIGH)**	**Consequences (HIGH)**
Transportation assets will be sensitive to storm-related flooding and daily tidal flooding, erosion, and groundwater interaction in later years of the study. These impacts could cause the assets to be damaged and thus unusable.	Compared to other port assets, roads can be re-built relatively quickly. In addition, if only one lane is affected by flooding or erosion, the road can potentially still continue to function.	Impaired transportation facilities would have a high economic consequence, because they are vital for transporting cargo from terminals to their final destinations. It could also have a high impact on communities living in San Pedro, Wilmington, and permanent residents in the marinas due to reduced access. The transportation assets are estimated to have a $1 billion replacement value.
Replacement value (e.g., cost of inaction)	$1 billion	

Port of Los Angeles
Marinas
425 South Palos Verdes Street
San Pedro California 90731

Asset Overview		
Owner: Port of Los Angeles		
City Department and Point of Contact: Harbor		
Regulatory Oversight: California Coastal Commission, California Department of Boating and Waterways		
Description of Assets: Marinas are docks with moorings for relatively small boats.		
Current Observed Vulnerabilities		
Although the Port's assets are highly sensitive to flooding and inundation, the port has low vulnerability because of its high capacity to adapt by building future infrastructure at a higher elevation.		
Physical Vulnerability to Sea Level Rise Based on USGS Exposure Analysis		
Sensitivity (MEDIUM)	**Adaptive Capacity (HIGH)**	**Consequences (MEDIUM)**
Marinas are sensitive to storm-related flooding, daily tidal flooding, and erosion, because they would be damaged by such impacts.	Marinas are relatively resilient to storm-related flooding, because they float on the water, but their groundings would become deteriorated from daily tidal flooding and erosion. In addition, these impacts could reduce access to the marinas.	The consequences of impaired marinas primary relates to their recreational value. They also have an estimated $180 million replacement value. Lastly, permanent residents of the marinas could potentially be displaced.
Replacement value (e.g., cost of inaction)	$180 million	

Social Vulnerability Assessment

A social vulnerability study was conducted by Dr. Julia Ekstrom and Dr. Susanne Moser (see Appendix 3 for full report), which examined the socioeconomic implications of sea level rise to residents and communities in the City of L.A. The authors provide demographic overviews of the three coastal areas within the City of L.A. (Pacific Palisades, Venice/Playa del Rey/LAX, San Pedro/Harbor area) that are likely to experience impacts from sea level rise and other associated flooding (i.e., such as that from stormwater system overflows) (see report in Appendix 3 for more details on demographics). The social vulnerability study focused on census data-derived demographics of the coastal communities rather than directly on the flood models. The demographic overviews are followed by a description of population characteristics that demonstrate which segments of coastal communities may be more socially vulnerable to flooding than others.

The assessment utilizes a variety of sources to discuss characteristics that are commonly associated with higher sensitivity and/or lower adaptive capacity to flooding and sea level rise. Information was compiled from Census 2010 data when available, American Communities Survey Census 2006-2010 data, Census 2000 data (when it provided information at a higher resolution), and pre-existing information from secondary data sources, such as City and County planning documents, other assessments related to vulnerable segments of the City (and some cases County's) population, and newspaper articles about past floods. The characteristics discussed include: income, poverty, education, females as head of household, race, linguistic isolation, age, housing type and age, and physical and mental illnesses and disabilities.

Income and poverty level are considered the primary indicators of adaptive capacity. While per capita income in Los Angeles overall tends to be higher along the coast than in the interior, there are communities along the coast that average some of the lowest income levels in L.A. County (Figure 7), (e.g., portions of San Pedro and Wilmington have an average income of $13,000 per year compared to

Per Capita Income ($) - City of L.A.

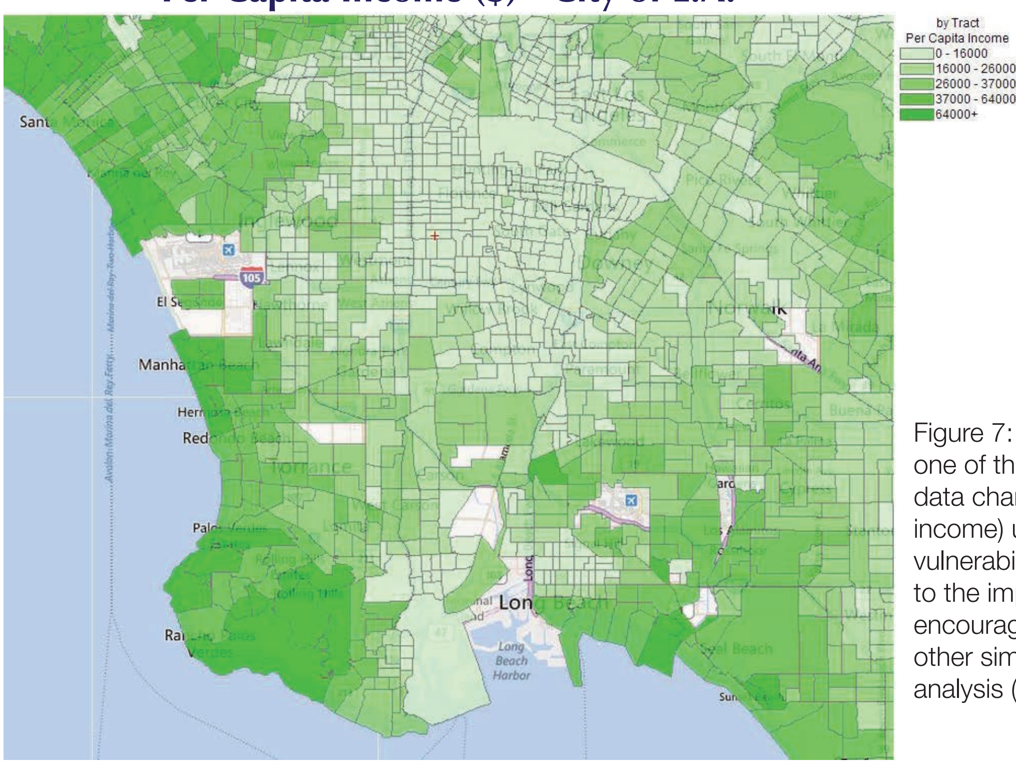


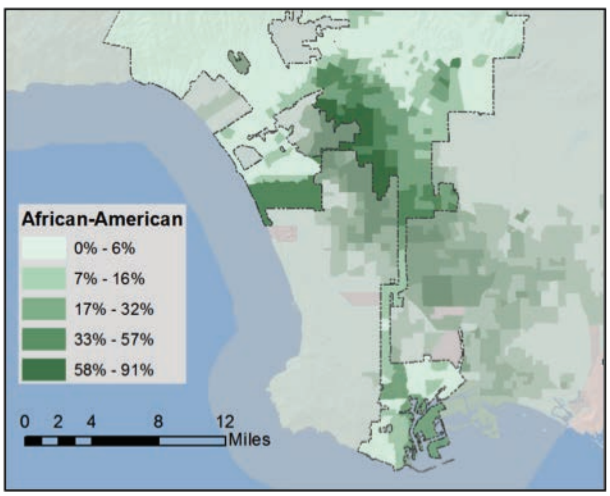
Figure 7: This figure provides an example of one of the many figures representing census data characteristics (in this case per capita income) utilized to determine the social vulnerability of City of Los Angeles residents to the impacts of sea level rise. Readers are encouraged to view the full report to review other similar figures for other census data analysis (Appendix 3).

the more affluent communities on the Palos Verdes Peninsula which average $128,000 per year). Similarly, over 76% of the census tract population on the west side of Wilmington lives below the federal poverty level. While these are not the only areas in the City of L.A. that have this combination of low income and high poverty levels, these are the most vulnerable communities within the sea level rise exposure zone.

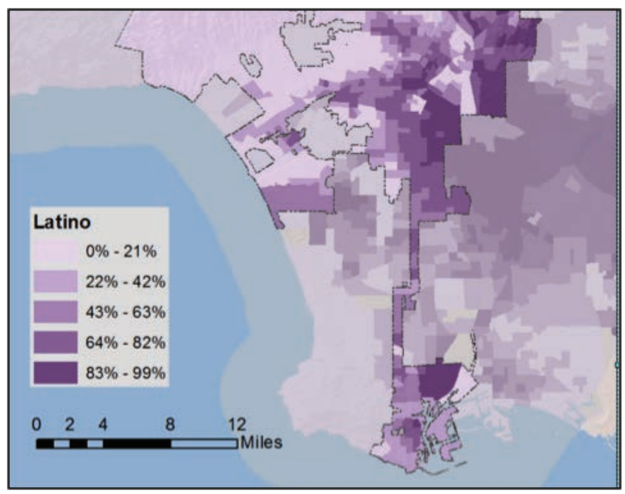
Studies of public health and vulnerability to disasters also indicate that minority populations tend to have lower capacity for responding to disasters and adapting to climate change than non-Hispanic whites. Other studies have shown that the likely reason for the correlation between race and lower adaptive capacity is the disproportionate amount of poverty and lower incomes among African Americans and Latinos compared to White/non-Hispanic segments of the population. In coastal communities within the City of L.A., there are very high concentrations of Latino populations residing in the eastern, low lying portion of San Pedro (closest to the inner Harbor/Port) and throughout Wilmington, as well as some small areas of Latino populations in Venice and El Segundo. African Americans are mainly concentrated in the interior of Los Angeles, but some higher concentrations reside in San Pedro, Wilmington and Long Beach (the latter is outside of the City of L.A.'s boundaries) (Figure 8).

Geography of Race in L.A. by Percent of Total Population

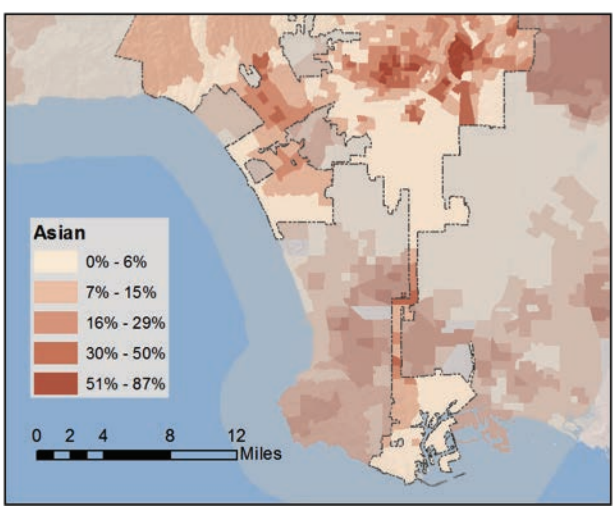
A. Percent African American



B. Percent Latino



C. Percent Asian



D. Percent Native American/Pacific Islander

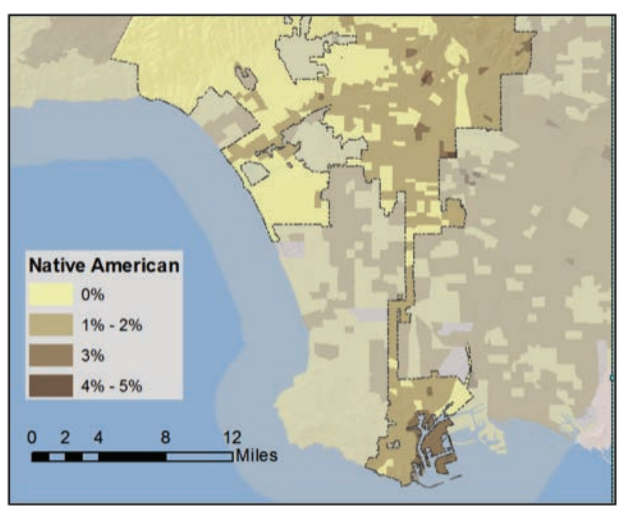


Figure 8: Figures showing the geography of race in Los Angeles by percentage of the total population. The boundaries of the City of Los Angeles are indicated by the black dashed line (Source: Census 2010).

Similarly, low education levels and linguistic isolation (defined by the U.S. Census Bureau, as a household in which no one over the age of 14 speaks English or speaks English less than "very well") leads to lower adaptive capacity by limiting the household's ability to obtain and understand emergency preparedness and response information. Census data in San Pedro and Wilmington show high proportions of Latino populations that are linguistically isolated. Identifying populations that are more vulnerable because of these factors (low education level, race and linguistic isolation) can inform emergency response planning for flooding and help to develop communication strategies to engage community members in the climate adaptation planning process.

Other vulnerable communities include segments of the population that may need special assistance in emergencies because of lack of mobility or other disadvantages. These include the elderly, homeless, those with physical or mental illness or disabilities, and those living in group quarters. An important first step in preparing special assistance for these populations during emergency situations is to document where they reside so first responders understand the extent of the need and can direct assistance appropriately when the time comes.

Beyond examining census data in isolation, in recent years, a number of tools and indices have been developed that identify communities' social vulnerability to various hazards. The social vulnerability index (SOVI), a method developed by Susan Cutter and colleagues at the University of South Carolina, integrates 32 census variables to create a picture of relative social vulnerability within a given region

Social Vulnerability Index (SOVI) Results for the City of L.A.

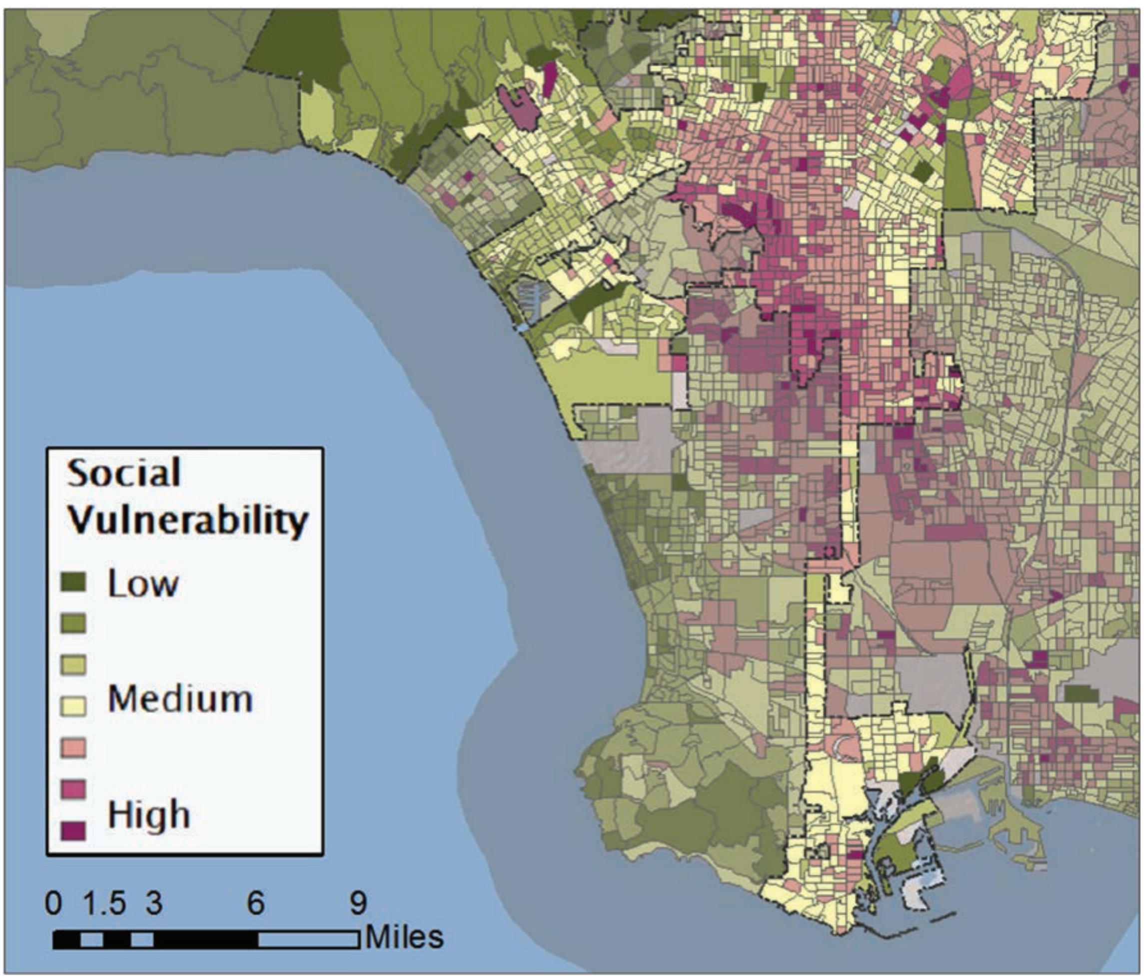


Figure 9: The social vulnerability index (SOVI) provides an integrated view of a population's social vulnerability. The index integrates 32 socioeconomic and demographic variables. (Source: Census 2000 data, Integrated summary provided by NOAA Coastal Services Center).

(Cutter et al. 2003). It does not integrate physical climate change factors, thus providing an objective snapshot of where the populations reside that are associated with low adaptive capacity and high sensitivity to hazardous events. Based on these data, portions of San Pedro, Wilmington and a portion of Venice show relatively high social vulnerability compared to the rest of the City (Figure 9).

The results of the integrated SOVI analysis provide the same snapshot of vulnerability as the analysis of specific census data sets. That is, the communities of Wilmington, Venice, and low-lying portions of San Pedro, seem to have the highest social vulnerability with respect to sea level rise impacts.

Other social characteristics presented by Ekstrom and Moser that indicate high vulnerability include housing type and control over living situation. Census data show a high proportion of older housing units, which may be more sensitive to flooding (e.g., less restrictive building codes, less flood-proofing), in Venice and in neighborhoods around the Port of Los Angeles. These same communities have a high proportion of renters (over 80% in Wilmington and eastern portions of San Pedro and 45 - 80% in Venice), who tend not to have the means or incentive to flood-proof their homes.

The social vulnerability assessment also reveals that a number of community services and supporting infrastructure are potentially at risk of impairment from short-term or long-term damage from flood events as sea level rises. These include impairment of drainage and treatment of wastewater and sewage, rapid emergency response, access to food and prescription medicines, risk of salinization to coastal groundwater reservoirs, access to and functionality of energy-related facilities, transmission and transformers, and important ecosystem services. Interruption of these services can have disproportionate impacts on residents who are more sensitive and have lower adaptive capacity for dealing with flooding as sea level rises.

This assessment thus allows the City to begin to identify adaptation and communication strategies that target these populations. Strategies can include: documenting where these vulnerable populations reside, so first responders understand the extent of the need and can direct assistance appropriately when the time comes; conducting workshops and preparing other public outreach materials in multiple languages; and, given low education and high poverty levels, using alternative educational/informational methods that do not require literacy or internet access.

Economic Vulnerability Assessment

USC Sea Grant commissioned Dr. Dan Wei and Dr. Sam Chatterjee from the USC Price School of Public Policy to conduct a preliminary analysis of the potential economic impact of sea level rise on the City of L.A. (see Appendix 4 for full report).

In this study, the researchers analyzed temporary flooding in the coastal zone caused by extreme coastal storms (10-year and 100-year flood event scenarios) and sea level rise increase of 0.5 m from 2000 - 2050 and 1.4 m from 2000 - 2100. The study focused on the coastal regions within the City that are directly affected by coastal flooding events (Pacific Palisades, Venice/Playa del Rey, and San Pedro/ Wilmington).

Economic impacts evaluated in this study included property losses (building and content losses), as well as direct and indirect business interruption losses due to extreme coastal flooding events. Indirect business interruption losses included not only the multiplier (ripple) effects of the direct business interruption losses taking place within the City, but also the indirect effects to the City stemming from the losses to the coastal regions that are outside of the City but within the boundaries of L.A. County. Potential impacts to the transportation and utility systems were evaluated. Impacts caused by long-term and permanent beach area losses from sea level rise were not covered in this study.

The analysis in the study was performed based on the application of two modeling tools. HAZUS MH 2.1, the Federal Emergency Management Agency's (FEMA) standardized modeling tool for estimating potential losses from hazards, was used to evaluate the property damage to building stocks (including both buildings and their contents) and the direct business interruption losses in the flooding affected region. The Input-Output (I-O) model, one of the most widely used tools for analyzing regional impacts, was then applied to calculate the total business interruption losses based on the direct loss estimates from the HAZUS model.[6]

Based on the researchers' analysis, the potential direct building-related losses could be substantial. Direct property losses with respect to buildings include: 1) building repair and replacement costs (including both structural and non-structural damage); 2) building contents losses; and 3) building inventory losses. The results indicate that the expected general building losses increase with sea level rise and the severity of the flooding. For a 10-year flood event, the total building losses are $242.7 million under baseline conditions. The losses increase to $410.3 million in the 0.5 m sea level rise scenario, and to $714.9 million in the 1.4 m sea level rise scenario. For a 100-yr flood event, the building losses increase from $588.6 million under current conditions to $820.2 million and $1,441.3 million in the 0.5 m and 1.4 m sea level rise scenarios, respectively. Losses to residential buildings account for about 50% of the total losses. The other 50% losses are split evenly between the commercial buildings and the industrial buildings in all the scenarios except for the scenario of a 100-yr flood with 1.4 m sea level rise (Table 1).

Notably, and consistent with findings from the physical vulnerability assessment, the researchers found that flood events with the two sea level rise scenarios simulated in this study would only cause very limited impacts to the utility systems. According to their simulation, in the worst case scenario (the 100-year flood event in the 1.4 m sea level rise scenario), there are only moderate damages to two

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[7.] Please refer to the full study for more specific information on the modeling analysis tools utilized (see Appendix 4).

Category	Baseline Conditions 10-yr Flood	Baseline Conditions 100-yr Flood	0.5 m Sea Level Rise 10-yr Flood	0.5 m Sea Level Rise 100-yr Flood	1.4 m Sea Level Rise 10-yr Flood	1.4 m Sea Level Rise 100-yr Flood
Building Losses	$103.3	$260.9	$179.4	$364.4	$315.0	$649.9
Content Losses	$132.6	$312.1	$219.6	$435.5	$380.2	$759.9
Inventory Losses	$6.8	$15.5	$11.3	$20.3	$19.7	$31.5
Total Building Losses	$242.7	$588.6	$410.3	$820.2	$714.9	$1,441.3

Table 1. This table presents the summary results of general building losses in millions of 2010 $US. (Table from Wei & Chatterjee Economic Vulnerability Assessment, Appendix 4).

Category	Baseline Conditions 10-yr Flood	Baseline Conditions 100-yr Flood	0.5 m Sea Level Rise 10-yr Flood	0.5 m Sea Level Rise 100-yr Flood	1.4 m Sea Level Rise 10-yr Flood	1.4 m Sea Level Rise 100-yr Flood
Output Losses	$3.4	$7.4	$5.8	$10.5	$9.1	$21.9
Income Losses	$2.3	$4.9	$3.8	$6.6	$5.9	$13.6
Employment Losses	24	52	41	74	64	158

Table 2. This table presents the summary of business interruption losses in millions of 2010 $US (output/income losses) and number of jobs (employment losses). (Table from Wei & Chatterjee Economic Vulnerability Assessment, Appendix 4).

wastewater treatment facilities and three oil refineries. The simulations indicate no damages in all the scenarios for other critical lifeline facilities, including water, natural gas, and electricity. In examining business interruption losses, the simulation suggested that for a 10-year flood event, the total output losses (i.e., total business interruption losses) increase from $3.4 million under current conditions to $5.8 million in the 0.5 m sea level rise scenario, and to $9.1 million in the 1.4 m sea level rise scenario. For a 100-year flood event, the output losses increase from $7.4 million under current conditions to $10.5 million in the 0.5 m and $21.9 million in the 1.4 m sea level rise scenarios (Table 2). The impacts to income and employment have similar patterns across the scenarios. The major reason for the relatively low business interruption losses caused by the coastal flood events is that over 95% of the damaged buildings are residential buildings, rather than buildings of producing sectors. Another reason for the relatively low business interruption losses is the HAZUS model has taken into consideration likely production recapture. This refers to the ability of businesses to recapture lost production through overtime and extra shifts until operational capability is restored.

The researchers emphasize that the potential economic impacts of sea level rise to the City in their analysis should be considered to be on the conservative side. The analysis only focuses on the potential impacts from the temporary flooding in the coastal area due to extreme coastal storms, and how those impacts can be amplified by sea level rise. Any impacts caused by long-term and permanent coastal erosion and beach area losses were not covered in this study. Also, the researchers did not perform further economic impact analysis on the potential damages to the transportation system. While the preliminary simulation results indicated there are minimal impacts to the transportation system in the City, analysis under the Physical Vulnerability Assessment found that city roads are vulnerable to flooding, inundation, and groundwater inflow. Further economic studies to assess potential impacts on tourism, transportation systems, goods movement, and the regional economy would help to elucidate a more robust picture of potential impacts. At the same time, addressing the impacts of which we are aware could be viewed as strengthening resilience and therefore maintaining a strong economic climate in Southern California.

Ecological Vulnerability Assessment

Most of the coastal zone in the City of L.A. is highly urbanized. The vulnerability of the least urbanized areas such as open space areas, parks or recreation centers, was assessed in the physical vulnerability assessment conducted by ICLEI (Appendix 2). While most of the beaches along the coast, with the exception of Cabrillo Beach, fall within city lines, these are primarily managed by L.A. County's Department of Beaches and Harbors. Therefore, these resources were not analyzed directly in this vulnerability assessment. We anticipate that these resources will be studied more thoroughly when the planning process is expanded to include other coastal cities and L.A. County, through collaboration with LARC and coastal cities.

However, it is necessary to highlight one very important ecological asset located within City boundaries: the Ballona Wetlands Ecological Reserve. Ballona Wetlands Ecological Reserve is located between Marina del Rey and Playa Del Rey (the del Rey bluff) at the estuary of Ballona Creek (Figure 10). It is a 600-acre ecological reserve mostly owned by the State of California with a portion of the site in unincorporated L.A. County and the rest in the City of L.A. Elevation varies and ranges from 0 to 25 feet above sea level. Remnant areas of the wetland complex also include Del Rey Lagoon, Ballona Lagoon, Marina del Rey, Oxford Basin, and the Venice Canals.

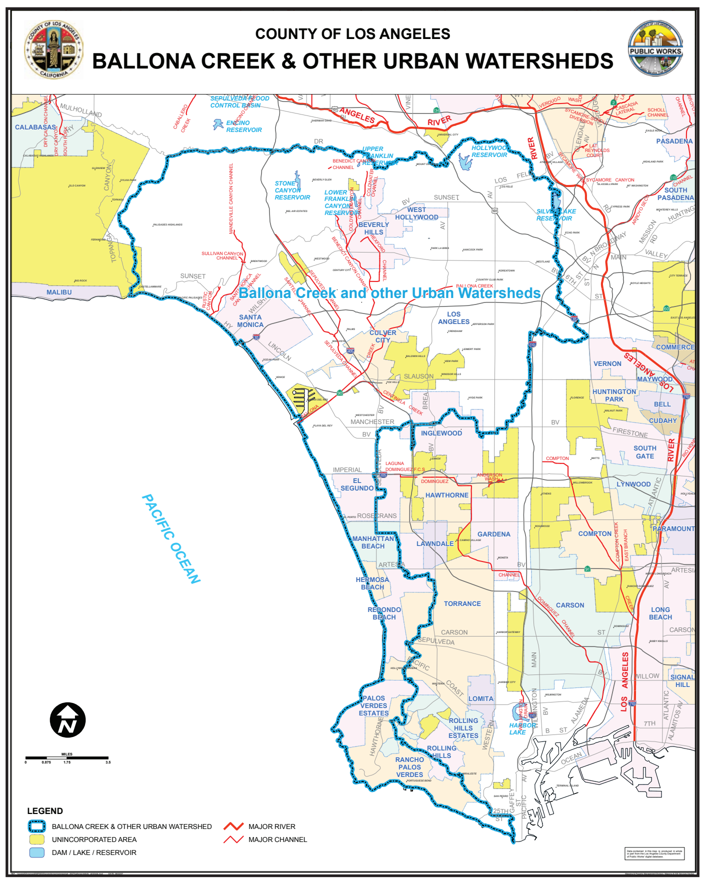

Figure 10: Map of the Ballona Creek Watershed. (Map courtesy of L.A. County Department of Public Works: http://ladpw.org/wmd/watershed/bc/).

The Ballona Wetlands is the largest remaining coastal wetland within urban L.A. County and is an ecological treasure. It supports a range of habitats and functions, including estuarine-dependent plants and animals and creates opportunities for aesthetic, cultural, recreational, research and educational uses by people throughout the region.

Researchers from Loyola Marymount University and the Santa Monica Bay Restoration Foundation (SMBRC), with funding from the Environmental Protection Agency's Climate Ready Estuaries Program, recently conducted a study to understand the climate change implications for Ballona Wetlands Restoration (Bergquist et al. 2012). This included an analysis of the impacts of 0.5 m and 1.4 m sea level rise with a 100-year storm scenario.[7]

It was determined that an increase in frequency, duration, and intensity of storm events would cause flooding over the current flood control levee structures that divide Ballona Creek from the

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8. *Climate Change Implications for Ballona Wetlands Restoration* study was not funded by the City of L.A. or USC Sea Grant; thus, it was not included in the appendix of this report. If readers are interested in this research, the study report can be accessed at http://www.santamonicabay.org/ballonarestoration.html. For further information, contact USC Sea Grant (seagrant@usc.edu) or SMBRC (http://www.santamonicabay.org/).

Reserve. The levees are not currently sufficient to support a 100-year storm event. This flooding could cause significant impacts to the habitats currently within the Reserve. Furthermore, extreme wet weather will cause additional flooding in developed areas and roadways adjacent to the site boundary that are below sea level and currently experience flooding in wet weather conditions (e.g. Culver Boulevard and Playa Del Rey).

Ballona Wetlands Ecological Reserve. (Photo credit: Lisa Fimiani, http://www.cooperecological.com/BallonaBirds.htm).

Additionally, the current western wetland habitats of the Reserve receive muted tidal flooding via self-regulated tide gates. Sea level rise would reduce the functionality of these gates, resulting in altered hydrology and tidal influence. Significant sea level rise would prevent the tide gates from functioning at all and would allow no tidal influence to remain to the wetland habitats. This altered hydrology and freshwater influence would have significant effects on the habitat types, salinity, and current ecosystem of the area. To alleviate the predicted impacts of sea level rise on the restored wetlands, planners and land managers may want to consider a restoration alternative that can accommodate the transgression of habitats upslope.

Although the City of Los Angeles does not manage Ballona Wetlands, this wetland is an important ecological resource for the City, which provides a plethora of ecosystem services including, but not limited to, biological productivity energy flow, nutrient cycling, foraging, nursery, and sheltering and resting places for wildlife, sediment accretion, and wave attenuation. Another important and well-known function of the wetlands is water purification such as infiltrating and thereby treating runoff and stormwater from the watershed upstream. As such, it is in the interest of the City to ensure that the wetland is protected and that it is involved in identifying any adaptation strategies and plans.

Moving Forward - Guidance for Developing Adaptation Measures

The main purpose of this report is to provide information on the vulnerabilities the City of L.A. currently faces and may face in the future due to sea level rise. Understanding these vulnerabilities is an important first step toward preparing to meet the challenges of climate change. The next milestone is to begin to identify appropriate adaptation strategies. To help the City of L.A. move forward on this next step, in this section, we review several important considerations for the development of adaptation strategies and provide a matrix of possible coastal adaptation strategies.

Considerations for Development of Adaptation Strategies

Invest in a Strong Foundation for Climate Adaptation

Climate adaptation is a complex process, involving decision-makers at all levels of government (even if the focus of adaptation is a local community), as well as in civil society and the private sector. As we have noted throughout this study, we advocate a model of "adaptive adaptation planning." This means that adaptation planning is not a one-time effort; it requires periodic updates of information to correspond with the latest scientific understanding and needs to include this new information in the decision-making process. Ideally, the process goes far beyond technical and structural actions, and involves policy changes, creative financing, capacity-building among key staff and decision-makers, and effective public engagement.

At this early stage in sea level rise adaptation, it is important to lay a strong foundation for such an ongoing planning process. Elements of such a foundation could include:

- Acquiring the best available science and developing a formal strategy for regular updates of scientific information in planning and decision-making procedures;

- Investing in engineering and geotechnical studies for vulnerable assets that require technical approaches (e.g. as noted in the physical vulnerability assessment for Bureau of Sanitation, engineering studies that include assumptions about flood depth and duration would help to refine an evaluation of adaptive capacity);

- Conducting robust and thorough risk analyses;

- Assessing and ascertaining the information needs of local government departments, agencies, commissions, and boards as well as their capacity and willingness to integrate sea level rise vulnerability and social vulnerability into their planning, budgetary, and policy decisions;

- Initiating 'soft' adaptation strategies, such as staff training, developing trusting relationships with community organizations, identifying and supporting local champions in government, business, and civic organizations, and building governance structures across sectors and jurisdictions to increase adaptive capacity, foster buy-in, and generate the necessary institutional and political support (Cicin-Sain et al. 1998);

- Creating opportunities to foster periodic, meaningful public engagement that gathers information about affected neighborhoods and communities' concerns, vulnerabilities, and constraints; to educate communities about risks related to climate change; and to jointly develop strategies that are designed to meet current and future needs. Such engagement should also offer opportunities for communities to express any concerns and needs around procedural justice and equitable burden sharing and outcomes of adaptation.

Define Clear Adaptation Goals

Most adaptation planning processes to date in the U.S. have been undertaken without clearly defining goals and "success." Goals could focus on both procedural and outcome intentions. Failing to define success has several important implications directly relevant to local decision-making: it is difficult to prioritize and justify expenditures when a goal or purpose is not identified, and it is politically difficult to justify when people cannot visualize the intended outcome (even if just a temporary outcome). It is also difficult to show that a strategy made a positive difference or to measure progress toward the desired goal. The City would therefore be well advised in not just stating a "pie in the sky" goal, but to spend concerted effort both internally and with community involvement to define desirable and feasible outcomes of adaptation. Effective strategies flow more easily from clearly identified goals.

Develop Clear Prioritization and Selection Criteria for Choosing Among Possible Adaptation Strategies

A corollary to the need for a clearly defined goal is the establishment of criteria that help select options from the universe of potential adaptation strategies. Such criteria would help with prioritization when budgets, timelines, technical considerations, and social concerns and political feasibility inevitably place constraints on preferred solutions. Again, such criteria are best selected in consultation and agreement with affected stakeholder communities, as exclusion from defining how decisions will be made can lead to political resistance and lack of buy-in. That, of course, could endanger the ultimate success of the entire effort.

Continue "Adaptive Adaptation Planning" Approach

As stated in this report, the use of a 10-year flood scenario with sea level rise was a pragmatic choice in light of the best available, most defensible physical science at this time. Ten-year floods, however, are not the common planning standards (100- and 500-year floods are benchmarks for FEMA, for example). In addition, sea level rise scenarios may change over time; as the science advances, so will decisions about land use, the level of coastal protection, and the demographic and socioeconomic situation of coastal populations. Thus, the City would be well advised to closely track scientific developments and update the current vulnerability assessment as needed to ensure its adaptation plans and preparedness measures are up-to-date.

Expand Partnerships in Developing Adaptation Options

Much adaptation that addresses social vulnerability and public concerns requires close collaboration with the affected groups. Thus, to the extent collaborative ties are not yet established, it is important to establish working relationships with marginalized groups or organizations that represent them, and to expand the network of adaptation stakeholders to include those already working on increasing community resilience in the face of disasters. Doing this early in the process helps to build the trust and long-lasting bonds that will be needed to make difficult choices.

LARC
Los Angeles Regional Collaborative for Climate Action and Sustainability

The Los Angeles Regional Collaborative on Climate Action and Sustainability (LARC) is an important partner of the City's effort and will serve to help expand partnerships within the region by applying the techniques and strategies to the hazards posed in the other coastal communities and municipalities through greater Los Angeles.

Matrix of Potential Coastal Adaptation Strategies

The matrix provided on pages 60-76, developed by Lesley Ewing (California Coastal Commission) and Dr. Reinhard Flick, outlines some of the most common coastal adaptation techniques available to coastal communities. This matrix is divided into adaptation techniques that help communities:

- Avoid hazards;
- Move development away from hazards;
- Move hazards away from development;
- Provide barriers between hazards and development; and
- Flood-proof.

For each of these sub-categories, information is provided on the details of the technique, the spatial and temporal scales associated with the technique, the ability to adjust the technique depending on changing conditions (referred to in the matrix as “adaptive capacity”), the party or agency that would be responsible for managing the adaptation technique, a relative approximation of costs (e.g. high, medium or low), and general comments.

This matrix is intended to provide insight into the available options for communities and help the community better understand the described technique. In considering any of these options for application in the adaptation planning effort, each should be analyzed for the site-specific conditions, environmental concerns, technical feasibility and compatibility with existing constraints. Clearly, not all techniques are available for all situations; rather, this matrix is meant to provide a range of adaptation response options.

A Google Earth image of heavy rock armoring along PCH in Malibu. Rock armoring is one of the many adaptation strategies described in the matrix on pages 67-83.

Avoid Hazards

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Land Acquisition	Fee Simple Acquisition	One or more lots	Short/ Long-term	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	High	Provides greatest control over land use and hazard response. Land can be purchased from willing sellers or by governments using eminent domain.
	Conservation Easements	One or more lots	Short/ Long-term – lessen with time	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	Low to Moderate	Provides less control than fee simple acquisition. Can be part of a permit action. Land can be purchased from willing sellers.
	Transfer Development Credit	Jurisdiction, Region	Moderate/ Long-term	Yes	Government, Geologic Hazard Abatement District	Low to Moderate	Provides fee simple acquisition of high hazard lots. Takes time to set up TDC Program and develop criteria for hazardous lot acquisitions. Costs to administer are low. Acquisition costs paid by developers. Cost of coastal land may make program infeasible.

Move Development Away from Hazards

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Land Acquisition	(see above)						
Managed Retreat		One or more lots	Moderate/ Long-term – Increase with time	Yes	Government, Homeowner Association, Geologic Hazard Abatement District	Moderate	Best if included in initial design to allow phased removal of development. Costs paid by owners with or without government or non-profit contributions.
Rolling Easements		One or more lots	Moderate/ Long-term – Increase with time	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	Moderate to high	Easements acquired by government or NGO. Costs to acquire will be likely to vary indirectly with risk.
Setbacks		One or more lots	Moderate/ Long-term – Lessen with time	Not normally	Government, Homeowner Association, Geologic Hazard Abatement District	Low	Setback provides protection from hazard until setback is gone. Variable cost to developer and/or homeowner - foregoing use of some portions of the property.
Elevation		One or more lots	Moderate/ Long-term – Lessen with time	Not normally	Government, Homeowner Association, Geologic Hazard Abatement District	Low to moderate	Elevation provides protection from ocean hazards. May introduce other risks from slope instability, etc. Need to include access and utilities for long-term effectiveness.

Move Hazards Away from Development

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Maintain or Restore Natural Sand Supply	Remove dams	Region/ watershed	Long time/ Long-term	No	Government, Water Board, Non-Governmental Organization	High to Very High	Only effective if stream flows are sufficient to move sediment to the coast. Raises difficult engineering issues if sand must be moved to the coast. Involves multiple jurisdictions. But, dam removal is occurring with as yet unknown benefits.
	By-pass sand around dams	Region/ Littoral cell	Moderate/ As long as continued	Yes	Government, Water Board	High to Very High	Only effective if stream flows are sufficient to move sediment to the coast. Raises difficult engineering issues if sand must be moved to the coast. Feasibility for large volumes is unlikely, since sand transportation cost to the coast is high, and may have unacceptable traffic and air quality impacts as well as barriers to truck access at the beach.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Maintain or Restore Natural Sand Supply	Harbor dredging or By-passing	Region/ Littoral Cell	On-going/ As long as continued	Yes	Government, Harbor district	Moderate to High	Dredging is often necessary for harbor maintenance. Historically, this has been a major source of nourishment sand in certain locations. Testing and placing sand on beaches often adds only a marginal cost.
Improve or Augment Sand Supplies/ Beneficial Reuse of Sand	Interrupt rip currents	Local	Long time/ As long as continued	Yes	Government	High	Complex engineering issue. Unlikely to be feasible even for fixed rip currents located at structures or geomorphic features. This is an unproven idea likely not suitable to high tide-range environments with public opposition to surf-zone structures and likely high cost. Effects would be similar to offshore breakwaters with less guarantee of success.
	Nourish with coarser sand than native	Multiple lot/ Region	Moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	High	This approach is widely used by engineers to increase the lifetime of beach replenishment projects. Feasibility depends on availability of suitable sand sources.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Improve or Augment Sand Supplies/ Beneficial Reuse of Sand	Canyon Interceptors	Region/ Littoral Cell	Long time/ As long as continued	Yes	Government	Very High	Complex and unproven engineering concept that would need detailed studies to determine feasibility. Likelihood of success is not knowable since the amount of offshore sand loss in canyons versus offshore losses along the beach is unknown.
Sources of Beach Material	Offshore Sand	Multiple lot/ Region	Short to moderate/ As long as continued	Yes		Moderate to High	Costs very dependent on scale --- mobilizing the dredge is a fixed cost regardless of volume delivered.
	Reservoir and Debris Basins	A few lots to multiple lots	Moderate/ As long as continued	Yes		High to extreme	Sand testing important. Sorting and handling costs can be large. No unit savings on transport costs with larger volumes moved. Feasibility is unlikely for large volumes, since sand transportation cost to the coast is high, and may have unacceptable traffic and air quality impacts as well as barriers to truck access at the beach. Involves multiple jurisdictions.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Sources of Beach Material	Back-passing	Region/ Littoral Cell	Moderate/ As long as continued	Yes		Moderate to high	Sand quality normally compatible with existing beach material. This method holds promise since fixed plants can be used and engineering basis is relatively simple.
	Cobbles	A few lots to multiple lots	Moderate to long/ As long as continued	Yes		High to Very high	Cobble sources are limited. Poses environmental concerns for beaches without existing cobble.
	Crushed glass	A few lots to multiple lots	Moderate to long/ As long as continued	Yes		Very high	Crushed glass would need to be tumbled to round off sharp edges. Handling costs would be high.
Retention of Sand/Beach Material	Beach Berms	A few lots to multiple lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District	Low	May need to be repeated multiple times a season. Source of sand should be identified. State sovereign land issues arise.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Retention of Sand/Beach Material	Groins	Region/ Littoral Cell	Long/ Moderate to long	Yes	Government, Homeowners Association, Geologic Hazard Abatement District	Very high	Engineering issue. Pre-fill likely to be required to minimize downcoast impacts. Sensitive to orientation of waves and sediment supplies and transport direction and magnitude. Public opposition to structures is an issue that needs to be solved.
	Jetties	Region/ Littoral Cell	Long/ Long	No	Government, Harbor District	Very High	Engineering issue. Normally only used at river mouths and harbor entrances. Public opposition to structures is an issue that needs to be solved.
	Dune Nourishment	A few lots to multiple lots	Moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, individual		Limited application in CA, since few beaches depend on dune storage of sand, especially in southern California.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Retention of Sand/Beach Material	Breakwaters	Region/ Littoral Cell	Long/ Long	No	Government, Harbor District	High	Proven effective and feasible. Public opposition to structures, especially ones that directly impact surfing, is an issue that needs to be solved. Presents potential swimming and boating safety hazards. Construction cost is high, but benefits are long-term. Santa Monica Breakwater is about 80 years old and functions well with little maintenance.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Perched beach	A few lots to multiple lots	Long/ Long	No	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, individual		May require frequent re-nourishment. Also can produce negative consequences if large storm waves remove sand shoreward of perching structure that then cannot migrate back upslope onto the beach. Can modify offshore slope and pose a danger to swimmers. Also reduces circulation in the perched beach area, leading to water quality and sand contamination issues.
	Artificial seaweed	Region		Possible	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low to high	Never shown to be effective in field tests, and almost certainly cannot be effective due to low mass in high wave and tide-range environment. Clean up costs can be high.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Artificial headland	Region/ Littoral Cell		No	Government	Very high	Complex engineering; experimental effort. Likely to be effective and feasible if designed to function like a groin or jetty. Public opposition to structures, especially ones that impact beach access or surfing, is an issue that needs to be solved.
	Delta augmentation	Region/ Littoral Cell		Possible	Government	Very high to extreme	Complex engineering; experimental effort unproven in practice. Would require large additions of material spread over large area, and may require multiple additions of material.
	Active Beach dewatering	A few lots to multiple lots	Short to moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Moderate	Principle is sound. Would be a localized effort. Only financially feasible if co-located with other active dewatering, such as desalination plants. May have consequences on other beach communities downcoast. No long-term results known in the reviewed engineering literature.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Passive beach dewatering	A few lots to multiple lots	Short/ As long as maintained	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Passive beach dewatering has never been successfully demonstrated.
	Floating breakwaters	Region/ Littoral Cell	Short to moderate/ Moderate	Slightly	Government	High	Complex engineering, but proven principle. Most uses have been for temporary protection or ship deployment.
	Multi-purpose reefs	Region/ Littoral Cell	Long/ Moderate to long	No	Government	High to very high	Complex engineering; experimental efforts. Costs to remove have proven to be very high (i.e., Pratte's Reef). Engineering criteria conflict for dual-use surfing-shore protection reefs because of high tide range in CA. Reef must be low to enable surfing at most tide elevations, but high to protect property during high wave and tide events.

Barriers between Hazards and Development

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Revetments	Rock	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Public opposition to structures, especially ones that impact beach access is an issue that needs to be solved.
	Concrete units	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Also, public opposition (see above).
	Gabions	One or more lots	Moderate/ Short	Possible, but not likely	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Moderate to high	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Poor long-term performance due to weaknesses in netting. Also, public opposition (see above).

Barriers between Hazards and Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Seawalls	Vertical tie-back walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).
	Gravity walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Also, public opposition (see above).
	Cantilever walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).

Barriers between Hazards and Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Miscellaneous	Native vegetation	One or more lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Not useful by itself on the CA moderate-wave energy and high tide-range coast. Normally used as part of a larger sand nourishment project to stabilize back shore.
	Sea cave fills	One or more lots	Moderate/ Moderate	No	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low to moderate	Can slow erosion in areas with bluff undercutting or cave formation. Proven feasible and cost effective. Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).
	Surface & ground water controls	One or more lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Normally used as part of a larger project. Proven feasible and effective (even necessary) to reduce or prevent sudden cliff collapse. Not usually considered a form of beach sand erosion control.

Flood Protection

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Building Protection	Elevate structure	Individual structures	Moderate/ Long-term – Lessen with rising sea level	Not unless part of initial design	Building Owner	Low to Moderate	Elevation can provide protection from flood water if building is high enough. Often includes lower stories with break-away walls that can become floating debris.
	Sand Bags	Individual structures	Short term/ Long-term – lessen with rising sea level	Height will depend on bag stability	Building Owner	Low	Sand bagging can provide short-term protection. Requires warning of impending flood and ability for rapid response prior to the flood event. Interrupts building access while in use.
	Storm shutters	Individual structures	Moderate/ Long-term	Moderate	Building Owner	Low	Storm shutters can be available to cover all openings (normally doors and windows). Requires warning of impending flood to secure all entrances. Interrupts building access while in use.

Flood Protection (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Electrical Equipment	Elevation	Individual structures	Short term/ Long-term	Depends on building height	Building Owner Building Code	Low	Elevation of electrical equipment can insure continuity of power during and after a flood provided equipment can be located higher than flood levels
	Vaults	Individual structures	Short-term/ Long-term	None	Building Owner	Low to Moderate	Vaults would protect electrical equipment from flooding; would need routine maintenance to insure effectiveness when needed.
	Pumps	Individual structures	Short-term/ Moderate	None	Building Owner	Moderate	Useful to remove flood waters from sensitive areas. Require a reliable power source and location to which water can be pumped.

Flood Protection (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Tunnels	Permanent Storm Barriers	Individual systems	Moderate/ Long-term – Lessen with rising sea level	Low	Community/ Project Manager	Moderate	Storm barriers would need to cover all openings – tunnel openings, ventilation, etc. Requires warning of impending flood to secure all entrances. Interrupts access and tunnel use while barriers are in place. Depending upon storage method, they can be an annoyance to travelers when not in use.
	Temporary Entrance covers	Individual structures	Short term/ Long-term – lessen with rising sea level	Low	Building Owner	Low	Entrance covers (sand bags, inflatable plugs, etc,) can provide short-term protection. Requires warning of impending flood and ability for rapid response prior to the flood event. Interrupts tunnel access while in use.

Conclusion

By commissioning these studies and implementing the planning process, the City of L.A. has shown leadership by confronting climate change, and sea level rise specifically, proactively rather than reactively.

We have summarized the findings from a coastal issues report, and three commissioned vulnerability assessments that examined the potential social, physical and economic challenges the City of L.A. may face in the future due to accelerated sea level rise. We also discuss the importance of the Ballona Wetlands Ecological Reserve to the City and the region. We close by providing guidance for moving ahead with identifying the range of appropriate adaptation strategies that will build the City's resilience. The findings in this report, while preliminary, are meant to provide the City with a starting point for planning.

Although the results of this study highlight some of the City's physical, social and economic vulnerabilities, the City is now well poised to begin planning now and not in 20 years when many of the impacts of sea level rise will already be felt. We encourage the City to continue its efforts and to embrace the "adaptive adaptation planning" process in which new science and information is continuously assessed and incorporated. This will allow the City to plan in the efficient manner necessary to tackle the challenges. We also encourage the City to continue its strategy to include stakeholder and public input to the greatest extent possible. With broad public support and a coherent and continuous strategy for confronting change, Los Angeles will continue to serve as a model for other large metropolises facing a changing future.

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Ms. Grifman is Associate Director of the USC Sea Grant Program. Her background in marine and environmental policy underscores work administering the NOAA Sea Grant Program at the University of Southern California. As Associate Director, she manages the program's research, outreach and education portfolios, in addition to working with stakeholders at state, local and federal levels. Her responsibilities include improving public awareness of Sea Grant's mission and accomplishments and developing programs and partnerships to foster the connections between science and policy. Ms. Grifman received her B.A. and M.A. (Political Science) from the University of California Santa Barbara. Her major interests include marine policy development and implementation, and public education.

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Ms. Ladwig has more than 15 years of professional experience writing in the areas of science and technology, highlighting their impacts on human lives. She has written about climate change and other environmental issues since 1991. As principal of Science Communications International, senior writer at the Wisconsin Alumni Research Foundation, and science communicator at the universities of California, Hawaii, and Wisconsin, she has made the complexities of scientific discovery and new technologies accessible for a variety of audiences. Her work as a journalist and as a corporate communications writer have garnered state and national awards, including a nomination from the Milwaukee Press Club for best feature writing. Ms. Ladwig has a master's degree in journalism from Northwestern University and a bachelor's degree from the University of Wisconsin-Madison.

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Dr. Reinhard E. Flick earned a BS in Physics from Cooper Union of the Advancement of Science and Art in New York City and a PhD in Oceanography from Scripps Institution of Oceanography, University of California San Diego. He has 43 years of experience studying nearshore processes including flow-induced electric currents, waves, tides, sea level, and beach and cliff erosion. He has authored over 50 scientific papers, several book chapters, and the 1997 World Book Encyclopedia entry on Tides. He has served as an expert witness on several large tidal boundary disputes, including U.S. v. Alaska in the U.S. Supreme Court, and in two murder cases. Dr. Flick is a certified SCUBA diver and sailing instructor, holds a U.S. Coast Guard 100-ton Inland Masters license and amateur radio license K6REF.

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Appendices

The University of Southern California Sea Grant Program assembled an interdisciplinary team of experts to identify the potential exposure to and vulnerabilities of sea level rise in the City of Los Angeles. The authors are recognized locally, nationally, and internationally as experts in their respective fields of study. The following reports include a review of the coastal and shoreline assets within City boundaries and three vulnerability assessments examining physical, social and economic vulnerabilities to sea level rise and coastal storm events. While all are appendices in support of the overall summary report, each can be considered a standalone study. Instructions on how to access the appendices is provided in the information below.

Appendix 1: City of Los Angeles Coastal Issues Related to Future Mean Sea Level Rise by Dr. Reinhard E. Flick, Principal Oceanographer, TerraCosta Consulting Group, Inc.

Appendix 2: Physical Vulnerability Assessment Findings for the City of Los Angeles by Brian Holland and Melissa Higbee, ICLEI - Local Governments for Sustainability U.S.A.

Appendix 3: Sea-Level Rise Impacts and Flooding Risks in the Context of Social Vulnerability: An Assessment for the City of Los Angeles by Dr. Julia A. Ekstrom and Dr. Susanne C. Moser, Susanne Moser Research & Consulting

Appendix 4: Economic Impact of Sea Level Rise to the City of Los Angeles by Dr. Dan Wei and Dr. Sam Chatterjee, USC Price School of Public Policy, Center for Risk and Economic Analysis of Terrorism Events

Access at: http://www.usc.edu/org/seagrant/research/sea_level_rise_vulnerability.html

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