Sea Level Rise Adaptation Strategy for San Diego Bay

January 2012

Prepared by ICLEI-Local Governments for Sustainability for the project's Public Agency Steering Committee, with the support of The San Diego Foundation.

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TABLE OF CONTENTS

List of Figures

List of Tables

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Cover, top: Kristen Goodrich
Cover, 2nd: Port of San Diego
Cover, 3rd: Flickr, User: Jeff Kubina
Cover, bottom: Lisa A. Cox
Figure 4.1: Lisa A. Cox
Figure 4.2: Wikimedia Commons, User : Tewy
Figure 4.3: Kristen Goodrich
Figure 4.4: San Diego Coastkeeper
Figure 4.5: Kristen Goodrich
Figure 4.6: San Diego Coastkeeper
Figure 4.7: Kristen Goodrich

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EXECUTIVE SUMMARY

The San Diego region is a center of economic activity, diversity, and culture in Southern California. The region has long been known for its remarkable landscape, biological diversity, economic prowess, and prestigious academic institutions, and many have acclaimed it as one of the nation's most livable communities. While the region's growth and status as an economic center is projected to continue for the foreseeable future, real threats to this status are posed by the impacts of climate change. Among these expected climate change impacts, perhaps none poses a greater risk than sea level rise. This century, elevation of average high tide could change by as much as 1.5 meters, or approximately five feet.

San Diego is a region defined by its relationship with the coast and heavily invested in its coastal communities. San Diego Bay, in particular, is a treasured asset, the anchor of the regions' tourism and military economies. With so much at stake, it is critical to begin considering policy responses long before the worst impacts associated with sea level rise are projected to occur, because developing and implementing solutions will require unprecedented collaboration with long lead-times, and because infrastructure is being built now that will be vulnerable to impacts in the future. To begin, a Public Agency Steering Committee comprised of staff from the five bayfront cities, the San Diego Unified Port District, and the San Diego County Regional Airport Authority came together to develop this *Sea Level Rise Adaptation Strategy for San Diego Bay* (Adaptation Strategy). The Adaptation Strategy consists of two primary components: a Vulnerability Assessment that evaluates how community assets could be impacted by sea level rise, and Recommendations for building the resilience of those community assets.

The Adaptation Strategy was prepared by ICLEI-Local Governments for Sustainability through a collaborative, regional stakeholder process that included most of the public agencies and private sector representatives with a major interest in the future of San Diego Bay. Over the course of multiple workshops, stakeholders and technical advisors developed common assumptions and consensus-based recommendations that should form the basis of the region's climate adaptation planning going forward. The Adaptation Strategy is a living document that can be implemented by local agencies and re-evaluated as new information becomes available in the coming years.

Sea Level Rise Scenarios and Impacts

Greenhouse gas emissions from human activities are trapping heat within the Earth's atmosphere, leading to a well-documented warming trend in average global temperatures. As the Earth warms, oceans undergo thermal expansion and sea levels rise; over the past century, sea level in San Diego has risen by just under one inch per decade on average. The scientific community expects the rate of sea level rise to increase as higher concentrations of emissions lead to faster warming and the melting of glaciers into the ocean. Rising seas can lead to widespread flooding and erosion in low-lying areas, as well as impacts such as shifting habitats and rising water tables.

While these concepts are widely agreed upon, there remains significant uncertainty around the timing and severity of sea level rise, particularly in the latter half of the century. The State of California the use of projections of between 10 and 17 inches (26 to 43 cm) in 2050 and of 31 to 69 inches (78 to 176 cm) in 2100.[1] The Adaptation Strategy project utilized sea level rise assumptions on the upper end of this range to ensure a risk-averse approach to planning.

Vulnerability Assessment Findings

The Vulnerability Assessment evaluates where and when sea level rise impacts may occur, as well as the extent to which exposed community assets would be impaired by an impact and whether they may be able to cope or adapt on their own. The assessment was conducted through a combination of modeling, mapping, and intensive consultation with the project's Technical Advisory committee. Key findings of the Vulnerability Assessment include:

- In the next few decades, the greatest cause for concern will be an increase in the kind of flooding that the region already experiences due to waves, storm surge, El Nino events, and very high tides. When planning for this period, an emphasis should be placed on preparing for more common and more severe extreme events.

- Starting around mid-century, the Bay may become more vulnerable to regularly-occurring inundation of certain locations and assets, some of which are being planned and built today. As a result, this longer-term risk of inundation should be a consideration in today's decision-making.

- The most vulnerable sectors in the community include stormwater management, wastewater collection, shoreline parks and public access, transportation facilities, commercial buildings, and ecosystems.

[1] State of California, Sea Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), *Sea Level Rise Interim Guidance Document.* October 2010.

Primary Vulnerabilities by Sector

Ecosystems and Critical Species

- Bay ecosystems, which provide habitat for many endangered and threatened species, are extremely vulnerable to **inundation** that is expected to result in habitat shift. These shifts could cause the loss of irreplaceable habitats for critical species in many areas.
- Upland areas are vulnerable to **erosion**, and subtidal ecosystems are threatened by erosion of upland areas when it results in degraded water quality.

Contaminated Sites

- Hazardous waste sites are highly vulnerable to **flooding and inundation** as storage tanks in the area could be opened or moved, or motors and pumps could be impaired thus releasing contamination into flood waters or area soils.

Stormwater Management

- In all scenarios, storm sewers are highly vulnerable to **flooding and inundation** in the Bay due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas.

Wastewater

- Sanitary sewers in low-lying locations will be vulnerable to **floodwater inflow** which could exceed their capacity, potentially resulting in discharge of wastewater to the Bay.
- The entire wastewater collection system in the planning area will be vulnerable to **inundation** impacts.

Potable Water

- Above-ground water distribution components such as valves, meters, and service points will be vulnerable to **flooding and inundation**.

Energy Facilities

- Above-ground electricity transmission and distribution in limited areas will be vulnerable to **erosion**, particularly after 2050 and during major storm events. Erosion could undermine infrastructure, causing outages or safety issues.
- Above-ground electricity transmission and distribution will be moderately vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring flood events.

Local Transportation Facilities

- Access provided by local transportation facilities will be vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring inundation.
- Roads and other facilities could also be vulnerable to **flooding and inundation** due to saturated soils and impacts on road substructure and pavement degradation.

Building Stock

- Residential buildings have a low vulnerability to **flooding** in the 2050 scenario due to limited exposure. They are highly-vulnerable to **flooding and inundation** in the 2100 scenarios as exposure expands to large portions of residential neighborhoods and major commercial facilities.

Emergency Response Facilities

- Fire stations in San Diego and Coronado are moderately vulnerable to **flooding** in the 2100 Extreme Event scenario**.**

Parks, Recreation, and Public Access

- Shoreline parks and recreational facilities are extremely vulnerable to regular **inundation** due to extensive exposure around the Bay and high sensitivity to inundation impacts.
- The system is highly vulnerable to **flooding** because of extensive exposure and high sensitivity, but adaptive capacity to cope with flooding is higher than for most other systems.

Regional Airport Operations

- Parts of the Airport site will be vulnerable to **localized flooding** from blocked storm outfalls in the Bay.
- In the 2100 scenarios, Airport operations will be extremely vulnerable to Bay **flooding and inundation**, particularly from impacts on access roads, future terminal areas, and portions of the runway/airfield.

Vulnerable Populations

- Many groups that are currently vulnerable – such as low-income residents, the homeless, elderly, and ethnic minorities – will face even greater threats from future flooding, particularly in the 2100 timeframe.
- Residents that work in sectors that could be adversely impacted by future flooding are also a key vulnerability for the region.

Adaptation Strategies

As described above, the region faces a multitude of threats from a rising Bay. While it is critical that the region play its part in reducing the global greenhouse gas emissions that cause sea level rise, it must also be recognized that the seas are already rising and this trend is expected to intensify. Preparing for these changes through climate adaptation is necessary to fulfill the public obligation to protect public safety, health, and quality of life. Participants in this project identified the following ten "comprehensive strategies," designed to address multiple impacts, sectors, assets, and timeframes. In addition to these comprehensive strategies, a set of "targeted strategies" were developed to address the specific vulnerabilities of each community sector; these targeted strategies are described in the main body of the Adaptation Strategy.

Comprehensive Strategies

1. Create a staff-level regional sea level rise (SLR) adaptation working group consisting of representatives from public agencies around San Diego Bay to implement the Adaptation Strategy.

2. Provide regular opportunities for stakeholder engagement around implementation of the Adaptation Strategy.

3. Create and enhance existing outreach, education, training, and peer exchange programs tailored to public agency staff, stakeholders, and the general public.

4. Establish and promote a regional research agenda to advance understanding of sea level rise impacts, vulnerabilities, and adaptation responses in the San Diego region.

5. Engage regulatory agencies to advocate for clear and consistent regulatory guidance on how to address sea level rise impacts in development permitting.

6. Engage the Federal Emergency Management Agency (FEMA) to encourage the incorporation of future risks from sea level rise into non-regulatory maps associated with upcoming Flood Insurance Studies (FIS).

7. Institutionalize or mainstream sea level rise adaptation by incorporating sea level rise and associated impacts into relevant local and regional plans and projects.

8. Consistently utilize guidance provided by the State of California Climate Action Team in developing sea level rise assumptions for planning purposes.

9. Perform more detailed vulnerability assessments at a site-specific level as significant plans or capital projects are undertaken.

10. Develop decision-making frameworks in each jurisdiction for selecting and implementing appropriate management practices in communities vulnerable to inundation or regular flooding, utilizing such frameworks as risk management and cost/benefit analysis.

Next Steps

Many of the recommendations in this Strategy are intended for consideration and implementation in each of the participating local jurisdictions in their own planning processes, such as Climate Mitigation and Adaptation Plans in the City of San Diego and Port of San Diego, and in bayfront planning in Chula Vista. A key next step will be to communicate these recommendations to local officials and stakeholders for adoption in local plans. Regional coordination in building resilience to sea level rise will continue to be critical, and the Public Agency Steering Committee will continue to meet to begin implementing the Adaptation Strategy, with support from ICLEI and The San Diego Foundation, in 2012.

1. PROJECT DESCRIPTION

The San Diego region is a center of economic activity, diversity, and culture in Southern California. The region has long been known for its remarkable landscape, biological diversity, economic prowess, and prestigious academic institutions, and many have acclaimed it as one of the nation's most livable communities. While the region's growth and status as an economic center is projected to continue for the foreseeable future, real threats to this status are posed by the impacts of climate change to the social, economic, and environmental well-being of the San Diego region. Among these expected climate change impacts, perhaps none poses a greater risk than sea level rise. By 2100, elevation of the mean high water line could change by as much as 1.5 meters, or approximately five feet.

San Diego is a region defined by its relationship with the coast and heavily invested in its coastal communities. With so much at stake, many jurisdictions are beginning to evaluate and manage risks from sea level rise and other climate impacts through a planning process known as climate adaptation planning. These communities recognize that it is critical to begin considering policy responses long before the worst impacts associated with sea level rise are projected to occur, because developing and implementing solutions will require unprecedented collaboration with long lead-times, and because infrastructure is being built now that will be vulnerable to impacts in the future.

It is in that spirit that a Public Agency Steering Committee comprised of staff from the five bayfront cities, the San Diego Unified Port District, and the San Diego County Regional Airport Authority came together to develop this *Sea Level Rise Adaptation Strategy for San Diego Bay* (Adaptation Strategy).

1.1 Project Participants and Rationale

The Adaptation Strategy is intended to provide participating Steering Committee jurisdictions with policy recommendations that will aide in making bay-front communities more resilient to sea level rise and its associated impacts, such as coastal flooding, erosion, and ecosystem shifts. The Steering Committee consists of staff from:

- City of Chula Vista
- City of Coronado
- City of Imperial Beach
- City of National City
- City of San Diego
- Port of San Diego
- San Diego County Airport Authority

The planning effort complements several related initiatives in the region. The City of Chula Vista recently adopted one of the first stand-alone climate adaptation plans in the nation. Both the City of San Diego and the Port of San Diego are developing adaptation policies in their climate action plans, targeted for adoption in 2012, and the City of National City also recently adopted a climate action plan.

Significant research is being performed by The San Diego Foundation and researchers from University of California San Diego, Scripps Institution of Oceanography, and San Diego State University around climate change projections and sea level rise scenarios for the greater San Diego Bay area. This multi-jurisdictional Adaptation Strategy draws upon and informs these local efforts. Because the Port of San Diego is developing its own Climate Mitigation and Adaptation Plan, the Strategy does **not** address specific facilities or sites managed by the Port, but rather focuses on issues requiring inter-jurisdictional collaboration or that are explicitly under the jurisdiction of Steering Committee cities or the Airport Authority.

The Adaptation Strategy project is meant to address the early steps in ICLEI's climate adaptation planning framework, called the Five Milestones of Adaptation. As shown in Figure 1.1, the Five Milestone framework is a guide that enables local governments to make their communities more resilient in a systematic, transparent way—from understanding the problem, to setting goals, developing policy, implementation, and monitoring.

The Adaptation Strategy and associated vulnerability assessment provide the analysis and policy recommendations to move participating jurisdictions through Milestone 3 with regards to sea level rise planning. Having completed the first three milestones, participating jurisdictions will be set up to undertake Milestone 4 by implementing the Strategy. Finally, ICLEI recommends re-evaluating the Strategy over time and incorporating lessons learned into a new iteration of the Five Milestone process.

Figure 1.1 Five Milestones of Adaptation

1.2 Guiding Principles

Early in the planning process, the Steering Committee and stakeholders came to consensus around the following principles for guiding the San Diego Bay initiative, many of which are adapted from the *2009 California Climate Adaptation Strategy* to align the region with the State's approach.

1) The San Diego region must begin now to adapt to the impacts of climate change. We can no longer act as if nothing is changing.

2) Use the best available science in identifying climate change risks and adaptation strategies.

3) Understand that data continues to be collected and that knowledge about climate change is still evolving. As such, an effective adaptation strategy is "living" and will itself be adapted to account for new science.

4) Involve all relevant stakeholders in identifying, reviewing, and refining the adaptation strategy, and in ensuring that emissions reduction is also prioritized in local efforts.

5) Establish and retain strong partnerships with federal, state, and local governments, tribes, private business and landowners, and non-governmental organizations to develop and implement adaptation strategy recommendations over time.

6) Utilize a precautionary approach to minimize risk borne by local communities.

In addition to these overarching principles, a set of principles were also established to guide the development of the Strategy's recommendations:

7) When possible, give priority to adaptation strategies that modify and enhance existing policies rather than solutions that require new funding and new staffing.

8) Understand the need for adaptation policies that are effective and flexible enough for circumstances that may not yet be fully predictable.

9) Ensure that climate change adaptation strategies are coordinated with local, state, national and international efforts to reduce GHG emissions.

10) Give priority to adaptation strategies that initiate, foster, and enhance existing efforts that improve economic and social well-being, public safety and security, public health, environmental justice, species and habitat protection, and ecological function.

11) The San Diego region must protect public health and safety and critical infrastructure.

12) The San Diego region must protect, restore, and enhance ocean and coastal ecosystems, on which our economy and well being depend.

13) The San Diego region must ensure public access to coastal areas and protect beaches, natural shoreline, and park and recreational resources.

14) New development and communities must be planned and designed for long-term sustainability in the face of climate change.

15) The San Diego region must look for ways to facilitate adaptation of existing development and communities to reduce their vulnerability to climate change impacts over time.

1.3 Planning Process

The Adaptation Strategy was developed through a series of milestones and deliverables developed by ICLEI and the Steering Committee between August 2010 and October 2011. The major deliverables were:

- An **Existing Conditions Report** that documents the San Diego Bay landscape and the science of climate change and sea level rise.
- A **Vulnerability Assessment** that evaluates how sea level rise will impact various sectors and systems in the region and how impaired or resilient those systems will be.
- **Policy Recommendations** that participating jurisdictions can consider adopting through existing planning processes.
- The **Adaptation Strategy**, which assembles the previous work in a narrative planning document.

Stakeholder Engagement

In addition to the Steering Committee participants described previously, a Stakeholder Working Group was assembled to contribute to the planning process for the Adaptation Strategy. The group consisted of approximately 25 organizations and agencies that have a direct interest in the future of the Bay shoreline. A Technical Advisory Committee consisting of approximately 20 subject matter experts in a variety of fields also provided technical guidance.

Through a partnership with the Tijuana River National Estuarine Research Reserve-Coastal Training Program, these groups were assembled for three workshops and multiple subgroup meetings over the course of the project. The workshops served as vehicle to build collaboration among participants, increase understanding of climate adaptation and resilience, and solicit critical feedback that informed the development of the Adaptation Strategy.

At the workshops, stakeholders and technical advisors:

- Received training on climate change and adaptation approaches
- Identified vulnerabilities and issues of concern
- Developed a vision of desired future outcomes that integrates diverse perspectives
- Evaluated and prioritized potential adaptation responses
- Identified their role in implementing the Adaptation Strategy

Post-workshop surveys reported 96 to 100 percent increased understanding of vulnerability assessments and adaptation strategies, and 100 percent reported intent to apply the knowledge they gained. Through the stakeholder engagement process, an appreciation of challenges and potential solutions emerged that was richer and more comprehensive than the Steering Committee could have developed alone. The engagement process produced a robust outcome with broad buy-in among the entities that have a direct interest in the future and resiliency of the Bay.

1.4 Planning Area Description

The Adaptation Strategy is focused on lands around San Diego Bay that could be affected by sea level rise in the 2050 and 2100 timeframes. The planning area for this effort was established to include all areas shown on flood maps depicting a high-end sea level rise scenario for 2100 (1.5 meters). As a result, the area extends beyond the historic mean high tide line that serves as the Port's jurisdictional boundary, and slightly beyond the Coastal Commission's coastal zone boundary.

The planning area contains a broad spectrum of land uses and building types. Most significant are residential neighborhoods; neighborhood-serving commercial uses and commercial centers such as downtown San Diego; hospitality and recreational uses supporting the region's important tourism sector; military facilities; and transportation facilities such as San Diego International Airport, cruise ship terminals, and heavy and light rail facilities. The area is largely built-out and development usually takes the form of small infill projects or redevelopment of underutilized parcels. Major redevelopment is planned for the downtown San Diego waterfront and the Chula Vista Bayfront.

Adaptation planning often prioritizes important infrastructure identified as critical facilities. The San Diego Multi-Jurisdictional Hazard Mitigation Plan defines a critical facility as "a facility in either the public or private sector that provides essential products and services to the general public, is otherwise necessary to preserve the welfare and quality of life in the County, or fulfills important public safety, emergency response, and/or disaster recovery functions." Critical facilities in the planning area include water, wastewater, and energy utilities, transportation facilities, and emergency response facilities.

Despite being mostly developed, the area also includes a number of important habitat areas, including Sweetwater Marsh, the Salt Ponds, Silver Strand, and eelgrass beds. Many of the habitat areas in South Bay are protected in the San Diego Bay National Wildlife Refuge, managed by US Fish and Wildlife Service. The Bay is home to a wide diversity of plant and animal life, including several threatened or endangered species.

Jurisdictional Authority and Boundaries

Multiple local, regional, state, and federal agencies are responsible for managing the San Diego Bay coastal area. This section provides a brief overview of these responsibilities.

San Diego Unified Port District. The San Diego Unified Port District is a public benefit corporation established in 1962 by an act of the California State legislature and ratified by the voters of the Port's five member cities—Chula Vista, Coronado, Imperial Beach, National City and San Diego. This legislation established the Port to manage the development of commerce, navigation, fisheries, and recreation on behalf of the state of California. The lands are conveyed to the Port as a trustee of the state by the State Lands Commission, and include approximately 2,500 acres of land and 3,400 acres of water. The Port is governed by a Board of Commissioners appointed by the five member cities.

Cities. Five cities border San Diego Bay: San Diego, National City, Chula Vista, Imperial Beach, and Coronado. These cities regulate land use in the planning area, except in Port-managed areas where the Port retains land use authority. For Port tenant projects, the Port defers to the member cities for review of building permits under applicable building codes, and relies on the cities to provide potable water and wastewater facilities.

San Diego County Regional Airport Authority. The San Diego County Regional Airport Authority has planning and operational jurisdiction for the 661 acres that comprise San Diego International Airport located on state tidelands. It is governed by an appointed board representing all areas of San Diego County.

California Coastal Commission. Under the California Coastal Act of 1976 (Coastal Act), the California Coastal Commission regulates development along the coast to ensure compliance with Coastal Act standards for public access, recreation, views, environmental protection, and hazards. The Commission's jurisdiction is applicable inside the Coastal Zone boundary.

U.S. Navy. San Diego Bay is home to a large naval fleet and multiple facilities related to research, training, cargo handling, storage and other uses by Naval Base San Diego, Naval Base Coronado, and Naval Base Point Loma. The Navy owns and has sole regulatory authority over approximately 1,900 acres in the planning area.

U.S. Fish and Wildlife Service. The Fish and Wildlife Service manages San Diego Bay National Wildlife Refuge, which includes Sweetwater Marsh, the Salt Ponds, and part of the Otay River floodplain. Most of these lands are managed under a lease from the State Lands Commission and are under protection for threatened and endangered species.

California Department of Parks and Recreation. California Department of Parks and Recreation manages Silver Strand State Beach for recreation, under a land grant from the State Lands Commission.

2. Vulnerability Assessment Overview

A climate change vulnerability assessment evaluates the degree to which important community assets are susceptible to, and unable to accommodate, the adverse effects of climate change. By identifying likely impacts and the vulnerabilities of critical systems, this vulnerability assessment starts to define the problem of sea level rise on San Diego Bay. The assessment informs policymaking in several ways. First, it identifies the functional systems or sectors—such as buildings, utilities, emergency response, or critical habitat—that are likely to be affected by climate change-related impacts. Secondly, it enhances understanding of the causes and components of each system's vulnerabilities, explicitly identifying vulnerable points in the system. Finally, it provides information about the relationships between vulnerabilities of different systems to allow both for prioritization and for a systems approach to policy-making.

This section describes the contemporary scientific understanding of sea level rise and associated impacts; sea level rise scenarios developed for planning purposes; the vulnerability assessment methodology; and a summary of assessment findings.

2.1 Sea Level Rise Science and Planning Scenarios

Global, or eustatic, sea level rise is caused by two principal factors – the thermal expansion of water and the melting of land-based ice (commonly called glaciers) – both of which are influenced by climate change. Globally, oceans rose at an average rate of 0.7 inches (18 mm) per decade from 1961 to 2003.[2] Local, or relative, sea level rise is affected by global sea level rise, as well as key additional factors such as El Nino events, circulation patterns, and land elevations changes. As shown in Figure 2.1, sea level rise has been documented in the San Diego Bay since 1906 with a rise of 0.8 inches (20.6mm) per decade over the past century.

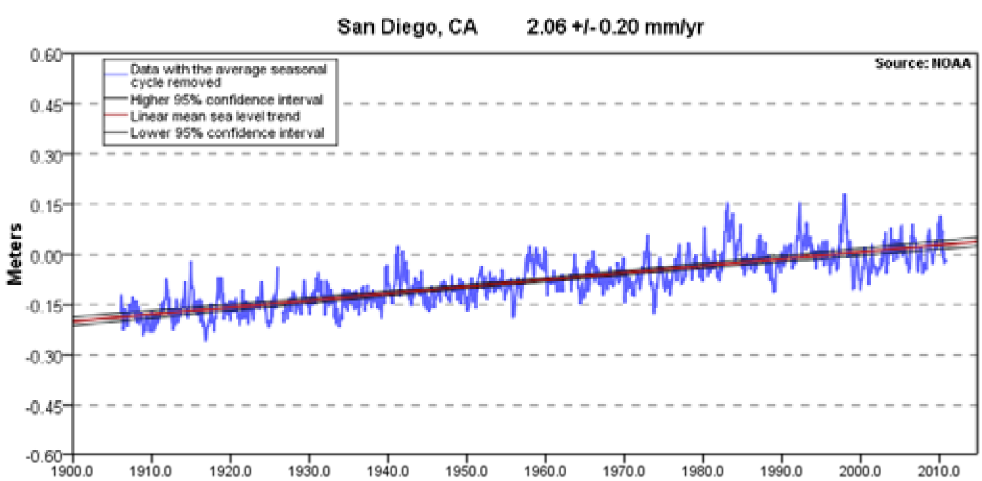


Figure 2.1 Observed Sea Level in San Diego

[2] Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: Synthesis Report for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Available Online: www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

Moving from documentation of past sea level rise to prediction of future sea level rise, scientists rely on several methods including trend analysis and modeling of both thermal expansion and melting of land based ice. Based on these methods, scientists currently predict that the rate of sea level rise will increase in the coming century. Although there is deepening understanding of sea level rise trends, there remains uncertainty around the rate and timing of sea level rise. This uncertainty stems both from unknown future greenhouse gas emissions and from uncertainty about the precise relationships between emissions, temperature, and glacial melt.

Despite this uncertainty, scientists have used greenhouse gas emissions scenarios and other methods to create a range of possible future sea level rise amounts. Figure 2.2 shows the historic global sea level rise trend as well as an estimated range of future global sea level rise trajectories. In California, the State is recommending the use of projections of between 10 and 17 inches (26 to 43 cm) in 2050 and of 31 to 69 inches (78 to 176 cm) in 2100.[3]

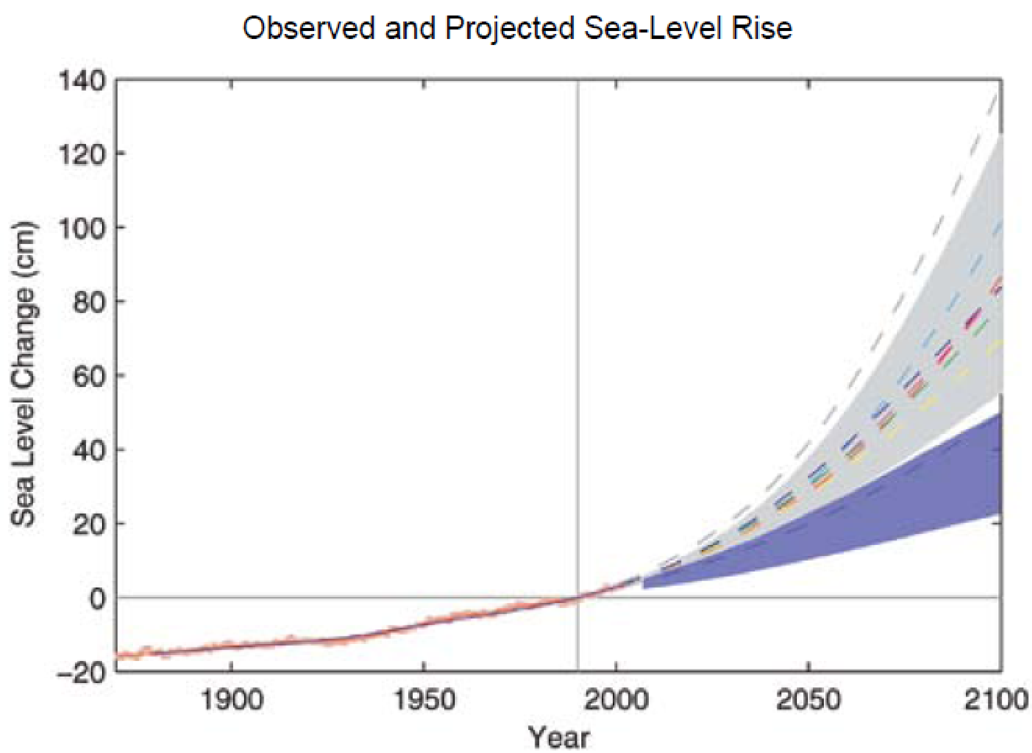


Figure 2.2: Historic global sea-level observations (red) and future projections (dashed lines). The blue shaded area is from Meehle et al. 2007 analysis and the higher grey projections are from Rahmstorf, S. 2007 analysis.

[3] State of California, Sea Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), *Sea Level Rise Interim Guidance Document.* October 2010.

Four sea level rise "planning scenarios" are considered in this Strategy. Embodied in these scenarios are three considerations that assist in the development of policy: *amount of sea level rise, horizon year, and variability.* This assessment utilizes a 20 inch (0.5 meter) increase in sea level in 2050 and a 59 inch (1.5 meter) increase in sea level in 2100. Higher-end sea level rise scenarios are chosen from the range of possibilities to encourage a risk-averse approach to planning, as recommended by the State guidance, and to leverage existing research and data. Variability in the occurrence of flood events is another key consideration in sea level rise planning; policy responses will vary depending on how often a community asset is exposed to flooding, whether on a daily, annual, or once-a-century basis, for example. The following planning scenarios are referred to throughout this document:

Sea Level Rise Planning Scenarios

2050 Daily Conditions — Mean high tide in 2050 with 0.5 meters of sea level rise

2050 Extreme Event – 100-year extreme high water event in 2050, with 0.5 meters of sea level rise, including such factors as El Nino, storm surge, and unusually high tides

2100 Daily Conditions – Mean high tide in 2100 with 1.5 meters of sea level rise

2100 Extreme Event – 100-year extreme high water event in 2100, with 1.5 meters of sea level rise, including such factors as El Nino, storm surge, and unusually high tides

2.2 Sea Level Rise Impacts

Rising sea levels are generally associated with a number of different impacts, including flooding, inundation, erosion, salt water intrusion, and water table rise. This section briefly describes these impacts.

Flooding and Inundation

Flooding refers to the circumstance of normally dry land being covered by water for a limited period of time. These events are often described in terms of their statistical potential to occur. For example, a flooding event referred to as the one-percent chance storm event (often called the 100-year storm) has a one percent chance of occurring in a given year and on average occurs once every 100 years. The Extreme Event scenarios considered in this report are the 100 year high water event, which accounts for a number of local water level factors including El Niño effects and storm surge, but does not account for precipitation and riverine flooding from storms. In the San Diego Bay area, it is expected that sea level rise will cause coastal flooding to reach farther inland and to occur more often. These extreme flood events for the two time horizons are shown in Figure 2.4 and 2.6.

Inundation, on the other hand, is when land that was once dry becomes permanently wet. Sea level rise could result in certain currently dry locations around the Bay being inundated by daily high tides. These potential future inundation scenarios for the two time horizons are shown in Figure 2.3 and 2.5. In addition to the clear threats inundation poses to the built environment, this impact is also predicted to impact natural systems or ecosystems in several key ways. Inundation is expected to cause the landward migration of intertidal and upland natural environments, such as marshes, tidal flats, and dunes. However, if there is nowhere for these features to migrate due to adjacent development, then inundation could result in the complete loss or fracturing of these systems. The loss of these intertidal habitats would be highly destructive to the many species that rely heavily on their existence. This dynamic is explored further in Section 3.

All flooding and inundation maps are based upon research performed by Rick Gersberg of San Diego State University with support from a grant by the San Diego Foundation. GIS layers showing flooding were created through a "bathtub" modeling method, which does not account for a number of factors—such as topography of the Bay floor, wave run-up, and erosion—that could increase or decrease the extent of the inundation and flooding. The method also does not account for existing shoreline protection infrastructure such as sea walls or revetments. Finally, this model cannot account for future changes to land use and land form. Despite these drawbacks, the maps provide meaningful information on low-lying areas that could be exposed to inundation or flooding under various sea level rise scenarios.

These future inundation and flood maps can be compared to current FEMA flood zones delineated on Flood Insurance Rate Map (FIRMs), shown in Figure 2.7. The FIRM shows the estimated extent of flooding during a hypothetical storm. It shows both the hypothetical "100-year storm" (also called a 1% storm) and "500-year storm" (also called a 0.2% storm). These are storms that have an estimated 1% chance and 0.2% chance respectively of being equaled or exceeded during any given year. Additionally, the map for the San Diego Bay area shows the levee protection area of Coronado Cays and the unstudied areas associated with military facilities. It is important to note that FEMA's mapping methods are different from those used to derive the sea level rise flood and inundation maps. Specifically, FEMA's map use a run up analysis that includes the potential force of water associated with storm events. Additionally FEMA's maps include considerations of freshwater riverine flooding. Despite these differences it is useful to note that there is some meaningful overlap and some differences between current and future flood zones.

Erosion

Erosion, which is defined as the wearing away of the earth's surface by any natural process, often occurs at the intersection of land and water. In coastal areas, there are thought to be two major erosion processes. The first is episodic erosion, which occurs during a major storm event and results in extreme shifts in shorelines. Natural environments typically recover from these episodic shifts returning to their pre-storm state over time; however, if either the frequency or the intensity of these episodic erosion events were to increase, a natural system might not be able to recover. Though the exact effects on erosion under the future extreme events scenarios are not known, it can be said that in both 2050 and 2100 episodic erosion is likely to increase in terms of the quantity of sediment that is lost.

The other type of erosion is chronic erosion, which is the slow migration of sand away from the shore (or shifting to a different location). Sea level rise, which will alter daily conditions and cause heightened sea events to persist for longer periods, could also exacerbate chronic erosion on non-hardened surfaces around the Bay.[4]

[4] Focus 2050 p. 14

Figure 2.3 Daily Conditions - Inundation in 2050

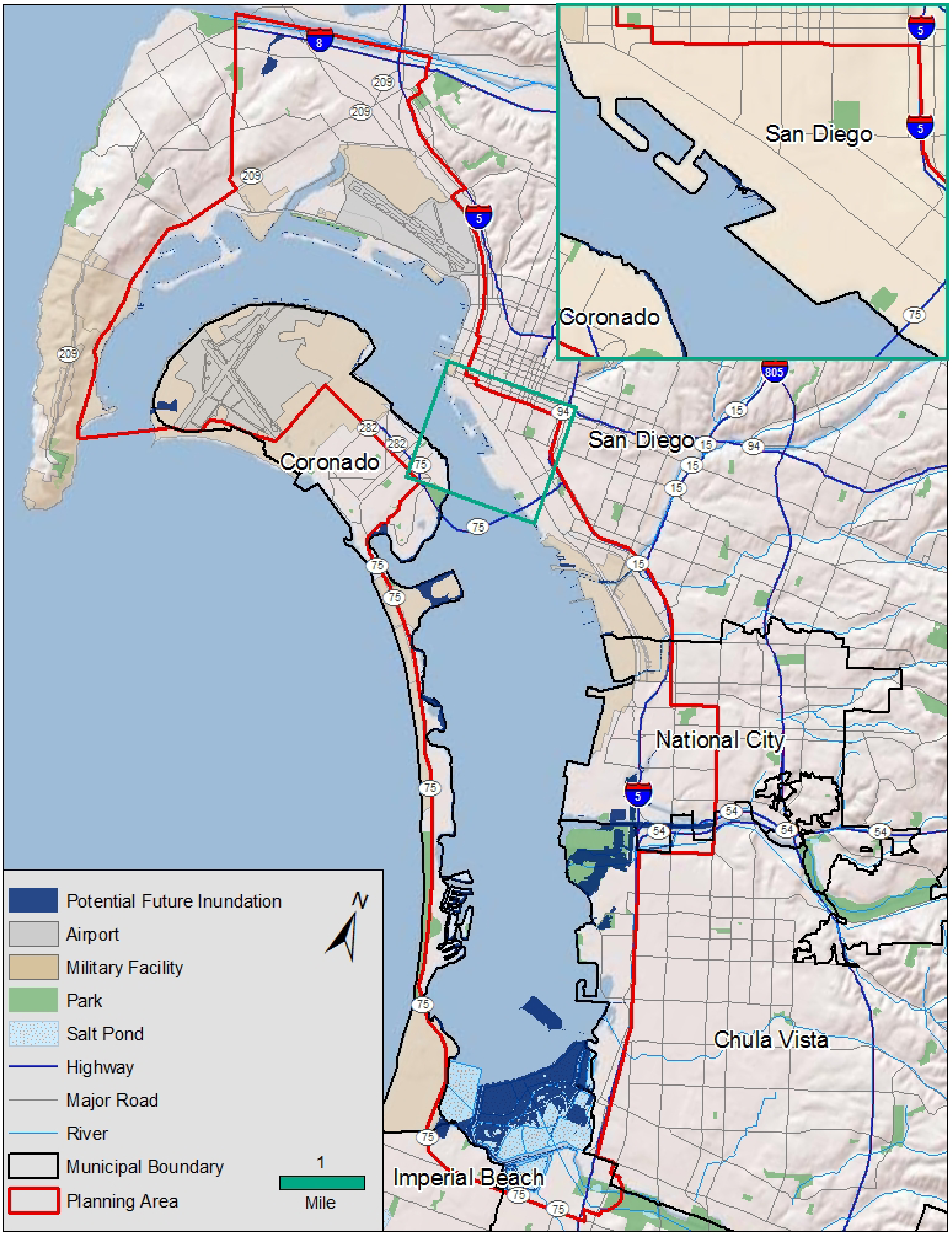


Figure 2.4 Extreme Event - Flooding in 2050

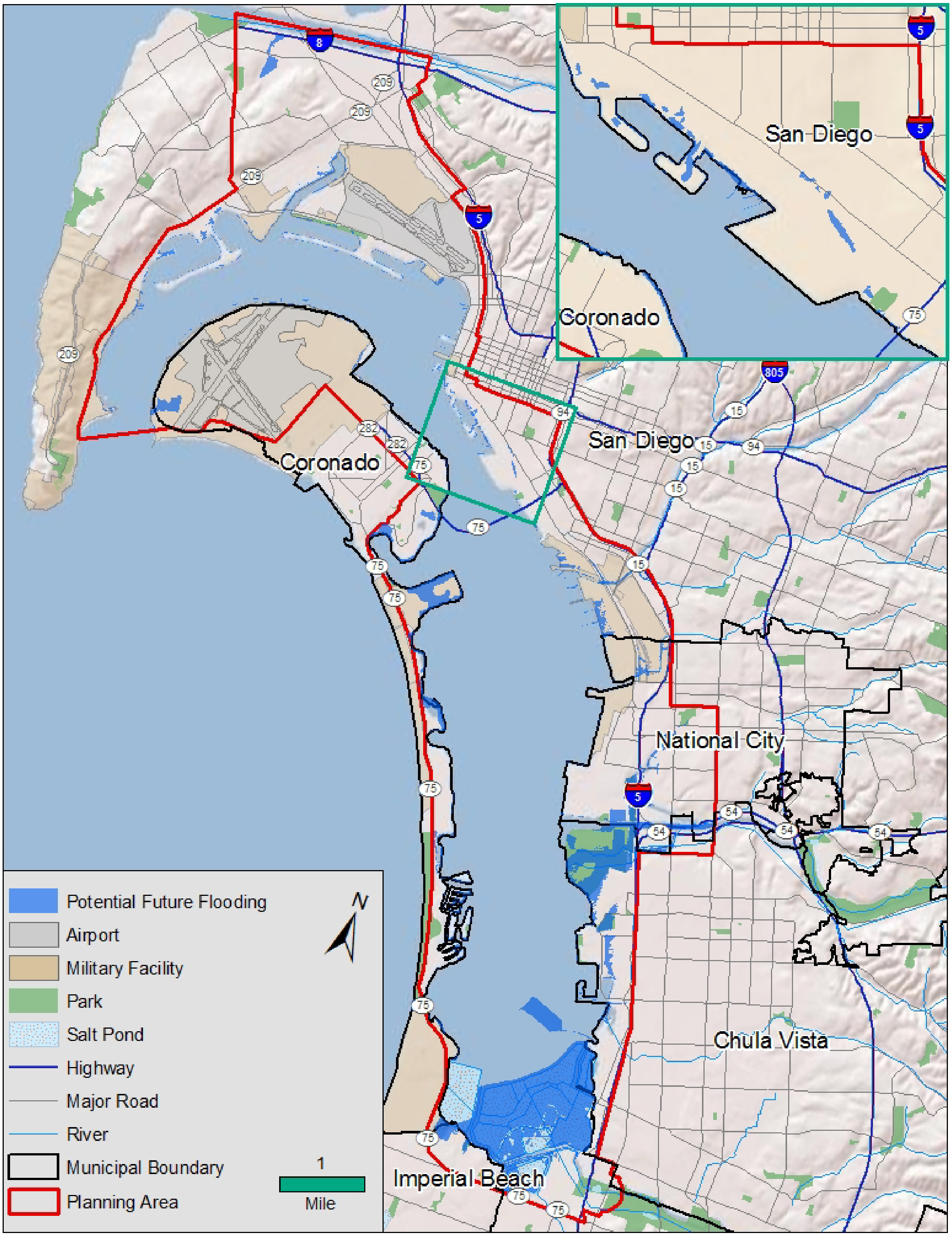


Figure 2.5 Daily Conditions - Inundation in 2100

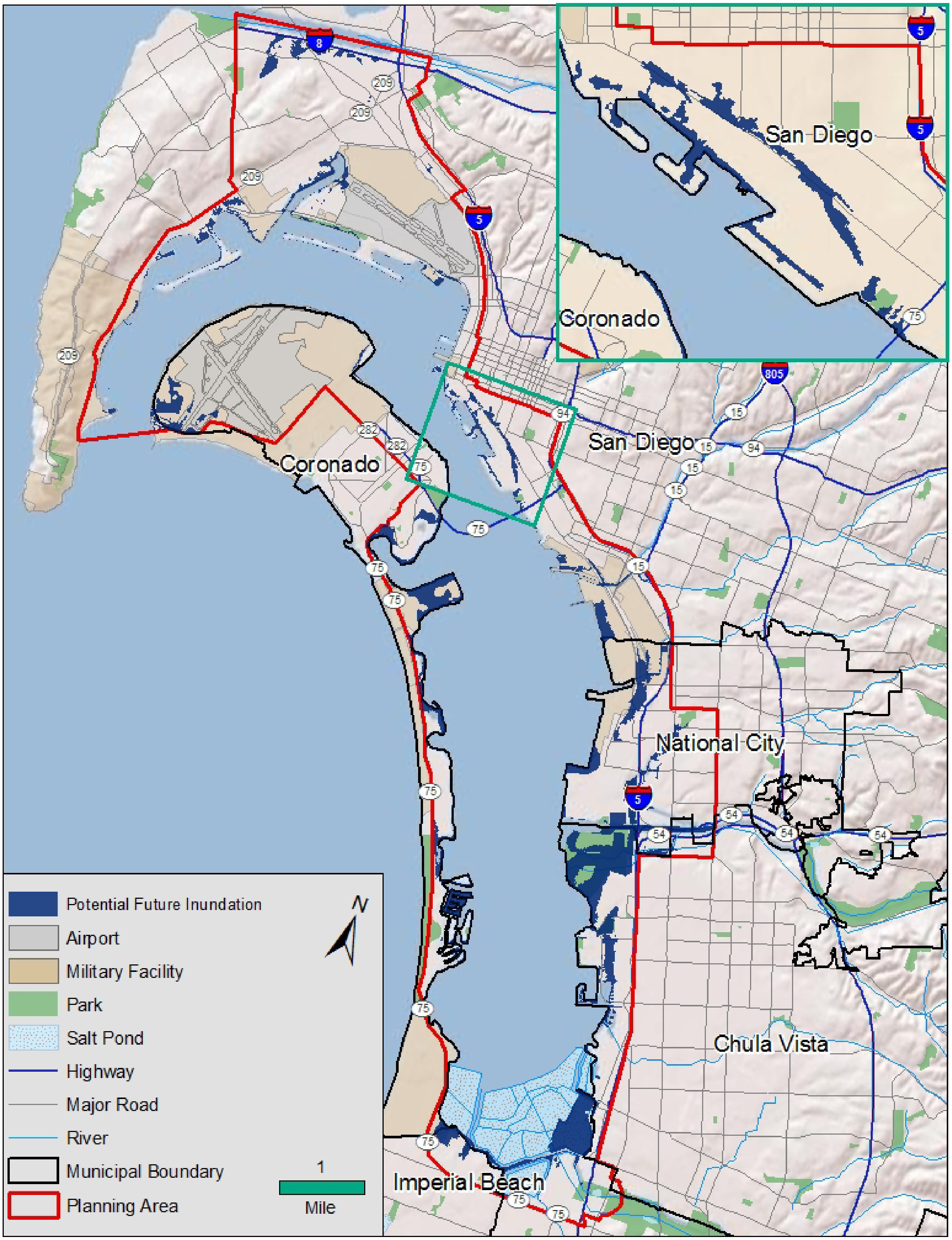


Figure 2.6 Extreme Event - Flooding in 2100

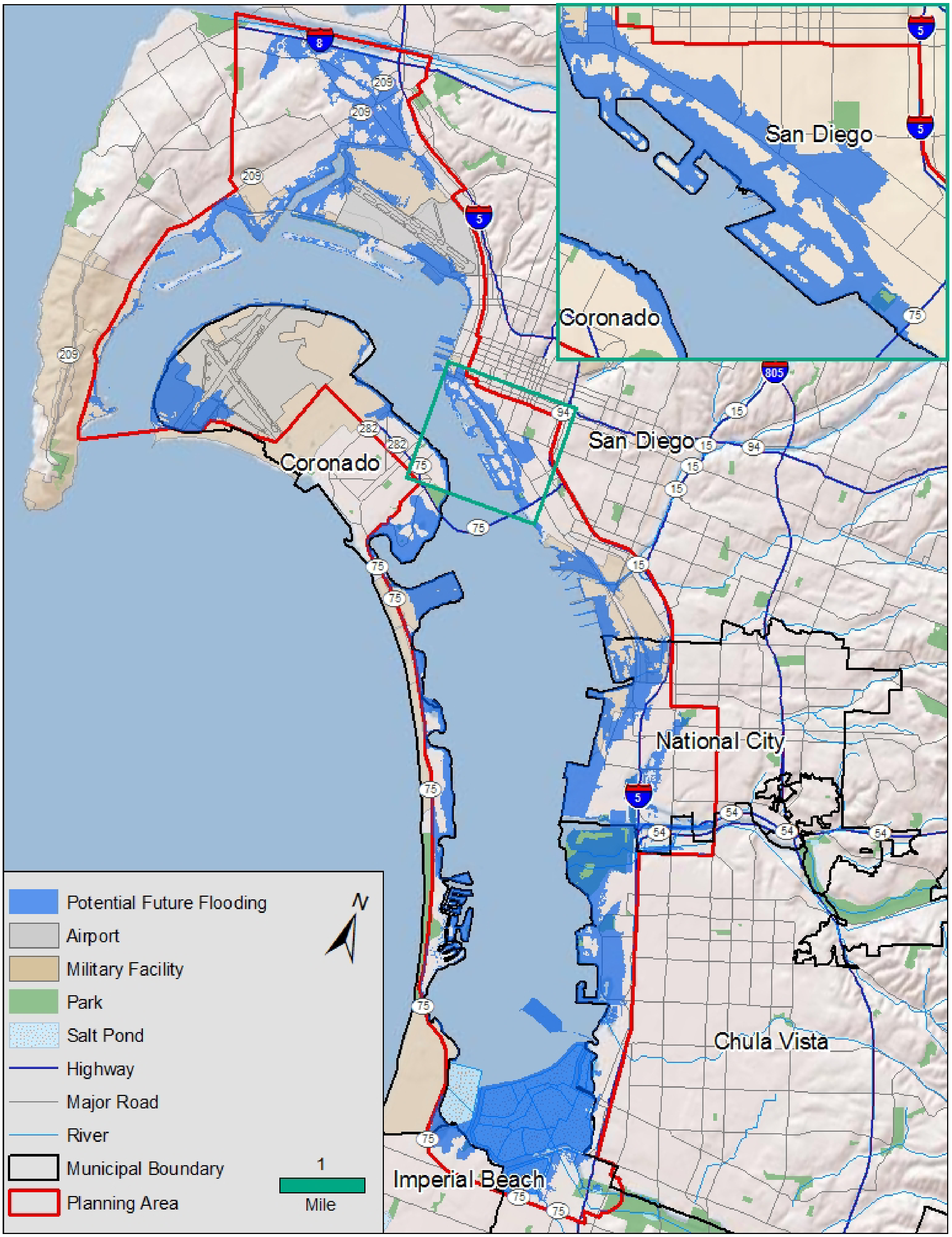
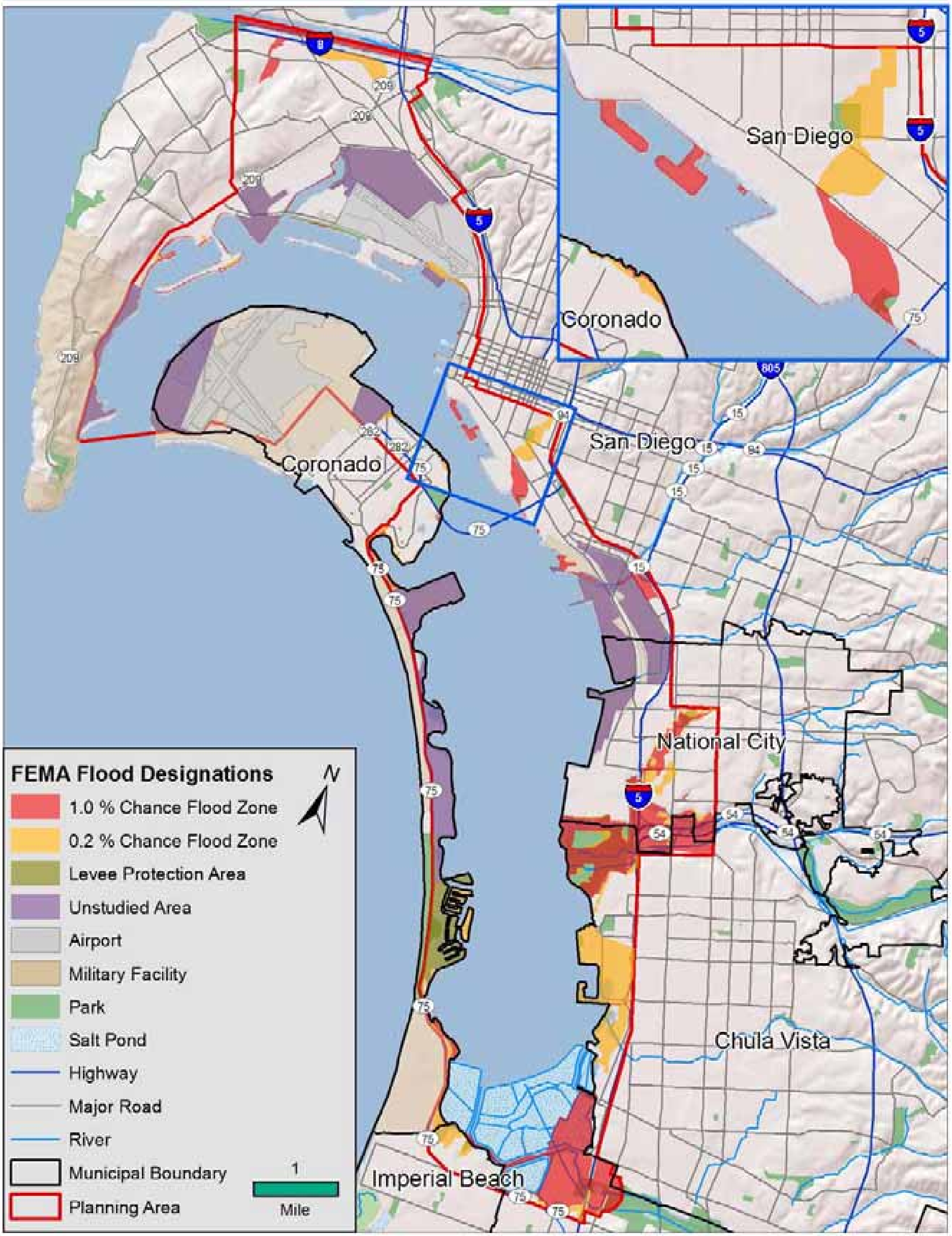


Figure 2.7 Current Extreme Events - FEMA Designated Flood Zones



Saltwater Intrusion

Saltwater intrusion is the physical migration of saltwater into freshwater aquifers. This is a natural process that is regulated by a number of factors including groundwater pumping, precipitation, the existence of channels, storm events, and sea level. The San Diego Formation aquifer, which runs north-south from the La Jolla area to the US-Mexico border and east-west from approximately Interstate 805 to the coast, could experience salt water intrusion from the San Diego Bay depending on the combination of these factors. To this point, research has shown that the relationship between the rising Bay and the aquifer could put the aquifer at risk of greater saltwater intrusion.[5] The details regarding the effects of the daily changes versus the extreme events are not known; however, the hydrodynamics of this aquifer are being studied in depth by the US Geological Survey in its San Diego Hydrogeology project and more information will likely be available through this initiative in the future.

In many places, saltwater intrusion into aquifers is a concern as it relates to the quality of groundwater used for potable water supply. Groundwater comprises approximately three percent of San Diego County's water supply currently. In the planning area, groundwater is utilized only in the Sweetwater Authority district, which serves National City and the central and western parts of Chula Vista. This water is desalinated at a facility located outside the planning area; an increase in the salt content of this water could affect operation of the desalination plant. However, the Sweetwater Authority groundwater supply is pumped from deep in the aquifer. Seawater infiltrates into shallow aquifers earlier and in this case, is unlikely to reach the Sweetwater water source for many decades. The hydrodynamics of this area are only beginning to be understood, and more research is needed to draw conclusions about the Sweetwater supply's exposure to saltwater intrusion. Until then, the sentiment among project technical advisors is that the region's potable water system is less vulnerable to saltwater intrusion than to flooding and rising water tables. As a result, saltwater intrusion is not addressed further in the vulnerability assessment or recommendations.

Water Table Rise

The water table is the top of the freshwater aquifer. Comprehensive data about water table elevations is not available for the area, but generally, water tables currently lie at sea level nearest the coast and gradually rise inland, to approximately 30 feet above sea level a few miles east of the Bay. Though the response of water tables to sea level rise in the Bay region has not yet been modeled, it is generally understood that if sea levels were to rise, the water table could also rise, impacting subsurface infrastructure, as illustrated in Figure 2.8.

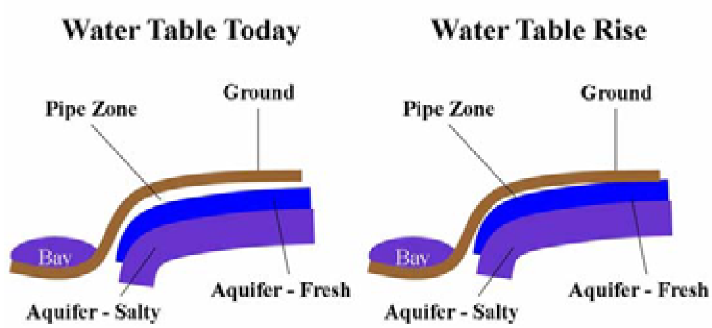


Figure 2.8: Rising Water Tables. A depiction of a salt water aquifer rising causing the water table to rise into the pipe zone.

[5] Personal communication with Wes Danskin, USGS, February 18 2011.

A rising water table would pose many risks to infrastructure, including stormwater facilities, sewer mains, potable water distribution, electricity and natural gas distribution, and transportation facilities. In general, concerns include structural integrity of surface infrastructure, maintenance of buried infrastructure, and groundwater infiltration into buried pipes. Subsurface structures such as parking garages and basements would also be at risk of flooding from groundwater, requiring expensive dewatering facilities, as is already the case at the Convention Center parking structure.

While these impacts are possible, too little is currently known about the water table and how it will respond to sea level rise to accurately assess these potential vulnerabilities. The response of water tables to sea level rise in the Bay region has not been modeled, so it is not possible to determine exposure of infrastructure in the 2050 or 2100 horizons. As a result, water table rise is not addressed further in the vulnerability assessment or recommendations sections of this document.

2.3 Assessment Methodology

The vulnerability assessment is intended to provide a comprehensive picture of the vulnerabilities of various functional systems in both the built and natural environment of San Diego Bay, with a focus on systems under City jurisdiction or cross-jurisdictional control. The vulnerability assessment analyzed three components of vulnerability – exposure, sensitivity, and adaptive capacity – relative to sea level rise impacts – flooding, inundation, erosion, salt water intrusion, and water table rise.

Exposure is a determination of whether community assets will experience a specific changing climate condition.

Sensitivity is the degree to which community assets would be impaired by the impacts of climate change if they were exposed those impacts. Systems that are greatly impaired by small changes in climate have a high sensitivity, while systems that are minimally impaired by the same small change in climate have a low sensitivity.

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

The combination of sensitivity and adaptive capacity determine a system's overall vulnerability level. Sensitivity has a positive relationship with vulnerability, meaning that as a system's sensitivity increases its overall vulnerability also increases. Adaptive capacity has an inverse relationship with vulnerability, thus as adaptive capacity increases the system's vulnerability decreases, as shown in Figure 2.9.

This vulnerability assessment used three methods depending on the sector and the sea level rise impact being assessed. For several sectors, exposure to flooding and inundation was estimated through Geographic Information Systems analysis (GIS is a suite of computer tools for mapping and spatial analysis). The physical location of each sector's core regional components was compared with flood mapping of each of the four planning scenarios (Figures 2.3 through 2.6). Based on this data overlay, it was determined if a location could experience future flooding or inundation. The flood exposure overlay maps are presented in Appendix II. Exposure to erosion, saltwater intrusion, and water table rise were determined primarily through information provided by experts in both their survey responses as well as in specific follow up.

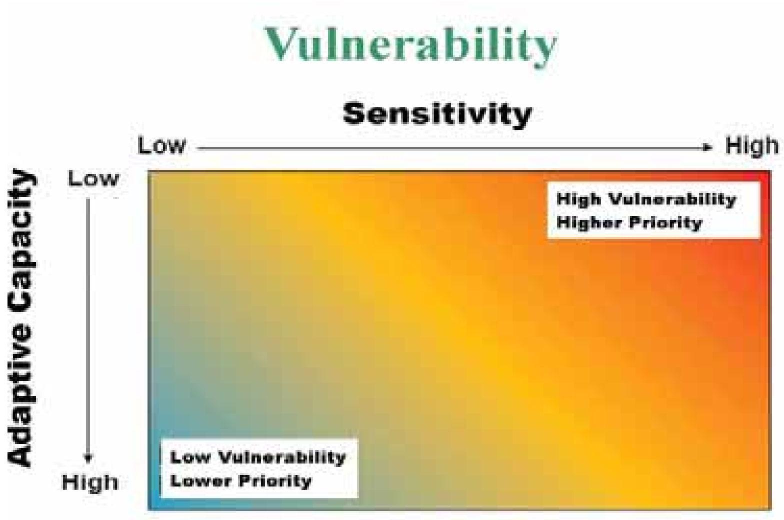


Figure 2.9: Components of Vulnerability. A depiction of the relationship between sensitivity, adaptive capacity, and vulnerability.

Additionally, the effect of inundation on habitat shifts was assessed based on the Sea-Level Affecting Marshes Model (SLAMM) performed Dr. Rick Gersberg at San Diego State University. This model simulates dominant processes – inundation, erosion, overwash, saturation, and salinity – that determine the makeup of coastal ecosystems, thus providing information on potential habitat shifts. The model was calibrated to location conditions and run for five different sea level rise scenarios. This assessment evaluated ecosystem exposure based on the general habitat trends that the model produced.

In conjunction with these exposure analyses, this vulnerability assessment used a written survey to gauge the sensitivity and adaptive capacity of all the systems addressed in this report. The steps of the survey method are provided below:

1. Several local technical experts for each system were identified and invited to serve as technical advisors based upon the depth of their knowledge in appropriate fields.
2. Technical advisors were provided with an information packet and a webinar explaining the tenants of sensitivity and adaptive capacity.
3. A detailed survey on sensitivity and adaptive capacity was developed in SurveyMonkey.com with the guidance of the Steering Committee. The survey required that applicants take some time to think about and answer guiding questions related to a system's sensitivity and adaptive capacity, then rate sensitivity and adaptive capacity on a scale of 1 to 5. The survey questionnaire can be found in Appendix I.
4. Finally, based upon answers to the survey, subsequent follow up with local experts, and the appropriate exposure assessment, primary vulnerabilities for each system were determined. Complete assessments of primary vulnerabilities for each sector are presented in section 3.

2.4 Summary of Findings

Table 2.1 below describes the primary vulnerabilities for the sectors evaluated. Section 4 presents the findings for each sector in detail.

Table 2.1 Primary Vulnerabilities by Sector

Ecosystems and Critical Species
➢ Bay ecosystems, which provide habitat for many endangered and threatened species, are extremely vulnerable to **inundation** that is expected to result in habitat shift. These shifts could cause the loss of irreplaceable habitats for critical species in many areas. ➢ Upland areas are vulnerable to **erosion**, and subtidal ecosystems are threatened by erosion of upland areas when it results in degraded water quality.
Contaminated Sites
➢ Hazardous waste sites are highly vulnerable to **flooding and inundation** as storage tanks in the area could be opened or moved, or motors and pumps could be impaired thus releasing contamination into flood waters or area soils.
Stormwater Management
➢ In all scenarios, storm sewers are highly vulnerable to **flooding and inundation** in the Bay due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas.
Wastewater
➢ Sanitary sewers in low-lying locations will be vulnerable to **floodwater inflow** which could exceed their capacity, potentially resulting in discharge of wastewater to the Bay. ➢ The entire wastewater collection system in the planning area will be vulnerable to **inundation** impacts.
Potable Water
➢ Above-ground water distribution components such as valves, meters, and service points will be vulnerable to **flooding and inundation**.
Energy Facilities
➢ Above-ground electricity transmission and distribution in limited areas will be vulnerable to **erosion**, particularly after 2050 and during major storm events. Erosion could undermine infrastructure, causing outages or safety issues. ➢ Above-ground electricity transmission and distribution will be moderately vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring flood events.

Local Transportation Facilities
➢ Access provided by local transportation facilities will be vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring inundation. ➢ Roads and other facilities could also be vulnerable to **flooding and inundation** due to saturated soils and impacts on road substructure and pavement degradation.
Building Stock
➢ Residential buildings have a low vulnerability to **flooding** in the 2050 scenario due to limited exposure. They are highly-vulnerable to **flooding and inundation** in the 2100 scenarios as exposure expands to large portions of residential neighborhoods and major commercial facilities.
Emergency Response Facilities
➢ Fire stations in San Diego and Coronado are moderately vulnerable to **flooding** in the 2100 Extreme Event scenario**.**
Parks, Recreation, and Public Access
➢ Shoreline parks and recreational facilities are extremely vulnerable to regular **inundation** due to extensive exposure around the Bay and high sensitivity to inundation impacts. ➢ The system is highly vulnerable to **flooding** because of extensive exposure and high sensitivity, but adaptive capacity to cope with flooding is higher than for most other systems.
Regional Airport Operations
➢ Parts of the Airport site will be vulnerable to **localized flooding** from blocked storm outfalls in the Bay. ➢ In the 2100 scenarios, Airport operations will be extremely vulnerable to Bay **flooding and inundation**, particularly from impacts on access roads, future terminal areas, and portions of the runway/airfield.
Vulnerable Populations
➢ Many groups that are currently vulnerable – such as low-income residents, the homeless, elderly, and ethnic minorities – will face even greater threats from future flooding, particularly in the 2100 timeframe. ➢ Residents that work in sectors that could be adversely impacted by future flooding are also a key vulnerability for the region.

3. Comprehensive Strategies

Recommendations in the Adaptation Strategy take the form of either "comprehensive" strategies or "targeted" strategies. While the targeted strategies are specific to certain impacts, vulnerabilities, sectors, or timeframes, the following 10 comprehensive strategies are designed to advance regional sea level rise adaptation planning broadly. Most of the strategies address both the 2050 and 2100 planning horizon timeframes; both new daily conditions and extreme high water events; multiple impacts and vulnerabilities; and multiple functional systems and sectors.

The first six comprehensive strategies are intended to be implemented collaboratively at a regional level. The final four strategies are intended to be considered for implementation at a local level among each of the Steering Committee jurisdictions.

Strategies for Regional Implementation

1. **Create a staff-level regional sea level rise (SLR) adaptation working group consisting of representatives from public agencies around San Diego Bay to implement the Adaptation Strategy.**

   A working group consisting of staff from the public agencies with jurisdiction around San Diego Bay would be formed to provide a venue for collaboration and peer exchange on technical and administrative topics. The working group will work to implement other regional strategies such as monitoring climate change science, promoting research, and providing stakeholder engagement opportunities. Additionally, the working group will pursue adaptation-related funding, monitor progress in implementing the Adaptation Strategy, and update the Strategy every five years or as needed.

   Formation and facilitation of a working group can be executed efficiently by building off existing groups such as the Adaptation Strategy Steering Committee. Other regional models can be adapted in devising a structure for the group, such as the Workgroup for the San Diego Bay Watershed Urban Runoff Management Program (WURMP) or the Regional Climate Protection Network, a group of agency staff working on climate mitigation coordinated by The San Diego Foundation.

2. **Provide regular opportunities for stakeholder engagement around implementation of the Adaptation Strategy.**

   The working group should look to host regular forums for stakeholders to be involved in implementation of the Adaptation Strategy. This strategy may also be implemented through existing channels and should build off of regional successes. Specifically, the group may be able to collaborate with the Tijuana River National Estuarine Research Reserve (TRNERR) Coastal Training Program, which has led a number of successful climate change adaptation stakeholder meetings in partnership with The San Diego Foundation and ICLEI.

3. **Create and enhance existing outreach, education, training, and peer exchange programs tailored to public agency staff, stakeholders, and the general public.**

   Sea level rise adaptation planning is a new and complex field, and outreach and education are critical in building capacity to adapt in the region. Many jurisdictions have articulated the need for increased outreach and communication around climate change, including climate change impacts and adaptation. In the San Diego Bay area, the City of Chula Vista's Climate Adaptation Strategies—Implementation Plans call for ongoing public education and outreach efforts.

   To implement this strategy, the working group should consider developing a communications plan that identifies target audiences and appropriate ways to reach those audiences. Some examples of possible communications actions include the creation of interpretive information at publicly accessible shoreline sites, the inclusion of sea level rise information in regional websites, the creation of training programs or brown bag lunch information sessions for agency staff, and even the utilization of social media to raise awareness of the region's efforts to increase resilience. In addition to building support for needed adaptation actions, improved public outreach around flooding can provide points for jurisdictions that may choose to participate in FEMA's Community Rating System (CRS), which can help to lower insurance premiums in communities around the Bay.[6]

4. **Establish and promote a regional research agenda to advance understanding of sea level rise impacts, vulnerabilities, and adaptation responses in the San Diego region.**

   The science of climate change is rapidly evolving, and the Adaptation Strategy vulnerability assessment revealed a number of gaps in understanding sea level rise dynamics in the region. By creating and promoting a research agenda, the region can greatly enhance local understanding of future impacts of sea level rise to inform more effective planning.

   This strategy may be best implemented through developing strategic partnerships with the region's world-class universities and research centers, including UCSD/Scripps Institute of Oceanography, San Diego State University, Hubbs-SeaWorld Research Institute, NOAA's California and Nevada Applications Program, and the Center for Bay and Coastal Dynamics. Research should also be coordinated and leveraged with the research initiatives of state and federal agencies in the region, such as US Fish and Wildlife Service, US Geological Survey, TRNERR, and California Department of Fish and Game. The following research items have been identified and should be considered for the initial research agenda:

   - *Precipitation, storms, and flooding.* The Adaptation Strategy vulnerability assessment evaluated flooding from higher sea levels and high water events, but precipitation patterns will also influence flooding and water table dynamics on the Bay. Greater understanding of climate-related precipitation changes and their relationship to San Diego Bay flooding, water quality, and water table elevation will enhance adaptation planning.

   - *Aquifer hydrodynamics.* As described in Section 2, water table rise may pose a risk to buried infrastructure around the Bay. While less of a concern, saltwater intrusion into San Diego Formation aquifer could eventually affect one source of the South Bay's drinking water. More information is needed about these processes, especially to inform the design,

[6] *Targeted Strategy, Building Stock #2*

construction, and maintenance of buried utilities, transportation facilities, and underground structures.

- *Survey of shoreline protection infrastructure.* There is currently no comprehensive data on the type, condition, and elevation of shoreline protection infrastructure on San Diego Bay. This information is critical to performing site-specific vulnerability assessments and engineering of capital projects.

- *Cost-Benefit analysis*. Economic analysis of sea level rise-related impacts and adaptation practices is needed to evaluate the cost of possible actions as compared to the cost of inaction.

- *Ecosystem valuation.* Analysis of the economic value of ecosystem services would help to inform decision-making about resource management as the Bay's ecosystems are increasingly threatened by sea level rise.

- *Sediment transport and SLAMM modeling.* The composition of Bay ecosystems is greatly influenced by the amount of sediment that is being eroded or deposited in different locations. More information about coastal and fluvial sediment transport will help natural resource managers better understand how nearshore environments will respond to sea level rise, and the extent to which they will act as critical habitat and natural protective barriers for adjacent infrastructure. Sediment transport data also improves the precision of the Sea Level Affecting Marshes Model (SLAMM), which models change in ecosystem types due to sea level rise.

5. Engage regulatory agencies to advocate for clear and consistent regulatory guidance on how to address sea level rise impacts in development permitting.

Many state and federal agencies play a role in regulating development around San Diego Bay. Clear and concise guidance or common regulations from these agencies would reduce uncertainty about appropriate planning and development practices, thereby reducing economic and political barriers to adaptation planning.

Relevant agencies include the Regional Water Quality Control Board, the Coastal Commission, the Governor's Office of Planning and Research, and the Army Corps of Engineers. Prior to engaging these agencies, the working group may wish to identify areas of permitting conflicts as well as areas that would most directly benefit from the inclusion of sea level rise considerations.

6. Engage the Federal Emergency Management Agency (FEMA) to encourage the incorporation of future risks from sea level rise into non-regulatory maps associated with upcoming Flood Insurance Studies (FIS).

Developed by FEMA, flood insurance studies and the flood insurance rate maps (FIRMs) that they inform are often used by local governments for regulatory purposes. Although local government can create their own improved flood maps and can regulate to higher standards using the existing flood maps, FIRMs are the authoritative benchmark for regulating and insuring development in flood-prone areas. Currently, flood risk in these documents must be based on current risk, as determined from historical observation. However, working with FEMA to create non-regulatory maps that reflect changing risks due to sea level rise would help to institutionalize adaptation planning into traditional local floodplain management procedures. In implementing this strategy, the group should work directly with FEMA to understand what the near term options are for improved mapping. The next Flood Insurance Study update is planned for the San Diego region in 2012.

Strategies for Local Implementation

While the previous strategies were geared towards collaborative regional implementation, the following four strategies are intended to be considered by each Steering Committee jurisdiction for implementation at the agency level. These strategies address at a high level many of the vulnerabilities identified in the vulnerability assessment.

7. Institutionalize or mainstream sea level rise adaptation by incorporating sea level rise and associated impacts into relevant local and regional plans and projects.

Public agencies on San Diego Bay are designing infrastructure, permitting development projects, and restoring critical habitat that is expected to serve community needs well into the 21st century. Local governments can ensure that these investments stand the test of time by incorporating sea level rise adaptation directly into local plans and policies. Stand-alone adaptation strategies can be useful in educating the community and coordinating action, but ultimately, climate adaptation must become "standard operating procedure" across a variety of departments and disciplines. The following plans include goals and policies that will be affected by sea level rise and as such are appropriate documents for integrating sea level rise adaptation:

- General Plans;
- Specific or Community Plans;
- Local Coastal Programs;
- Port of San Diego Master Plan;
- San Diego International Airport Master Plan
- Regional Aviation Strategic Plan;
- Flood Mitigation Plans;
- Multi-jurisdictional Hazard Mitigation Plan;
- Habitat Conservation Plans;
- Regional Comprehensive Plan and Smart Growth Concept Map;
- Regional Climate Action Strategy;
- Regional Transportation Plan/Sustainable Communities Strategy;
- San Diego Integrated Regional Water Management Plan;
- Green Book Design Standards for Capital Projects.

8. Consistently utilize guidance provided by the State of California Climate Action Team in developing sea level rise assumptions for planning purposes.

The California Climate Action Team is an inter-agency group tasked with helping the state meet its climate mitigation and adaptation goals. The Coastal and Ocean Resources Working Group (CO-CAT) has issued guidance for sea level rise assumptions that should be referred to in local decision-making: [7]

i. Use the ranges of SLR presented in the December 2009 Proceedings of National Academy of Sciences publication by Vermeer and Rahmstorf[8] as a starting place and select SLR values based on agency and context specific considerations of risk tolerance and adaptive capacity.
ii. Consider timeframes, adaptive capacity, and risk tolerance when selecting estimates of SLR.
iii. Coordinate with other state agencies when selecting values of SLR and, where appropriate and feasible, use the same projections of SLR.
iv. Future SLR projections should not be based on linear extrapolation of historic sea level observations.
v. Consider trends in relative local mean sea level.
vi. Consider storms and other extreme events.
vii. Consider changing shorelines.

9. **Perform more detailed vulnerability assessments at a site-specific level as significant plans or capital projects are undertaken**.

Looking carefully at specific locations will enable local agencies to more thoroughly determine the vulnerabilities associated with future sea level rise projects. This assessment could be in the form of a land survey that would better inform developers of the nature and type of future flooding and other sea level rise impacts. This strategy would best be implemented by identifying the types and locations of projects that would trigger additional analysis in advance. This pre-identification would help to ensure that projects that should be thoroughly reviewed for future vulnerabilities are properly analyzed.

10. **Develop decision-making frameworks in each jurisdiction for selecting and implementing appropriate management practices in communities vulnerable to inundation or regular flooding.**

Sea level rise management practices can include hard defenses, soft defenses, accommodation, managed retreat, and limitations on new development, each of which presents particularly opportunities and constraints.[9] Collaboration with other jurisdictions will be critical when implementation of these management practices needs to be coordinated, such as when a sea wall extends across jurisdictional boundaries.

[7] State of California Sea Level Rise Interim Guidance Document

[8] Vermeer, M. & Rahmstorf, S. (2009). Global sea level linked to global temperature. Proceedings of the National Academy of Sciences of the United States of America. Available Online: http://www.pnas.org/content/106/51/21527.full.pdf+html

[9] The Management Practices Toolbox in Section 5 can be used to better understand and ultimately implement this strategy. The toolbox provides information on four different management approaches and the opportunities and constraints of these approaches as identified at the Adaptation Strategy Stakeholder Workshop #2.

4. SECTOR VULNERABILITIES AND TARGETED STRATEGIES

This section presents the vulnerability assessment findings in greater detail, and offers recommendations for potential adaptation policy responses to each primary vulnerability. The section is organized by the following 11 functional sectors that framed the vulnerability assessment and recommendations:

- Ecosystems and critical species
- Contaminated sites
- Stormwater management
- Wastewater
- Potable water
- Local transportation facilities
- Building stock
- Emergency response facilities
- Parks, recreation, and public access
- Regional airport operations
- Vulnerable populations

The targeted strategies were developed through an intensive process of evaluation in consultation with the Technical Advisory Committee and Stakeholder Working Group. The evaluation was guided by the following evaluation criteria identified in Workshop #2:

A) Is the strategy within the purview of a Steering Committee jurisdiction?

B) Does the strategy build off existing policies and funded programs?

C) Is the strategy flexible enough to respond to changing circumstances?

D) Does the strategy complement efforts to reduce GHG emissions?

E) Does the strategy protect and promote:

- Economic and social well-being
- Public safety and security
- Public health
- Environmental justice
- Species and habitat protection
- Ecological function
- Public access to coastal beaches, natural shoreline, parks and recreational facilities
- Critical infrastructure
- Community character

F) Does the strategy address the planning and design of new development?

G) Does the strategy facilitate adaptation in existing communities?

Ecosystems and Critical Species

The San Diego region is valued by tourists and residents alike for its natural beauty and biodiversity. The region, which is known to be home to many threatened or endangered species, created a regional Multiple Species Conservation Program (MSCP) that designated approximately 23 percent the planning area as being of high species value. This section evaluates the vulnerabilities of upland ecosystems, nearshore transitional ecosystems, and subaquatic ecosystems around San Diego Bay, and suggests responses that could contribute to their resilience.

The most vulnerable ecosystems and habitat on the Bay are intertidal ecosystem types, which experience both dry and wet patterns on a regular basis. In the Bay, these include marshes, tidal flats, tidal creeks, and the rocky intertidal zone. Regionally significant locations include the Sweetwater Marsh, Paradise Marsh, J Street Marsh and tidal flats, and the vernal pools of Otay Mesa. While protected by dikes, the South Bay Salt Ponds are also home to many of the species prominent in intertidal ecosystems. Intertidal ecosystems in South Bay are a key location on migratory bird routes, and support multiple federally-listed plant and animal species, including:

- California least tern (endangered)
- Light footed clapper rail (endangered)
- Western snowy plover (threatened)
- Salt marsh bird's beak (endangered)

The San Diego Bay upland ecosystem consists primarily of undeveloped dry lands around the Bay. These areas can be found directly adjacent to transitional or aquatic ecosystems, as well as interspersed with the built environment. On the north side of the Bay, the area around Famosa Slough and the Least Tern nesting habitat in the airport provide significant upland habitat. On the southern portion of the Bay, upland ecosystems include the Silver Strand dune system and upland areas east of Sweetwater Marsh and south of the salt ponds that falls within the National Wildlife Refuge. Although the upland areas have experienced extensive human disturbance, portions of these uplands provide important habitat for ground nesting birds.

San Diego Bay's subtidal ecosystem is defined by its warm nutrient-rich composition, the shelter it provides from waves, and the protection it provides from marine predators. Eelgrass beds in San Diego Bay play a crucial role for area wildlife and economic life. These beds, which make up nearly 20% of all eelgrass habitat in California, support a variety of ecologically important species and play a key role in supporting area fisheries. Specifically, the endangered Eastern Pacific green sea turtle forages in the eelgrass beds in San Diego Bay. The shallow, hypersaline subtidal waters around the South San Diego Bay shoreline also support a great diversity of fish indigenous to the area.

Figure 4.1 Sweetwater Marsh, King Tide. 02.17.11, morning : ~7.0 feet above mean low tide.

Primary Vulnerabilities

- Bay ecosystems, which provide habitat for many endangered and threatened species, are extremely vulnerable to **inundation** that is expected to result in habitat shift. These shifts could cause the loss of irreplaceable habitats for critical species in many areas.
- Upland areas are vulnerable to **erosion**, and fisheries, piscivorous birds and aquatic plants are threatened by erosion of upland areas when it results in degraded water quality.

Primary Vulnerability – Inundation and Habitat Loss

San Diego Bay's ecosystems are extremely vulnerable to the effects of inundation, chief among them habitat loss. Intertidal ecosystems and habitat, in particular, are finely calibrated to the environmental conditions created by water level and tidal dynamics, such as water salinity, water temperature, and sediment erosion and accretion. When sea level rises, more intertidal areas will be inundated or regularly flooded, creating wetter and higher-salinity conditions that place stress on ecosystems adapted to existing conditions. In response, ecosystems and the species they support will try to shift, generally towards higher elevations landward that could become more like today's marshes and wetlands when water level rises.

Unfortunately, most of these upland areas around the Bay have been developed, and ecosystems are likely to be squeezed against adjacent developed areas, limiting their ability to adapt and ultimately resulting in habitat loss. This dynamic could drastically impact intertidal and upland ecosystems and the endangered and threatened species that depend on them. Moreover, intertidal ecosystems help protect and sustain subtidal ecosystems, which will also be vulnerable as neighboring biodiversity is lost and the water quality benefits of wetlands are compromised.

Exposure

Of different habitat types around the Bay, intertidal ecosystems are most exposed to inundation in both the 2050 and 2100 planning scenarios, followed by upland habitat in a few areas. Inundation is limited in the 2050 horizon, and becomes systemic towards end-of-century. The following exposure patterns are likely in intertidal areas:

- Sweetwater Marsh and J Street Marsh and tidal flats will gradually experience greater inundation going forward, with the rate of this change accelerating over time.
- A portion of the South Bay Salt Ponds may be exposed under the 2050 sea level rise scenario, with inundation affecting the majority of the ponds under the 2100 sea level rise scenario. It should be noted that these exposure estimates do not account for the levees that may protect the ponds from inundation.

In upland areas, the following exposure patterns are indicated in the inundation mapping:

- Silver Strand dune system could experience regular inundation and periodic flooding under both the 2100 and the 2050 sea level rise scenarios. In the 2100 sea level rise scenario the flooding will encompass the entire dune area, while in the 2050 sea level rise scenario, the flooding will be limited to lower elevations.
- The upland habitats east of Sweetwater Marsh could experience a combination of inundation and flooding under both the 2100 and 2050 sea level rise scenarios.
- The upland habitats south of the salt ponds may not experience inundation in either 2050 or 2100. However, the areas could experience significant periodic flooding during both scenario years, depending on the functioning and height of the salt pond levees.
- The Least Tern nesting habitat in the airport will not be exposed except under the 2100 Extreme Event scenario.
- Other Least Tern nesting habitat throughout the planning area, including Navy-managed sites, the D street fill and the Navy's mitigation wildlife island, are likely to be exposed under the 2100 Extreme Event scenario.

Habitat shift is an expected outcome of exposure to inundation. Habitat shift on San Diego Bay has been evaluated through a SLAMM (Sea Level Rise Affecting Marshes Model) model run developed by Dr. Rick Gersberg at San Diego State University. Although there is uncertainty in the results of the SLAMM, the model does provide information on the range of habitat shifts that are possible for different ecosystem types. The model shows a decline in intertidal ecosystems as a whole, as well as upland habitat declines. Subtidal ecosystems are expected to expand as existing salt marsh is inundated.

Sensitivity

While coastal ecosystems are generally not impaired by periodic flooding events, they are highly sensitive to long-term changes in sea level. Ecosystems are highly dependent on specific patterns of tidal fluctuation, water salinity, water temperature, sediment erosion and accretion, sediment saturation, interaction with the water table, and interaction with riverine freshwater sources. When these conditions change significantly over an extended period of time—as is seen with rising water levels—many coastal ecosystems and habitat cannot be sustained in place. Intertidal and upland ecosystems are particularly sensitive to these types of changes. Subtidal ecosystems are less sensitive, since they are already submerged, but they may be sensitive both to impaired water quality from the loss of adjacent wetlands and to increased water depths that change temperature and salinity.

Figure 4.2 Eelgrass provides important habitat for such species as the Bay Pipefish

In addition to the sea level rise-related factors described above, San Diego Bay ecosystems are made more sensitive to inundation by human activities in the region. Neighboring development contributes to the degraded water quality of the Bay and reduces the amount of necessary sediment that the areas receive. Pollutants from runoff and from contaminated sites contribute to the sensitivity of these habitats. Specifically, there are 274 water body segments in the area listed as impaired through the

Clean Water Act (303(d) List). Adverse conditions related to both sea level rise and regional development make San Diego Bay ecosystems highly sensitive to inundation and related habitat pressure. In the future, a more finely tuned SLAMM analysis with refined sediment transport analysis could provide a better quantified sensitivity level.

Adaptive Capacity

Ecosystems and habitat around the Bay have some capacity to cope with periodic flooding in the near term, but limited capacity to adapt to regular, sustained inundation. With regards to short-term coping capacity, intertidal ecosystems are already resilient to periodic high water levels that result from spring tides, El Niño events, and storm surge. Similarly, upland plants generally are tolerant to salt spray occurring during high water events. What is unclear is how much more frequently these periodic events can occur before a threshold is reached in terms of flood coping capacity.

In their natural state, the types of ecosystems found on San Diego Bay generally also have a high capacity to adapt to regularly-occurring inundation. A key adaptive response is to migrate to higher elevations where tidal dynamics and salinity are similar to the previous location before sea level rise. However, this adaptive response is not available to many ecosystems on San Diego Bay, because adjacent, higher elevation lands have been intensively developed over the past century. For example, coastal salt marsh in the Sweetwater Marsh and Paradise Creek Marsh areas may be pressured to shift eastward, but will be unable to do so as it encounters hardened shoreline at Interstate 5 and adjacent developed areas. This dynamic is likely to play out in intertidal and upland ecosystems throughout the region, resulting in low natural adaptive capacity for many ecosystem and habitat types, and for the species that rely on them.

Adaptive capacity is improved by the civic and institutional assets available for natural resource management in the region. These include designation of South Bay as a National Wildlife Refuge, managed by US Fish and Wildlife Service; capacity-building and research activities at Tijuana River National Estuarine Research Reserve (TRNERR); an active environmental community; and a general population that values the region’s natural resources. In spite of these assets, the overall adaptive capacity of Bay ecosystems and critical species is limited.

Overall, the vulnerability of ecosystems and critical species to inundation and habitat loss generally is very high, due to extensive exposure, high sensitivity, and low adaptive capacity. Intertidal and upland ecosystems and resident species are especially vulnerable to these impacts.

Targeted Strategies

The following strategies are options for addressing the **flooding, inundation, and habitat loss** vulnerabilities of ecosystems and critical species, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Strive to create habitat mitigation projects that are resilient to sea level rise. Evaluate how mitigation projects will be affected and encourage acquisition of upland areas also when analysis indicates that acquired nearshore habitat will be lost to sea level rise.

2) Expand or preserve ecological buffers around development, where feasible, to allow for inland migration of ecosystems and habitats.

3) Promote soft and hard low-impact development (LID) strategies to reduce stormwater runoff and protect water quality.

4) Evaluate threats to habitat connectivity, and protect habitat corridors to facilitate species shift to viable adjacent habitat as an adaptive response to sea level rise.

Primary Vulnerability – Erosion

Sea level rise-related erosion poses a threat to upland and subtidal ecosystems of San Diego Bay. Erosion depends in part on the amount of along-shore transport caused by water flow, the frequency and intensity of storms, the amount of re-supply (i.e. sand or soil) available, as well as the management practices and planning decisions. Taken together these factors indicate that higher sea levels are likely to result in increased erosion in upland ecosystems, bringing more sediment and turbidity to fragile shallow water ecosystems.

Sensitivity

Most completely natural, unaltered environments would not be greatly impaired by erosion. An exception is a narrow dune system bordered by both ocean and Bay waters—such as that found on Silver Strand—which would have a higher sensitivity even in a natural state. Ecosystems around the Bay, however, are more sensitive to erosion due to human activity in the region. Neighboring development and ever increasing development pressure make upland ecosystems more sensitive, while the lack of natural buffers and the presence of contaminated sediments make subtidal ecosystems more sensitive. The Bay's sediment is contaminated by a variety of different toxins including copper, mercury, PAHs, PCBs, and zinc. These toxins, which resulted in 20 federal listings of the Bay's sediments being impaired according to the Clean Water Act (303(d) List), pose a serious threat to the health of the subtidal aquatic ecosystem. These factors suggest that upland and subtidal ecosystems are moderately sensitive to erosion. Further research around the area's erosion and sediment transport processes and aquatic species' ability to tolerate certain turbidity levels could provide a more precise sensitivity level.

Adaptive Capacity

Upland ecosystems have a very limited capacity to adapt to systemic erosion over the long term. The subtidal system has mechanisms that currently help it to cope with the amount of erosion it experiences. A dramatic increase in erosion, however, could bring its adaptive capacity to a tipping point and prevent the system from functioning in the way it currently does. The governmental and social assets describing in the inundation section – state and federal resource management agencies, local nonprofits and citizen concern – may help build ecosystem adaptive capacity. Specifically, the implementation of the Otay River Habitat Restoration Plan and the pending completion of the Sub Area Management Plan (SAMP) for the Otay watershed could reduce erosion and enhance accretion of salt marsh habitat. This system's ability to maintain its current dynamics is relatively low, and although the natural environment is likely to evolve into a new steady state, it may not be one that can maintain the area's valued species or supply the region with other highly valued ecosystem services.

The overall vulnerability of the upland ecosystems to erosion is very high due to definite future exposure, high sensitivity and low adaptive capacity. The vulnerability of subtidal ecosystems is more moderate, due to lower sensitivity to erosion and greater adaptive capacity.

Targeted Strategies

The following strategies are options for addressing the **erosion** vulnerabilities of ecosystems and critical species, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Pursue research on sediment transport dynamics that improves understanding of both erosion and sedimentation. Adjust sediment management practices in response to research findings.

2) Improve the health of wetlands that provide natural buffers between sediments and subtidal habitat.

Contaminated Sites

According to the databases of the California Department of Toxic Substance Control and the California Water Resources Control Board, there are more than 400 sites in the planning area that have undergone review or clean up for being contaminated. These sites include operating hazardous waste sites, school clean up sites, voluntary clean up sites, leaking underground storage tanks (LUST), and others. Among these sites, local stakeholders have articulated concerns about the following:

- Tow Basin Facility, covering 1.41 acres in Harbor Island East Basin in San Diego.
- Several waste sites located at Naval Air Station North Island (NASNI), including the homeporting pier, Installation Restoration (IR) Site 9 (commonly referred to as fiery marsh), and the North Island Hazardous Waste Facility Complex.[10]
- The 24th Street Marine Terminal Landfill (Formerly PACO terminals) located in National City near the intersection of Terminal Avenue and West 32nd Street.[11]
- Campbell's Shipyard, located just south of the convention center.[12]
- The former Teledyne Ryan Aeronautical (TRA) facility adjacent to the San Diego International Airport.[13]
- Convair Lagoon, a 5.7-acre underwater confined disposal facility (CDF) site in the northern part of the Bay near the airport.
- The former San Diego dump site under the Convention Center expansion.

Primary Vulnerabilities

- Hazardous waste sites are highly vulnerable to major **flooding** events as storage tanks in the area could be opened or moved, or motors and pumps could be impaired, thus releasing contamination into flood waters or area soils.

Primary Vulnerability – Flooding and Inundation

Flooding and inundation pose a threat to hazardous waste sites throughout the San Diego Bay region. This section describes the vulnerability of the system as a whole in terms of exposure, sensitivity, and adaptive capacity looking specifically at exposure to both flooding and inundation under the various planning scenarios, as shown in Maps 5-8 in Appendix III.

Exposure

GIS exposure analysis indicates that potential flooding and inundation in 2050 would expose a very limited number of contaminated sites, and none of the sites of stakeholder concern. Inundation and flooding under the 2100 sea level rise scenarios could affect many more sites, including 24th Street Marine Terminal Landfill, Campbell's Shipyard, TRA, the former San Diego dump site, and several Naval Air Station North Island sites.

[10] 80001272 in EnviroStor
[11] L10005363930 in GeoTracker (http://www.geotracker.swrcb.ca.gov/)
[12] T0607391327 in GeoTracker
[13] SL209054180 in GeoTracker

Sensitivity

The strict regulatory process that governs hazardous waste clean up and management greatly affects the system as a whole. Generally, these high standards help to ensure that sites are thoroughly cleaned up and well managed; however, sites are not required to be cleaned up to a 100% standard and there are trace levels left behind. The high level of rigor involved in this process greatly reduces the system's overall sensitivity, helping to ensure that few factors (including shifts in environmental conditions) will cause regional problems.

Adaptive Capacity

This system as a whole has a number of regulatory, technological, and civic resources available to help it adapt. Despite these resources, the system could be overwhelmed by significant amounts of flooding and the lack of financial resources available to achieve a high enough level of clean up, and there was disagreement among technical advisors on adaptive capacity. Acknowledging this, the system of contaminated sites could be said to have a medium level of adaptive capacity.

Due to limited exposure, low sensitivity, and moderate adaptive capacity, the overall vulnerability of contaminated sites to flooding and inundation is low to moderate.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of contaminated sites, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Conduct a targeted assessment of specific high-risk contaminated sites, resulting in a map of these sites and utilize findings to prioritize adaptation responses where sites are vulnerable.

2) Conduct an improved regional assessment, in conjunction with the Navy, focused on the different types of sites and their specific vulnerabilities to future conditions.

3) In new remediation, ensure that BMPs are designed to be resilient to end-of-century sea level rise.

Stormwater Management

The stormwater management system in the San Diego Bay area consists of storm drains and a variety of best management practices (BMPs) that are designed to manage the volume, flow, and water quality of runoff during storm events. These BMPs include detention ponds, in-line BMPs that restrict runoff flow inside the storm drain, and infiltration BMPs—such as bioswales and rain gardens—that allow runoff to percolate into the ground instead of entering the storm drain system. Stormwater systems in the area are municipal separate storm sewer systems, which convey runoff separately from wastewater. These systems are designed, constructed, and operated by the individual local jurisdictions on the Bay.

Primary Vulnerabilities

- In all scenarios, storm sewers are very vulnerable to **flooding and inundation** of Bay drain outfalls due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas.
- This vulnerability will be compounded during storm conditions, when runoff in these drains would be obstructed by inundated outfalls, resulting in backwater flooding in low-lying areas.

Primary Vulnerability—Flooding and Inundation

The stormwater management system is vulnerable to impacts relating to flooding and inundation. This analysis addresses impacts *on* the stormwater system and the system's ability to minimize flooding and protect water quality; it does not evaluate all the impacts of storm-related flooding on other systems such as buildings. This section describes the vulnerability of the stormwater management system in terms of exposure, sensitivity, and adaptive capacity to flooding and inundation.

Exposure

The primary exposure concern is the inundation of storm drain outfalls on the Bay as sea level rises. Under high water conditions, water from the Bay flows through the outlet into the storm drain to the current sea level elevation. These conditions are exacerbated during storms, when stormwater runoff cannot drain due to inundation of the Bay outlets. This dynamic is of particular concern in inland areas located at or below sea level with shallow, minimally sloped drainage systems, and some areas already have outfalls that are tidally-influenced, including parts of the Airport and Midway districts, Shelter Island Drive, National City near Kimball Elementary School, and parts of Coronado generally within 100 feet of the shoreline.

Figure 4.3. Flooded Storm Drain Outfall. 01.20.11, morning : ~7.2 feet above mean low tide.

It is beyond the scope of this project to assemble comprehensive GIS data on storm drain elevation and evaluate site-specific exposure under the four planning scenarios. However, as described above, many sites are already exposed, and technical advisors expect the number of exposed sites to multiply under the 2050 scenarios.

The Chula Vista Bayfront is a notable exception. Plans for the redevelopment of the Bayfront call for elevating infrastructure to allow for gravity flow to higher outfalls that would not be submerged, thereby reducing their exposure. This response is designed to mitigate a 19-inch sea level rise by the 2050 timeframe. Even with this effort, several advisors concluded that the 2100 scenarios would result in systemic inundation of drainage systems across the Bay region.

Sensitivity

Stormwater management systems described above would be highly sensitive to inundation, particularly during storm events. Drainage systems will be impaired and flooding likely will result if drains are obstructed for a significant period of time.

Adaptive Capacity

Technical advisors consider the adaptive capacity of the stormwater system to be very low. In the short term, the system cannot cope with obstructed outfalls and flooding could persist until they are unobstructed. In the longer term, adaptation could require expensive reconstruction of drainage systems and financial resources are limited. However, advisors noted that well-established standards and governance structures, as well as civic support for improving water quality, could support adaptive capacity in the long run.

In conclusion, the stormwater management system in the Bay region is highly vulnerable to flooding and inundation impacts from sea level rise.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of stormwater management facilities, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Prioritize low-impact development (LID) stormwater practices that encourage infiltration to minimize reliance on storm sewers that could be impaired by SLR.

2) Update stormwater management plans and capital improvement programs to account for sea level rise-related challenges such as flooded Bay outfalls. Include strategic consideration of systemic reconstruction of stormwater facilities in the later-century timeframe.

3) Develop a detailed vulnerability assessment of stormwater management at the facility level for the most at-risk facilities, including drain outfalls and areas that could be exposed to localized flooding from Bay water inflow into drains.

4) Increase capacity of stormwater management facilities to accommodate more common and more extensive coastal flooding.

Wastewater

The regional wastewater system consists of facilities that collect and treat wastewater. Wastewater collection infrastructure in the planning area includes gravity mains, force mains, pump stations, holding tanks, and metering stations. There are no treatment facilities in the planning area. Local sanitary sewers are operated by each of the cities and fed into a regional collection system operated by the City of San Diego's Metropolitan Wastewater District (MWD). Port lands are served by these city-operated sewers within each city's boundaries.

Primary Vulnerabilities

- Sanitary sewers in low-lying locations will be vulnerable to **flooding** and could exceed their capacity during the 2050 Extreme Event scenario, potentially resulting in discharge of wastewater into the Bay.
- The entire wastewater collection system in the planning area will be vulnerable to **inundation** impacts by 2100.

Primary Vulnerability—Flooding and Inundation

The sanitary sewer system is vulnerable to future flooding and inundation impacts. This section describes the vulnerability of major system components in terms of exposure, sensitivity, and adaptive capacity under the four planning scenarios.

Exposure

Buried sewer infrastructure will be exposed to surface flooding under each of the planning scenarios. Sewer mains buried below flooded areas will be exposed to the extent that they are susceptible to inflow, where flood waters penetrate through manholes and other surface components. In 2050, it is likely that exposure to periodic flooding will be the main concern. In 2100, perhaps hundreds of linear miles of mains would be exposed below inundated lands on a daily basis. In addition to sewer mains, many pump stations and metering stations are buried in potentially exposed areas. Several pump stations are located in above-ground buildings that could be exposed to flooding as well. GIS analysis was performed to determine potentially exposed pump stations and metering stations under the four planning scenarios; the region's most significant facilities—Pump Stations 1, 2, 4, and the Transbay Pump Station—are not exposed in 2050, but are exposed in 2100. Exposure is also shown in Maps 9 and 10 in Appendix III.

Sensitivity

Components of the wastewater collection system would be sensitive to flooding or flood-related inflow if exposed. Gravity sewer mains are more sensitive to inflow than potable water mains because they are not pressurized. Significant floodwater inflow into sewer mains would cause their flow capacity to be exceeded, resulting in sewage backups potentially overflowing out of manholes and through storm drains into the Bay. Wastewater collection would be similarly impaired by pump station damage from exposure to floodwaters if conveyance was interrupted. Segments of the sanitary sewer not directly exposed to flooding would still be sensitive to impacts "downstream" due to the linear nature of the system. If exposed to severe flooding or inundation, the ability of the area's sewer systems to perform their function in a way that protects public health and water quality could be seriously compromised.

Adaptive Capacity

In the short-term, the wastewater collection system's ability to cope with flooding impacts is very low. Wastewater is conveyed through a linear system with a series of "chokepoints" and if a part of this system is impaired, there is little redundancy in the system to rely on. Over the longer-term, the system may benefit from substantial assets related to governance, environmental advocacy, and technology that may enable adaptive measures such as increased preventive maintenance, construction of overflow tanks, or reconstruction of mains.

Overall Vulnerability to Flooding and Inundation

Above-ground facilities are not very vulnerable to surface flooding and inundation until the 2100 scenarios.[14] Buried infrastructure will be vulnerable to periodic floodwater inflow in limited areas in the 2050 Extreme Event scenario, and would be vulnerable to inflow from regularly-occurring inundation in many areas by 2100.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of wastewater management facilities, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Update wastewater management plans and capital improvement programs to account for sea level rise-related challenges.

2) Develop a detailed vulnerability assessment of wastewater facilities including future sea level rise impacts for the most at-risk facilities, and work towards a map of these facilities.

3) Update wastewater emergency response and maintenance procedures to account for more common and more extensive coastal flooding of vulnerable infrastructure.

4) Depending on facility design, elevate pump stations and emergency generators as they are rehabilitated or in new construction.

5) Ensure that new sewer mains and manholes are sealed against floodwater inflow and groundwater infiltration. Expand programs to reduce inflow and infiltration through rehabilitation of sewer mains and manholes, prioritizing areas where risk of flooding is highest.

[14] City of Imperial Beach and City of National City above-ground facilities were not evaluated in detail due to unavailability of data.

Potable Water

Potable water systems in the planning area consist of distribution facilities such as pressurized water mains, pressure-reducing valves, and meter vaults. The only water source in the planning area is groundwater drawn from the San Diego Formation aquifer by the Sweetwater Authority. There are no water collection facilities (such as reservoirs) or water purification facilities. Potable water distribution is operated by the City of San Diego within San Diego city limits, the Sweetwater Authority in Chula Vista and National City, and California American Water in Imperial Beach, Coronado, and a small part of southwest Chula Vista. Port lands are also served by these entities.

Primary Vulnerabilities

- Above-ground water distribution components such as valves, meters, and service points will be vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring inundation.

Primary Vulnerability – Flooding and Inundation

The potable water system is moderately vulnerable to flooding and inundation in the 2050 scenarios, and more vulnerable in the 2100 scenarios. Much of the potable water distribution system is buried underground and would not be exposed to surface flooding. However, some components such as hydrants, valves, service access, and meters could be exposed under the four planning scenarios. Data on the location of these components was not available for the entire planning area. However, an analysis performed by the City of San Diego Public Utilities Department found that 12 hydrants, 77 service points, 30 valves, and 28 meters in the planning area could be exposed in a 2050 "daily conditions" scenario. While a complete spatial analysis of the region could not be performed, flood exposure in the 2050 scenarios would appear to be minor relative to the total number of facilities in the coastal area.

Exposed mechanical equipment in the water distribution system would be sensitive to the flooding impacts. In the short-term, however, the capacity of the broader system to adapt to periodic flooding is good, due to the ability to isolate impaired parts of the distribution system and maintain service to the rest. The system does not have capacity to cope with regular, daily inundation. Over the longer-term, the system's adaptive capacity may benefit from access to substantial resources associated with being one of the most critical facilities in the region.

Figure 4.4. Construction in pipe trenches, Coronado. 02.17.11, 8:50am : ~6.7 feet above mean low tide.

Overall, the area's potable water systems are not very vulnerable to flooding impacts in the 2050 timeframe, as exposure is likely to be limited and adaptive capacity is substantial. Vulnerability in the 2100 timeframe is likely to be high, however, as more of the system is exposed to daily inundation.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of potable water facilities, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Develop a detailed vulnerability assessment of potable water facilities including future sea level rise impacts for the most at-risk facilities. Evaluate the flood-resistance of specific mechanical equipment in areas vulnerable to future SLR-related flooding.

2) Update potable water emergency response and maintenance procedures to account for more common and more extensive coastal flooding in vulnerable areas.

Energy Facilities

Energy facilities in the San Diego Bay area consist mostly of electricity and natural gas transmission and distribution systems. High voltage transmission lines run north-south near the eastern shore of the Bay, above ground in many areas and buried in the vicinity of the Chula Vista bayfront. Lower voltage distribution lines are located throughout the planning area. Additionally there are several electrical substations around the Bay. There are no major electricity generation facilities in the area; the South Bay Power Plant on the southern Chula Vista bayfront was taken out of operation in January 2011. Natural gas infrastructure includes pressurized distribution lines and auxiliary equipment such as maintenance stations and meters. San Diego Gas and Electric (SDG&E) is the primary provider of electricity and natural gas throughout the San Diego region, including in the Bay cities and Port lands.

Primary Vulnerabilities

- Above-ground electricity transmission and distribution in limited areas will be vulnerable to **erosion**, particularly after 2050 and during major storm events. Erosion could undermine infrastructure, causing outages or safety issues.
- Above-ground electricity transmission and distribution will be moderately vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring flood events.

Primary Vulnerability—Erosion

Exposure

Local electricity distribution is likely to be the component of the energy sector most exposed to erosion, as most high-voltage regional transmission and gas distribution is either buried or well-protected from flooding. The extent of exposure to erosion in the future is unknown due in part to the fact that the amount of future erosion is related to the management practices and planning decisions yet to be made. However, most energy infrastructure in the coastal area is adjacent to hardened shoreline, which is less affected by erosion, so exposure will likely be limited to such areas as beaches and open space that have non-hardened shorelines. In addition to shoreline erosion, local distribution lines may be affected by erosion caused by storm-related runoff and localized flooding in inland areas such as the Midway and the Paradise Creek area; storm-related flooding is likely to be exacerbated by higher Bay water levels impairing storm drains.

Sensitivity

Erosion can wash away supporting soils around utility poles and protective fences, causing serious system-wide impacts that could require significant time and expense to repair. Additionally, these impacts could cause safety concerns such as fire for nearby communities.

Adaptive Capacity

In the short term, parts of the system are able to cope with erosion events; for example, substation sites are graded to divert waters away from facilities and to prevent erosion. However, the system's long-term adaptive capacity is low because primary solutions such as relocation are very costly and could require the de-energization of affected facilities.

The overall vulnerability of energy facilities to erosion is somewhat unclear, due to a lack of understanding of the location, timing, and severity of exposure. However, much of the system will be protected, particularly in the 2050 timeframe. As exposure to erosion expands later in the century, the system will be highly sensitive and not very adaptable, and is likely to be very vulnerable as a result.

Primary Vulnerability—Flooding and Inundation

Exposure

The exact flooding exposure locations have not been identified for this assessment due to the unavailability of spatial data for the electricity and natural gas systems. However, generally the system is not significantly exposed in either of the 2050 planning scenarios. In 2100, electricity transmission and distribution could be exposed during both daily conditions and extreme events, including parts of the high voltage line on the eastern Bay shoreline.

Sensitivity

The electricity transmission and distribution system is only moderately sensitive to flooding. Energized equipment is not at ground level and is structurally engineered to withstand some flood events, so minor flooding is not expected to cause equipment failure. However, as the number and severity of flooding events increase later in the century, the system may become more impaired.

Adaptive Capacity

In the short-term, the electric facilities system has a high coping capacity because underground and overhead utility structures and energized lines are designed to withstand a flood event current minor flood events. However, the long-term adaptive capacity options for this system are highly costly and include the relocation of lines and potentially the need to de-energize facilities.

Overall Vulnerability to Flooding and Inundation

It is not possible to judge the exact electric facilities system's overall vulnerability to flooding and inundation, due to a lack of comprehensive data on the location of specific facilities. Vulnerability is likely to spike during major storm and high water events, with vulnerability increasing after the mid-century timeframe. When infrastructure is exposed, it will be moderately sensitive and not very adaptable, and is likely to be moderately vulnerable as a result.

Targeted Strategy

The following strategy is an option for addressing the **flooding, inundation,** and **erosion** vulnerabilities of energy facilities.

1) Work with SDG&E to evaluate site-specific vulnerabilities of energy infrastructure, and to design new facilities to be resilient to end-of-century sea level rise.

Local Transportation Facilities

Transportation facilities in the planning area include roads, transit facilities, marine facilities, and San Diego International Airport (SDIA), which is addressed in the Regional Airport Operations section of this assessment. Because planning for state roads and transit facilities are under SANDAG jurisdiction and marine facilities are exclusively under Port jurisdiction, this section focuses on facilities under local control, namely local roads.

Primary Vulnerabilities

- Local transportation facilities will be vulnerable to **flooding and inundation**, particularly in the 2100 timeframe when more components are likely to be exposed to regularly-occurring inundation.

Primary Vulnerability—Flooding and Inundation

Exposure

Local roads are not at great risk of exposure in the 2050 time frame, but are likely to be impacted in every Bay jurisdiction by 2100. Major local roads that could be exposed are described in Table 4.1.

Sensitivity

Transportation facilities are sensitive to flood-related impacts, as the access function of roads would be impaired if exposed to flooding. Local transportation systems as a whole would be less sensitive, however, as most traffic could be re-routed onto unaffected streets. In the 2100 Daily Conditions scenario, access on significant local streets could be permanently impaired and would be very sensitive to regular inundation.

Adaptive Capacity

Local streets do not have significant capacity to cope with flooding and inundation when they are exposed. Over the longer term, adaptive capacity is also minimal. Potential adaptive responses are limited because local access streets in hazardous areas cannot be relocated; by their nature, they must be located to serve development where it exists, even if in flood-prone areas. Overall, adaptive capacity of local transportation facilities is very low.

Due to limited exposure, vulnerability of local transportation facilities around San Diego Bay in the 2050 timeframe is low, though specific facilities noted in the table above are more vulnerable. In later scenarios, vulnerability is high as more facilities are exposed, and because sensitivity is high and adaptive capacity is very low.

Table 4.1 Exposure of Significant Local Transportation Facilities

2050 Daily Conditions	2050 Extreme Event	2100 Daily Conditions	2100 Extreme Event
None	*National City*—18th and 24th Streets at Paradise Creek	*National City*—18th and 24th Streets at Paradise Creek *San Diego*—Shelter Island Drive at Shelter Island entrance *San Diego*—N. Harbor Drive at Laurel St. *San Diego*—Harbor Drive between W. Market St. and 5th Ave. *Chula Vista*—parts of the Bayfront, depending on form of redevelopment	*National City*—18th and 24th Streets at Paradise Creek *San Diego*—Shelter Island Drive at Shelter Island entrance *San Diego*—Multiple streets in the Midway *San Diego*—Most of N. Harbor Drive *San Diego*—Harbor Drive between W. Market St. and 5th Ave. *Chula Vista*—parts of the Bayfront, depending on form of redevelopment

Targeted Strategies

The following strategies are options for addressing the **flooding** and **inundation** vulnerabilities of local transportation facilities, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Design new local transportation projects to be resilient to sea level rise. Consider policies that require sea level rise to be factored into the design of all transportation projects and major repairs in areas vulnerable to flooding over the life of the project.

2) Work with SANDAG and Caltrans to evaluate the vulnerabilities of existing regional transportation facilities and to consider adaptation in the design of new facilities and in improvements to existing infrastructure in vulnerable areas.

3) Monitor changes in design standards relating to drainage, and consider applying floodplain-level standards in areas vulnerable to flooding in the life of the project but that may not be in existing 100-year floodplain.

Building Stock

Residential buildings in the planning area are concentrated in the San Diego-Barrio Logan, National City, and Coronado areas. Other concentrations of residential buildings are the Imperial Beach Bernardo Shores RV Park and senior housing in the San Diego-Midway area. High-density housing is planned for the Chula Vista Bayfront and the San Diego-Centre City area. Housing is not an allowable use on Port-managed lands. For the purposes of this assessment, “commercial” buildings are all non-residential occupied structures, including office, retail, hospitality, institutional, and industrial uses. The Adaptation Strategy does not address structures or operations on Port-managed lands, because the Port is preparing a Climate Mitigation and Adaptation Plan accounting for these facilities. Therefore, this section only evaluates vulnerabilities of buildings under City jurisdiction.

Primary Vulnerabilities

- The building stock has a low vulnerability to **flooding and inundation** in the 2050 scenarios due to limited exposure. Buildings are highly-vulnerable to flooding and inundation in the 2100 scenarios as exposure expands to large portions of residential neighborhoods and major commercial districts.

Primary Vulnerability—Flooding and Inundation

The building stock in the planning area is vulnerable to flooding and inundation impacts. This section describes the vulnerability of commercial buildings in terms of exposure, sensitivity, and adaptive capacity under the four planning scenarios.

Exposure

In the 2050 planning scenarios, flooding affects very few commercial facilities under City jurisdiction, primarily in National City at Kimball School and auto shops near Paradise Creek and Hoover Avenue. In the 2100 planning scenarios, exposed facilities multiply considerably. In San Diego, commercial buildings on both sides of the Naval Boat Channel and in the Midway District are affected, particularly east of Rosecrans Street. The north side of Harbor Drive is exposed from Market Street to the railyards, including such commercial facilities as Petco Park stadium and multiple large hotels.

Figure 4.5 Hotel in Downtown San Diego. 01.20.11, 8:20am : ~7.1 feet above mean low tide.

In Chula Vista, much of the Bayfront redevelopment area is exposed to flooding in the 2100 scenarios; most commercial uses in the Bayfront redevelopment will be under Port jurisdiction, however. One exception that is exposed in the 2100 scenarios is the Goodrich Aerostructures manufacturing facility. Commercial building exposure to flooding and inundation is shown in Maps 11-14 in Appendix III.

Residential exposure in each of the planning scenarios is shown in Maps 15-18 in Appendix III. Very few residential neighborhoods are exposed in the 2050 planning scenarios; one potential area of concern is the Coronado Cays, but more analysis is needed to ascertain the effect of existing shoreline protection infrastructure in this area. In the 2100 scenarios, exposure occurs in the following residential areas:

San Diego

- East of Rosecrans Street, near Southwestern Yacht Club
- Multi-family neighborhood in the Midway district, north of Barnett Street and east of Rosecrans Street
- Multi-family buildings north of Harbor Drive

National City

- Single-family neighborhood west of Paradise Creek, near Interstate 5

Chula Vista

- Residential areas in the Bayfront

Imperial Beach

- Part of the Bernardo Shores RV park
- Single-family homes on 7th Street and 8th Street

Coronado

- Coronado Cays
- All housing on the east side of 1st Street

Sensitivity

Building sensitivity depends to a large degree on design and construction techniques, as set forth in building codes and standards. By participating in FEMA's National Flood Insurance Program (NFIP), all of the local jurisdictions have been required to adopt minimum building standards for flooding. Flood-related building codes were not standardized prior to NFIP requirements, which took effect in 1968. As a result, some structures built before 1968 will be more sensitive to flooding than their successors. One estimate concludes that buildings pre-dating NFIP experience 70 percent more damage on average than post-NFIP buildings when exposed to flooding.[15] This contrast suggests that year of construction is an important indicator of flood sensitivity. Of the exposed commercial buildings described above, almost all were constructed after 1968, with few exceptions in the lower Gaslamp area near Harbor Drive and at the Goodrich Aerostructures site. Older, more flood-sensitive homes are found in the Paradise Creek area in National City and 1st Street in Coronado. While these areas are likely to be most sensitive, all buildings are likely to be impaired if exposed to flooding.

Adaptive Capacity

Generally, buildings in the San Diego Bay area do not have the ability to cope with flooding in the short-term. Over the longer-term, individual building owners exposed to inundation will struggle to adapt as their property becomes unviable. The NFIP provides insurance for property owners in the case of flooding, but few models currently exist for allowing property owners to recover their losses and

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[15] Thompson, A., Katzman, G., and Johann, M.A., "Building Design for Extreme Events." *Structure.* National Council of Structural Engineering Associations, May 2007.

relocate as their property succumbs to inundation. For these reasons, the adaptive capacity of the building stock is very low.

Overall Vulnerability to Flooding and Inundation

In the 2050 scenarios, buildings under City jurisdiction have a low vulnerability to flooding and inundation due to limited exposure. In the 2100 scenarios, the building stocks become highly vulnerable as exposure becomes widespread and affects major commercial facilities. Vulnerability is heightened due to high sensitivity and low adaptive capacity to flooding and inundation impacts.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of the building stock, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) In areas vulnerable to projected SLR-related flooding and in the existing 100-year floodplain, consider strengthening floodplain management regulations through participation in the FEMA Community Rating System or through incorporation of more flood-resistant building code provisions.

2) Work with FEMA to improve Flood Insurance Rate Maps (FIRMs) and create additional maps that include future sea level rise.

3) Create financial incentives for buildings constructed to higher standards.

4) Create a real estate disclosure statement that requires more explicit statements regarding future risks.

5) Develop, enhance and distribute outreach and education materials for building owners and tenants in flood prone areas.

6) Gather more specific elevation data creating a better understanding of current base floor building elevations.

7) In areas vulnerable to projected SLR-related flooding that are not in the existing 100-year floodplain, consider applying NFIP minimum requirements to new development.

Emergency Response Facilities

Emergency response facilities evaluated in this assessment consist of police and fire stations operated by the 5 Bay cities, as well as hospitals with emergency care facilities in the planning area.

Primary Vulnerabilities

- Fire stations in San Diego and Coronado are moderately vulnerable to **flooding** in the 2100 Extreme Event scenario.

Primary Vulnerability—Flooding

Emergency response facilities are moderately vulnerable to flooding impacts. Flood exposure is limited to the 2100 Extreme Event scenario. Potentially affected facilities are Coronado Fire Station 14 (near Coronado Cays) and San Diego Fire Station 20 (in the Midway District), as shown in Maps 19 and 20 in Appendix III. These fire stations would be very sensitive to flooding when exposed. In addition to building damage, the stations could be impaired by damage to equipment and flooding of streets accessing the facility. In the short-term, the coping capacity of emergency response facilities is moderate. Exposure occurs during a rare extreme event, not on a regular basis, so the system would be coping with a temporary impact. Until flooding subsided, emergency response services could be supplemented from nearby stations. Over the longer-term, resources would likely be available to relocate the fire stations serving these communities out of flood-exposed areas, so adaptive capacity in this respect is high.

The vulnerability of emergency response facilities to sea level rise is low. Exposure is limited to flooding impacts during extreme events in the 2100 timeframe. Sensitivity of affected facilities is high, but mechanisms to cope with a facility outage are available, and stations could be relocated out of the flood area.

Targeted Strategies

The following strategies are options for addressing the **flooding** vulnerabilities of emergency response facilities, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Set higher standards for all emergency response facilities that could be exposed to flooding during their life span.

2) Gather more specific information about each critical facility and ensure that a regional database contains key information on flood heights and building elevation levels.

Parks, Recreation, and Shoreline Public Access

The San Diego Bay area is populated with dozens of parks, promenades, marinas, and other recreational facilities that provide public access to the Bay shoreline. Parks in the area provide a mix of passive and active uses. Parks and recreational facilities that provide shoreline access are central to the character of the region and quality of life, and are also some of the most vulnerable facilities to sea level rise due to their proximity to the water.

Primary Vulnerabilities

- In the 2050 and 2100 Daily Conditions scenarios, shoreline parks and recreational facilities are extremely vulnerable to regular **inundation** due to extensive exposure around the Bay and high sensitivity to inundation impacts.
- In the Extreme Event scenarios, the system is highly vulnerable to periodic **flooding** because of extensive exposure and high sensitivity, but adaptive capacity to cope with flooding is higher than most other systems.

Primary Vulnerability—Flooding and Inundation

Parks, recreation, and public access are vulnerable to flooding and inundation impacts. This section describes the vulnerability of this system in terms of exposure, sensitivity, and adaptive capacity under the four planning scenarios.

Exposure

Because of their proximity to the shoreline, these facilities are at extreme risk of exposure to flooding, as shown in Maps 21 and 22 in Appendix III. In the 2050 scenarios, parks and recreation are the most exposed land uses, and are a significant percentage of all exposed lands in the 2100 scenarios.

Sensitivity

Shoreline access and recreational opportunities are prevented when these facilities are flooded. Because this system cannot perform its primary function when exposed, it is considered to have a very high sensitivity to flooding impacts. Passive recreation areas that consist of mostly natural features and well-draining pervious surfaces are less sensitive than active areas with impervious surfaces and buildings. Some marinas may have somewhat lower sensitivity if floating docks are not impaired and boats can be accessed.

Figure 4.6 Shoreline Path, Coronado. 02.16.11, 8:23am : ~6.7 feet above mean low tide.

Adaptive Capacity
Generally, shoreline parks and recreational facilities would have a moderate capacity to adapt to flooding in the Extreme Events scenarios. Individual facilities would not be able to cope with flooding in the short term, but while these facilities recovered, other unaffected sites could be relied on for access and recreational opportunities, so the system as a whole would have coping capacity. In the Daily Conditions inundation scenarios, coping capacity would be lower as facilities would be lost completely, resulting in fewer access and recreational opportunities for the region.

Longer-term adaptive capacity to inundation is mixed. As shoreline parks and recreational facilities become flooded more regularly or inundated altogether, it likely will be very difficult to maintain shoreline access by developing new facilities that would themselves be highly vulnerable. Most sites landward of shoreline parks are already developed, and acquisition and redevelopment into a "lower" use could be challenging. Decision-makers may also encounter resistance to spending funds on shoreline facilities that will be, by nature, vulnerable to future flooding. This vulnerability may also be an opportunity, however; as coastal land use evolves in the context of sea level rise, creating low-impact, passive open space in vulnerable areas may be appealing, since these uses require less investment and are more capable of coping with flooding than buildings and other infrastructure.

Overall Vulnerability to Flooding and Inundation
Shoreline parks and recreational facilities are highly vulnerable to flooding and inundation, due to their extensive exposure and high sensitivity. These uses will be more exposed to flooding and inundation than any other land use, and they are unable to serve their function when flooded. However, the parks and recreation system is fairly adaptable to the periodic flooding of the Extreme Event scenarios, as many activities can be shifted to unaffected facilities for short periods of time and passive parks with better stormwater infiltration capabilities may recover from flooding more quickly than other types of facilities. This coping capacity may provide good reason to continue investing in passive shoreline uses as sea levels rise, despite potential difficulties in land acquisition and in justifying public investment in vulnerable areas.

Targeted Strategies

The following strategies are options for addressing the **flooding and inundation** vulnerabilities of parks, recreation, and open space, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Prioritize the development of passive, naturalized parks, open space, and habitat land in areas that are vulnerable to flooding, to minimize risk to higher-value infrastructure; to promote public access as shoreline conditions change; and to promote low-impact development stormwater management.

2) Evaluate site-specific vulnerabilities, identifying structures such as buildings, docks, and piers that may be at risk. Identify adaptation responses as plans or projects are developed.

Regional Airport Operations

The San Diego County Regional Airport Authority is responsible for compatible land use planning for the San Diego County airport system, which includes 12 public-use airports. The largest of these, San Diego International Airport (Airport), is located at the northern end of San Diego Bay. It is the third busiest airport in California with over 17 million passengers annually, accommodating commercial passenger services, air cargo, and general aviation.

Primary Vulnerabilities

- Parts of the Airport site will be vulnerable to localized **flooding** from blocked storm outfalls into the Bay.
- In the 2100 scenarios, Airport operations will be extremely vulnerable to Bay **flooding**, particularly from impacts on access roads, future terminal areas, and portions of the runway/airfield.
- In the 2100 scenarios, Airport operations will be highly vulnerable to Bay **inundation**, particularly from impacts on access roads.

Primary Vulnerability—Flooding and Inundation

Regional airport operations are vulnerable to flooding and inundation impacts. This section describes the vulnerability of airport operations in terms of exposure, sensitivity, and adaptive capacity under the planning scenarios.

Exposure

In the 2050 scenarios, the Airport is not exposed to flooding from the shoreline. Parts of the site may be exposed to localized flooding from inundated Bay storm drains in 2050, but the precise nature of this flooding is not known, as described in the Stormwater Management section.

In the 2100 Daily Conditions scenario, North Harbor Drive north of the Coast Guard station is inundated regularly, thereby limiting access to passenger terminals from the east. The far western end of the site, west of the runway, is inundated in this scenario also. Flooding of the runway area is magnified in the 2100 Extreme Event scenario. Flooding is present on both the eastern and western North Harbor Drive approaches to the passenger terminals. The south side of the site, including the location of a planned passenger terminal, is flooded extensively. In addition to this coastal inundation, localized flooding during a storm would compound these effects.

Figure 4.7 West End of Runway (*background*), San Diego International Airport. 01.19.11, morning : ~7.1 feet above mean low tide.

Sensitivity

Operation of the Airport is extremely sensitive to flooding. Harbor Drive is currently the only access point to terminals and flooding would shut down passenger access. The Airport has only one runway, and it cannot be used if it is flooded. Flooding as described in the 2100 scenarios would likely necessitate closure of the facility on a regular basis. The risk of regular closure and potential damage to equipment would strongly deter airlines from operating at the facility. Despite many years of study, there are currently no plans to relocate major commercial aviation to other locations in the region. As it stands, if the Airport were to become unviable due to sea level rise impacts, the region would not have a functional commercial passenger and air cargo airport to meet the needs of a growing metropolitan area.

Adaptive Capacity

The Airport has no capacity to cope with the flooding impacts described in the 2100 scenarios, as currently operated. The coping capacity of the regional airport *system,* as currently operated, is minimal as well; McClellan-Palomar Airport in Carlsbad is the only other airport in the region with commercial passenger aviation operations, and its capacity to accept SDIA commercial air traffic is very limited due to a shorter runway. Because of the importance of aviation facilities to the region, the regional airport system does have the capacity to adapt to these challenges over the long-term. Resources could be made available to reconfigure the Airport—for example, by moving passenger access to a planned multi-modal terminal on the north side of the site—or to relocate commercial aviation operations to another location within the region.

Overall Vulnerability to Flooding and Inundation

Regional airport operations are very highly vulnerable to flooding and inundation impacts in the 2100 timeframe, due to extensive flood exposure, very high sensitivity to flood impacts, and low short-term adaptive capacity.

Targeted Strategies

The following strategies are options for addressing the **flooding** and **inundation** vulnerabilities of regional airport operations, as prioritized by the Stakeholder Working Group and Technical Advisory Committee.

1) Incorporate sea level rise flood scenarios at SDIA into the Regional Aviation Strategic Plan (RASP) process and the consideration of alternative sites.

2) In the SDIA Master Plan, explore potential for reconfiguring airport access away from key roads that may experience significant flooding and are threatened by inundation.

Vulnerable Populations

The planning area is home to many populations that would traditionally be considered vulnerable. These groups, including low-income residents, the homeless, elderly, ethnic minorities, and recent immigrants, often have more difficulty in accessing services and participating in planning processes that could help them increase resilience. Though a hub of commercial activity and higher-end residential units, the Centre City area also includes many single-resident-occupancy residences that are inhabited by low-income and housing-insecure populations. There are also several homeless shelters and social service organizations in the area, and a large homeless population is based here to access these services. Additionally, the Barrio Logan area to the south is a predominantly Latino neighborhood populated mostly by long-time, working-class residents, but with a significant population of recent immigrants and low-income people as well. National City and Imperial Beach have a similar demographic profile of vulnerable populations. Elderly populations are more significant in Coronado and in the Midway area, home to several nursing home complexes. Finally, in addition to the traditionally vulnerable populations, certain economic activities may be adversely affected by flooding and those employed in these activities may be vulnerable.

Primary Vulnerabilities

- Many groups that are currently vulnerable – low-income residents, the homeless, elderly, ethnic minorities, etc. – will face even greater threats from future **flooding**, particularly in the 2100 time frame.
- Residents that work in sectors that could be impacted due to future **flooding** are also a key vulnerability for the region.

Primary Vulnerability – Flooding

Traditionally vulnerable populations will remain vulnerable in the face of flooding impacts. Additionally some new populations – those working in specific job sectors – could become more vulnerable to flooding. This section describes the vulnerability of area populations based on exposure to flooding. It also touches on sensitivity and adaptive capacity considerations.

Exposure

Traditionally vulnerable populations face no major additional flooding threats in the 2050 time frame. In 2100 flooding expands to impact a greater number of vulnerable populations. The homeless population and the social services in Centre City could be exposed to future flooding impacts. Also, National City's single-family neighborhood west of Paradise Creek could be exposed to future flooding. In Imperial Beach, the flood-exposed Bernardo Shores RV park and single-family homes on 7th Street and 8th Street may also be home to traditionally vulnerable populations. Finally, elderly populations, concentrated in Coronado and in the Midway area, will be more exposed under the 2100 flooding scenario. These exposures can be seen most explicitly in Maps 15-18 in Appendix III – Residential Building Stock.

Employment sector exposure faces a similar pattern, with very limited exposure in 2050 and higher flooding exposure in 2100. In 2100, those employed by the hospitality sector, which ranges from airport staff, hotel workers and even personal home care staff, could be affected by job loss from flood exposure. The other sector most likely to be impacted by future flooding is shorefront industrial work, which may have to relocate due to increased frequency of flooding.

Sensitivity

Traditionally vulnerable populations are typically considered to have a high sensitivity to flooding impacts. These populations often cannot relocate, and they have fewer resources to rebuild after their homes have been destroyed by flooding. Additionally, these populations may have more difficulty evacuating during emergencies. Thus, even minor increases in flooding could have major impacts on these populations.

Adaptive Capacity

Generally, traditionally vulnerable populations in San Diego Bay have a relatively low adaptive capacity; however, the dynamics of different groupings of traditionally vulnerable populations have not been assessed for their adaptive capacity in this report. In general, vulnerable populations have fewer options for adapting to many challenges, and fewer financial, civic, and political resources on which to rely. This lack of resources can make many different adaptive activities less feasible—such as relocating or floodproofing homes, evacuating in an emergency, coping in the aftermath of flooding, or finding other employment when laid off from an affected job.

Overall Vulnerability to Flooding

Traditionally vulnerable populations as well as those employed in service functions of the hospitality sector are **highly vulnerable** to flooding in the 2100 timeframe. However, further research into specific sub-populations and their sensitivity and adaptive capacity would be needed to better understand the dynamics of traditionally vulnerable populations around San Diego Bay, and to identify targeted strategies for responding to these vulnerabilities.

5. MANAGEMENT PRACTICES TOOLBOX

This section presents a toolbox of options for managing sea level rise that are generally more aggressive than the strategies recommended in previous sections. The comprehensive and targeted strategies presented in previous sections are mostly “no-regrets” approaches that can be implemented at relatively low cost, that can be integrated into existing work programs, and that have co-benefits for reaching other community goals. However, in the long run, no-regrets strategies will not be sufficient to ensure resiliency in the region’s coastal zone. Successful implementation of the management practices described in this section will require significant technical and management capabilities, regional collaboration, financial investment, and political commitment.

Generally, sea level rise management practices can be classified into four categories: hard defense; soft defense; accommodation; and withdrawal. This toolbox illustrates specific practices in each of these categories through section diagrams and photographs. It also documents the opportunities and constraints of these four approaches, as determined in a map-based exercise in the second Stakeholder Working Group workshop. Each approach presents significant opportunities and constraints, and decision-making around these practices will require careful deliberation around the tradeoffs. Ultimately, a mix of hard defenses, soft defenses, accommodation, and withdrawal will likely emerge as the most optimal management approach, but existing frameworks for making these difficult decisions need to be enhanced, as recommended in Comprehensive Strategy #10.

strategy: HARD STRUCTURE

Hard defenses are designed to be impermeable structures intended to protect land, structures and investments along the water edge. Examples includes hard, impermeable defenses such as seawalls, revetments, dikes, and storm surge barriers that armor or "draw the line" between water and development and prevent flooding or erosion of edges.

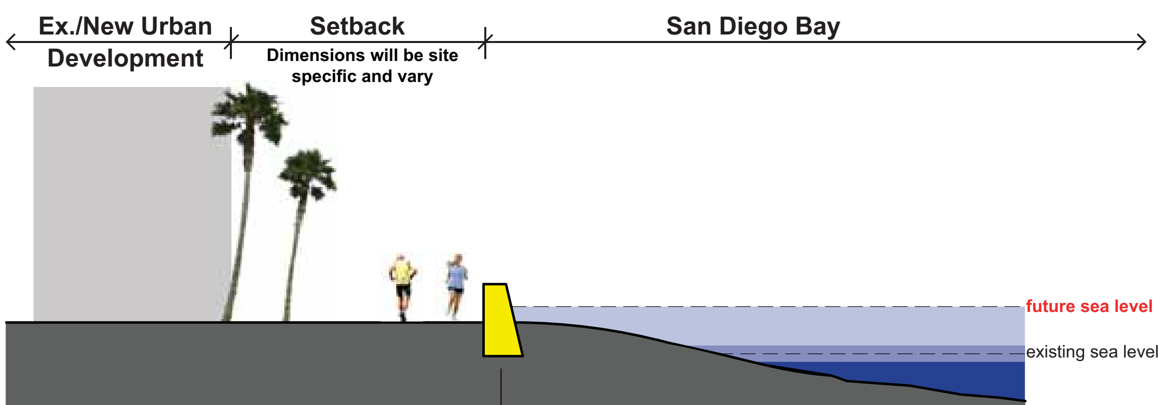

Seawall at Lake Michigan, Chicago

opportunities:
- Stabilizes upland areas
- Protects existing development and infrastructure
- Maintains property values for bayfront and low-lying development
- Setbacks can be used for recreation, infrastructure and non-habitable structures.

constraints:
- Expensive to construct, with annual maintenance required
- Areas outside of protective zone are often more subject to erosion and ecological degradation
- Shoreline habitats will be lost as space to migrate is eliminated

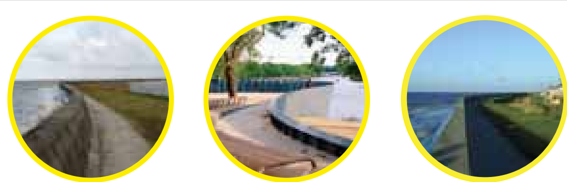
unknowns:
- Potential loss of public access and aesthetic link to waterfront

option A - Seawall - retaining

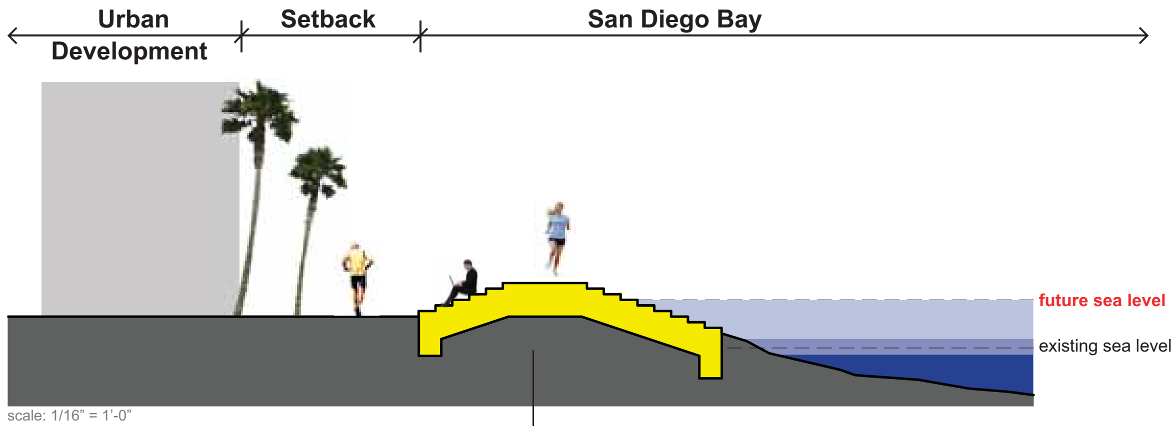


scale: 1/16" = 1'-0"

Seawalls are engineered, permanent barriers built parallel to shoreline to protect land and structures from flooding and erosion caused by wave action. Seawalls may be vertical or sloping, and massive gravity concrete walls or constructed of steel or timber.

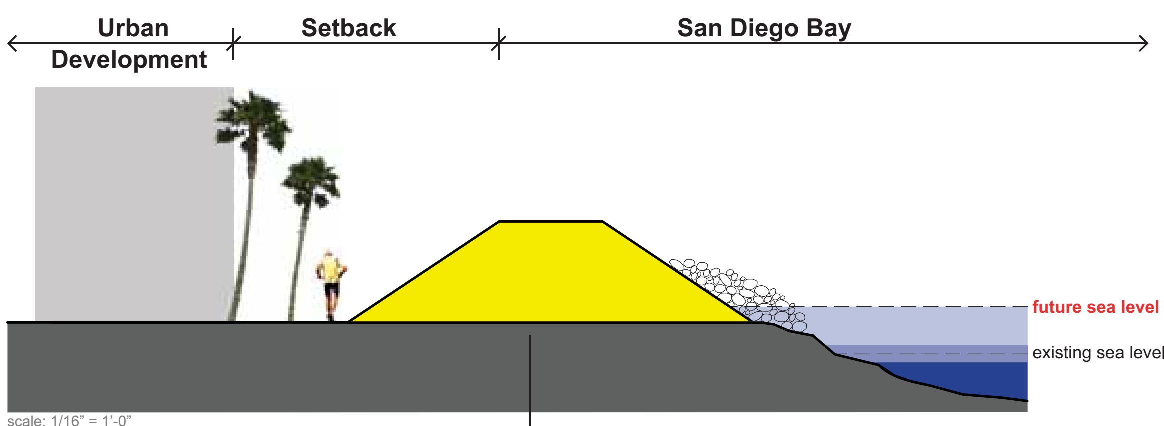


option B - Seawall - widened/stepped

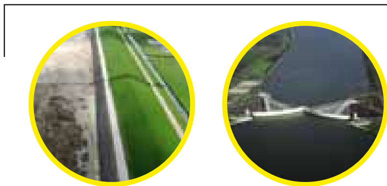


Seawalls may be stepped on both the bay and city sides, allowing for easier access and greater public uses while working to dissipate wave and tidal energy. More land would be required for this option, and construction expenses would increase

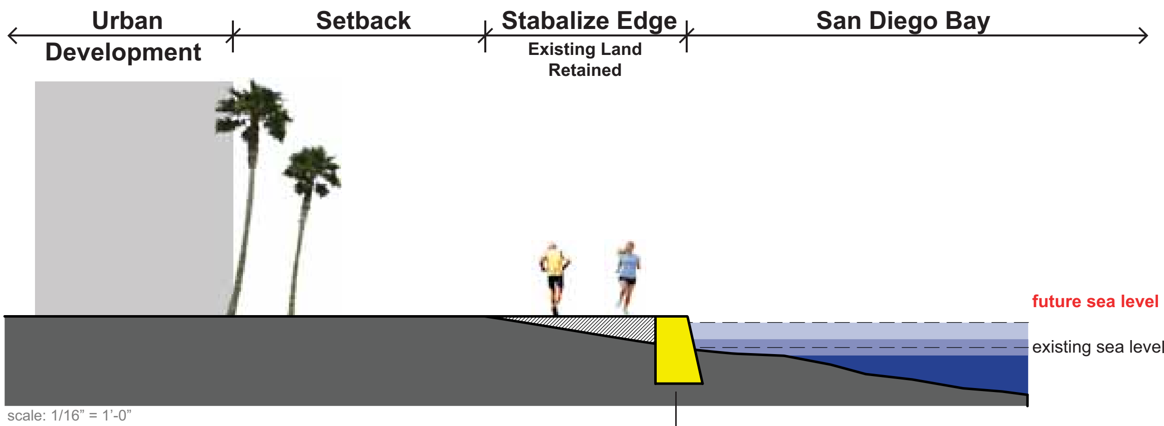
option C - Levee



Levees are engineered, permanent, impermeable barriers constructed to protect low-lying inland areas from flooding. The mounds are constructed of earth, sand and clay; the sloped sides are stabilized and protected from erosion and wave action by rip-rap or concrete armor units.

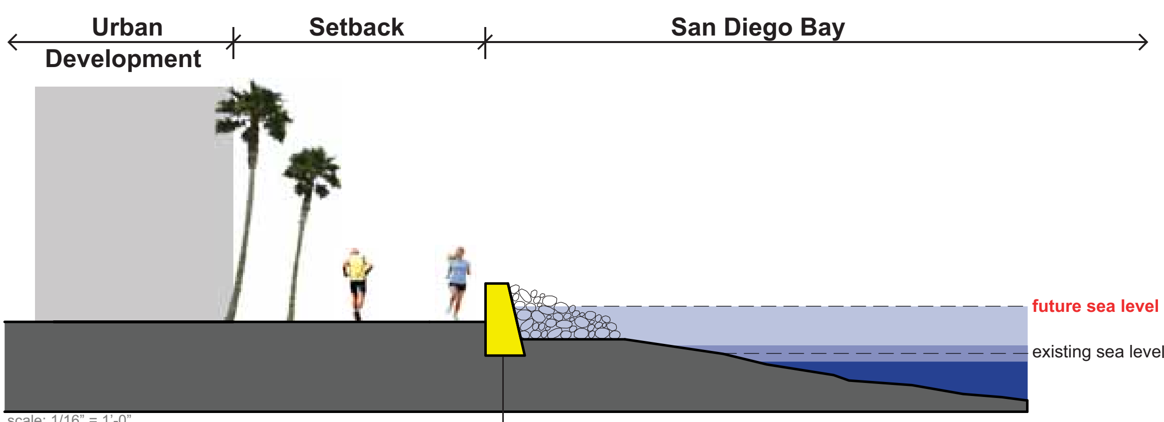


option D - Bulkhead

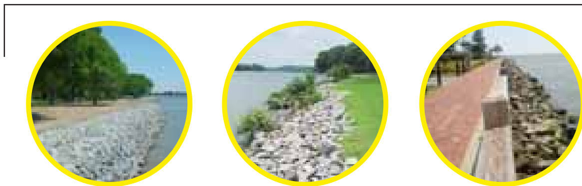


Bulkheads are engineered, permanent walls that retain land and provide erosion-protection. Secondary use to stabilize and protect upland areas from flooding. Bulkheads are soil retaining structures that may be constructed of concrete, rip-rap, or pilings with steel or timber.

option E - Rip-rap



Rip-rap is large, angular stone placed on existing beach, embankment, cliff or other shore edge to prevent erosion and help dissipate wave energy. Concrete armor units, such as tetrapods and cubes, perform similar functions.



strategy: **SOFT STRUCTURE**

Soft structures use natural systems and ecosystem services to protect development, investments, and ecosystem well-being. Soft defenses typically protect development through increasing the distance between the water and structures or through requiring space for percolation and retention of flood waters and runoff. Examples include wetland preservation and enhancement, and stormwater management with bioswales and detention basins to hold floodwaters.

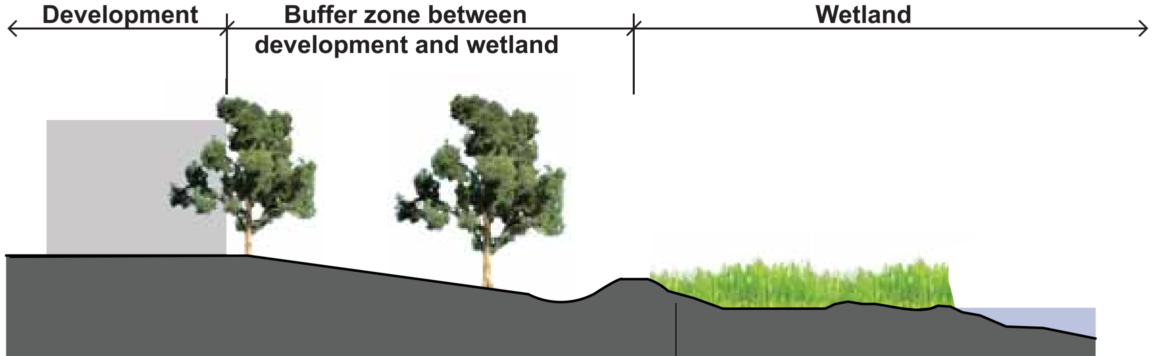
Tijuana Estuary

opportunities:
- Reduction of intensity and frequency of flooding, correspondingly reducing size and cost of any required seawalls or hard structures
- Preserves or increases valuable habitat
- Provides recreation and open space areas
- Reduces water pollution in bay and enhances groundwater recharge

constraints:
- More extensive land required to provide benefits
- Continued maintenance required
- Green infrastructure is typically cost effective

unknowns:
- Time to establish new habitat

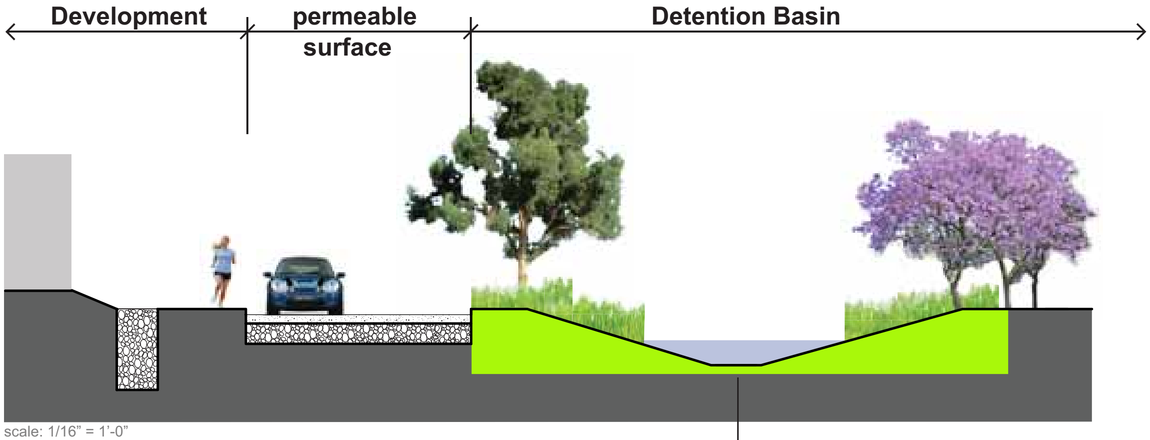
option **A** - **Wetland Restoration / Enhancement**

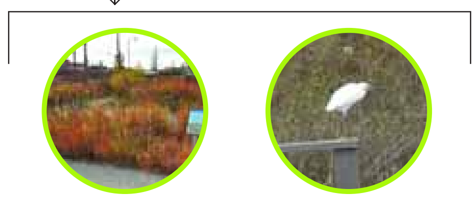


scale: 1/16" = 1'-0"

Wetland restoration/enhancement and their natural filtration and absorptive qualities provide flood water storage, buffers from wave and tidal energy, and shoreline stabilization. Wetlands are also particularly sensitive and will "naturally" shift upland with the increasing salinity and water depth that results from sea level rises. Wetlands provide ecosystem services to local communities in the form of improved water quality, support for fisheries, and recreation.

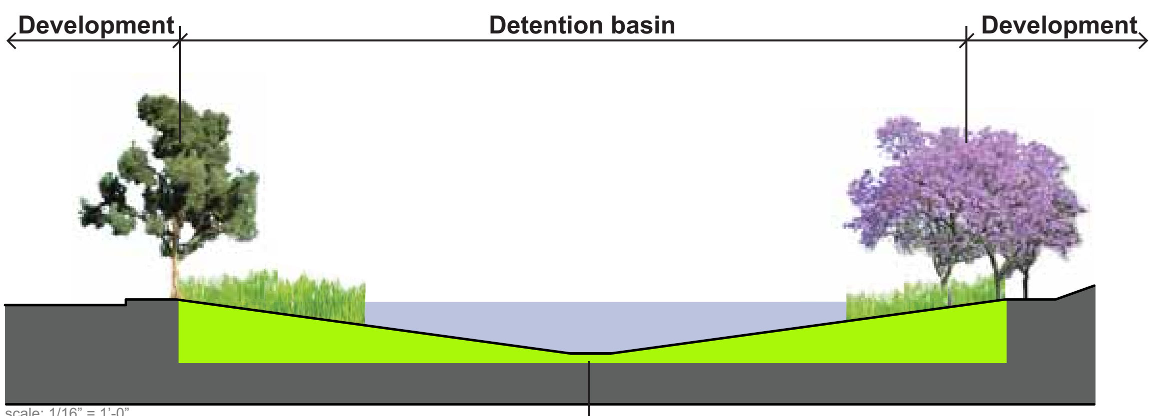
option B - Low Impact Development (LID) and Green Infrastructure

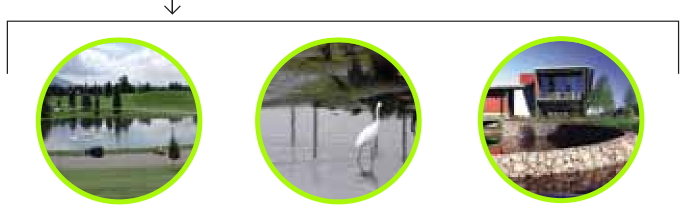




Low impact Development (LID) and Green Infrastructure work with natural systems to maximize the retention and percolation of stormwater. Green infrastructure includes the open, permeable spaces within a community, and seeks to adapt traditional "gray" infrastructure to allow for infiltration of stormwater and provide potential habitat.

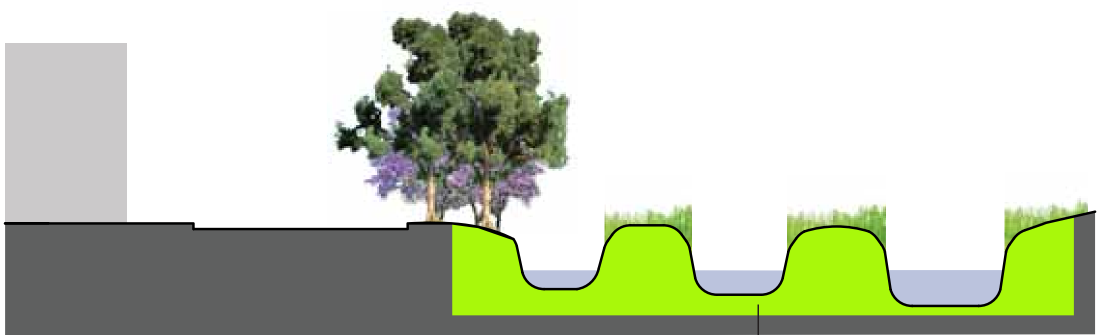
option C - Detention basins or upland "mini-floodplains"





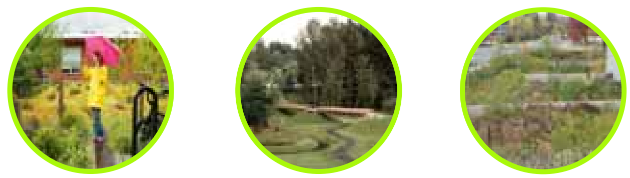
Detention Basins or Constructed Wetlands are engineered basins that collect stormwater, either allowing it to percolate on-site or releasing it after the major storm event has passed. Upstream basins help to prevent flooding by capturing it before it reaches the bay.

option D - Bioinfiltration / Stormwater Park

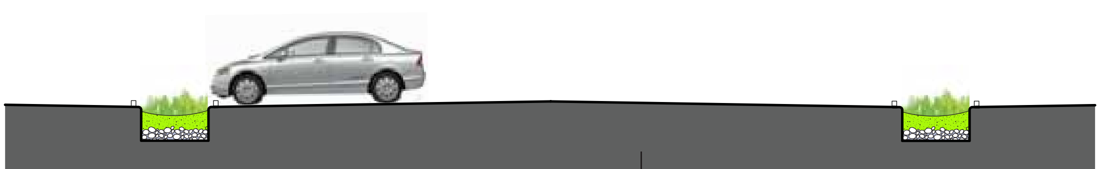


scale: 1/16” = 1’-0”

Bioinfiltration uses plants and topography to capture and filter stormwater, and create habitat areas. Examples are stormwater parks, rain gardens and small “pocket” wetlands that allow for “managed flooding”.

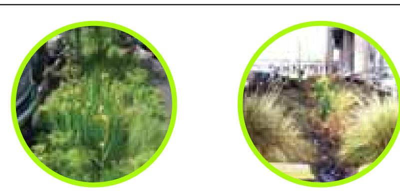


option E - Bioswales and other vegetated drain channels



scale: 1/16” = 1’-0”

Bioswales and other vegetated drain channels direct flood waters away from development, slow runoff, and allow for percolation of storm or flood waters.



strategy: ACCOMMODATION

Accommodation realigns traditional methods of planning and building with changing conditions of high water and tidal fluctuations. New building methods accommodate new flood plains and various degrees of flooding.

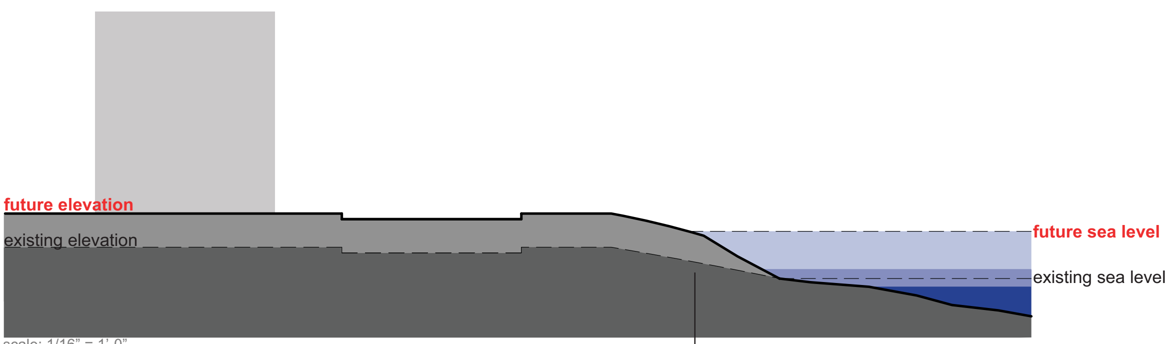
Loblolly House, Kieran Timberlake Architects

opportunities:
- Removes development from immediate threat of flooding
- May reduce flood insurance premiums• text here
- Property owner can control elevation of structure

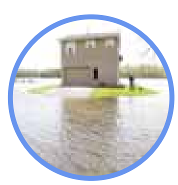
constraints:
- Expensive to retrofit existing development
- Not useful in areas with permanent flooding
- Adding fill and raising grades may impact wetlands and other habitat

unknowns:
- Accessibility
- Costs of allowing flooding of development, even if temporary

option A - Elevated Grade Surface

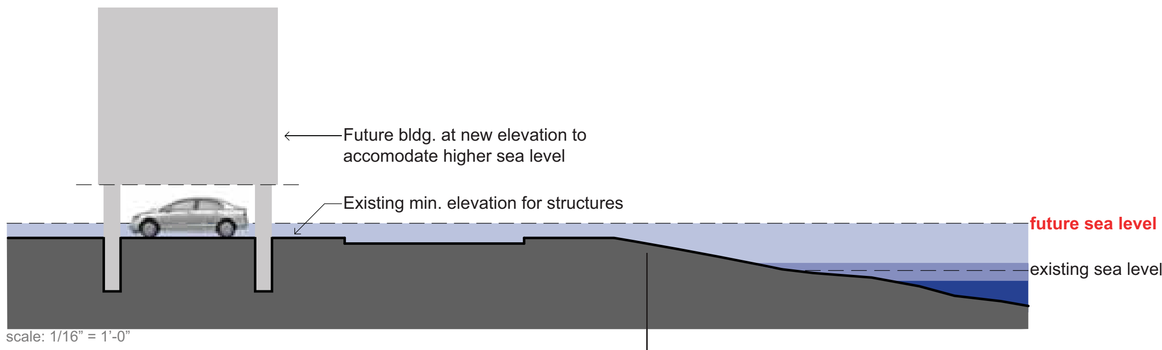


Elevated grade surfaces raise elevations of pads for new structures, infrastructure, and other land uses. Earth or gravel, or raised foundation walls, can be used to raise building pads and infrastructure up out of low-lying areas that might be expected to flood. Depending on edge conditions, elevated grades may require rip-rap and other armoring for protection. It may be possible to raise the land surface of wetlands.



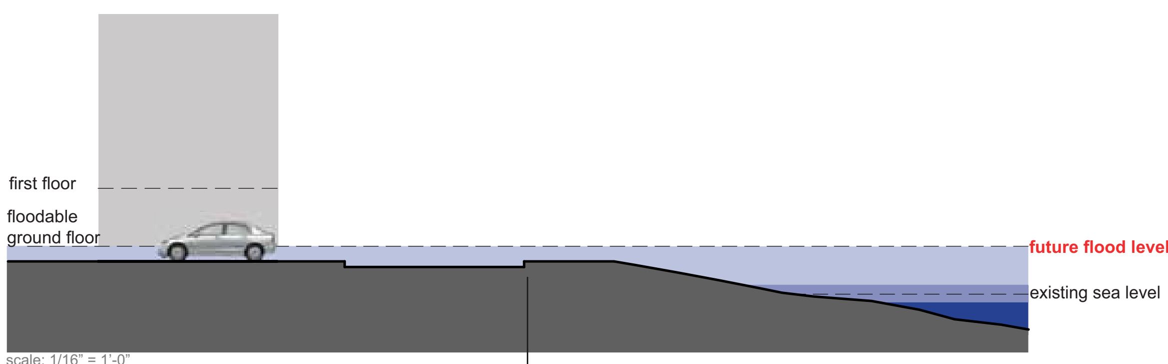
ACCOMMODATION STRATEGIES

option B - Elevated Structure

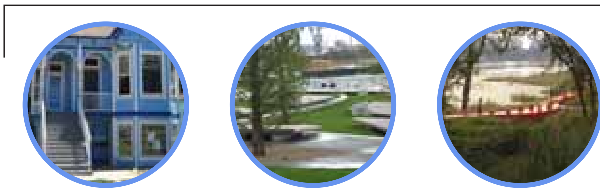


Elevated structures built in known flood plains are often constructed on pilings to allow for flood waters to flow under the structure.

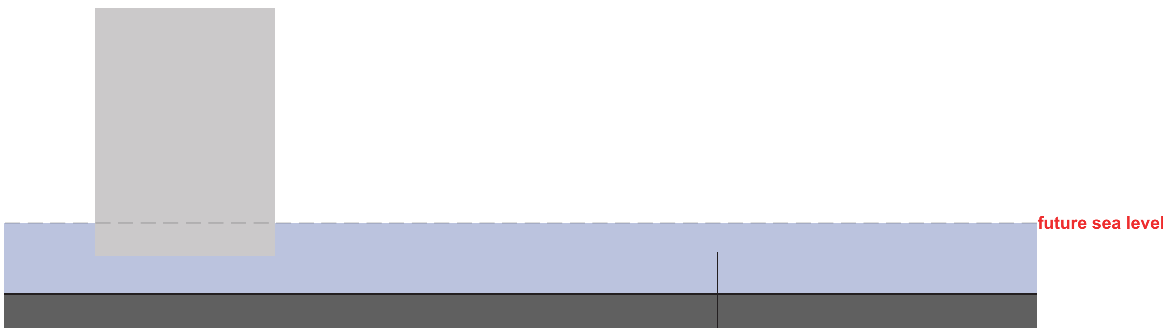
option C - Floodable Development



Floodable development allows for flooding of either built structures or open spaces. In built structures, the floodable area is designated as uninhabitable, and while habitable space is restricted to upper levels of development. Shore edge parks and plazas can also be flooded intermittently.



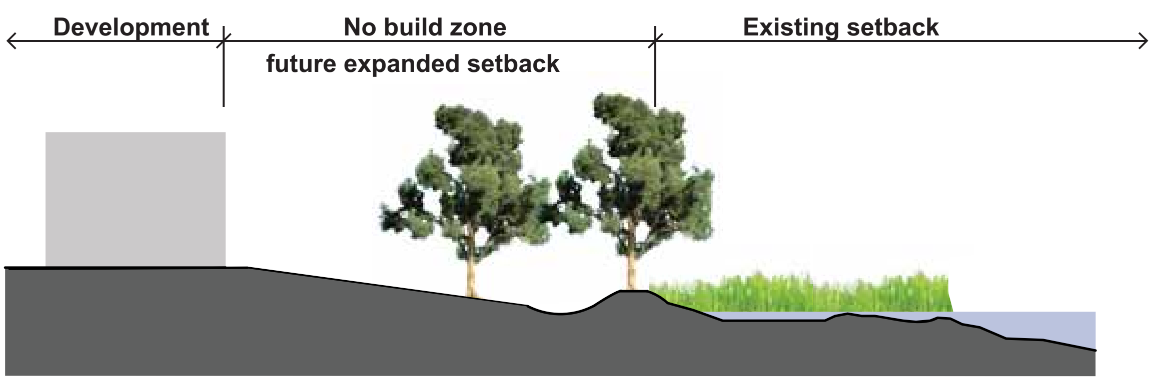
option D - Floating Structure



scale: 1/16" = 1'-0"

Floating structures range from houseboats to floating roadways and other infrastructure. The mooring or anchoring of the structure is critical to the success of this strategy.

option E - Buffers and Setbacks



scale: 1/16" = 1'-0"

Buffers and setbacks are land permanently dedicated to remain undeveloped and vegetated to protect adjacent land from flooding or other impacts. Setbacks from the water's edges are achieved through zoning, overlay zones, and land use restrictions. Buffers and setbacks are most effective when they are determined in conjunction with specific conditions, such as susceptibility to erosion or wave action, or capacity to provide valuable habitat. They may be established through regulation or land acquisition.

strategy: **Withdrawal**

Withdrawal from rising sea levels, or managed retreat, is a viable strategy when the economic and ecological costs of protecting development is prohibitive. The objective is to allow for flooding and rising sea levels through restricting development or moving structures out of the path of the water. New development would be prevented in vulnerable areas. Reducing federal or other subsidies for shore protection may help property owners manage the risk of bayfront development.


Shoreline in Dare County, North Carolina

opportunities:
- New space for tidal habitats
- New recreation and open space areas
- Increased or maintained public access to shoreline areas

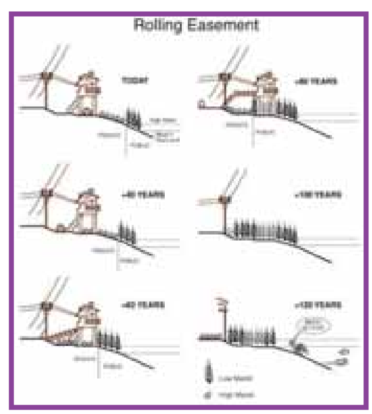
constraints:
- Property owner opposition
- More expensive than hard structure strategies in urban areas

unknowns:
- Legal and insurance issues
- Public perception

option A - Zoning and Overlay Zone
option B - Rolling Easements

Zoning and overlay zones guide the design and planning process for development and habitat areas through restricting land uses to avoid risks associated with flooding.

Rolling easements are a type of easement that prevents hard structures and armoring of the coastal edge, but otherwise doesn't prohibit land uses. The easement "rolls" or moves inland as the sea level rises, maintaining the area of public tidal lands, and allowing for shoreline habitats to also migrate inland. Structures may be moved elsewhere on the property, or elevated to allow for water flow.



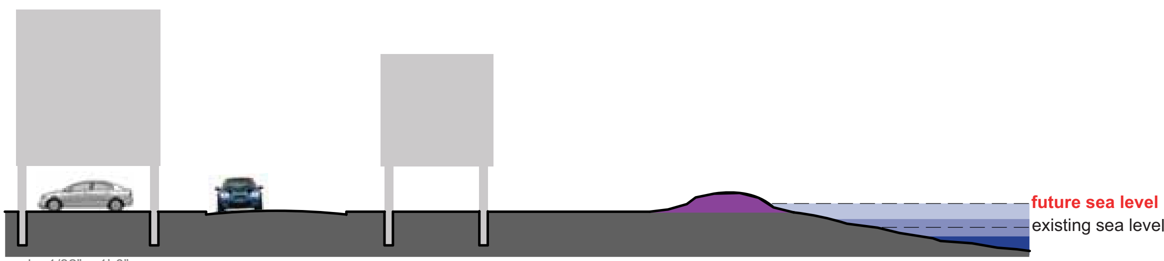
option C - Design for Disassembly

Design for Disassembly is a building process that plans for the future disassembly and reuse of building materials.

option D - Managed Retreat

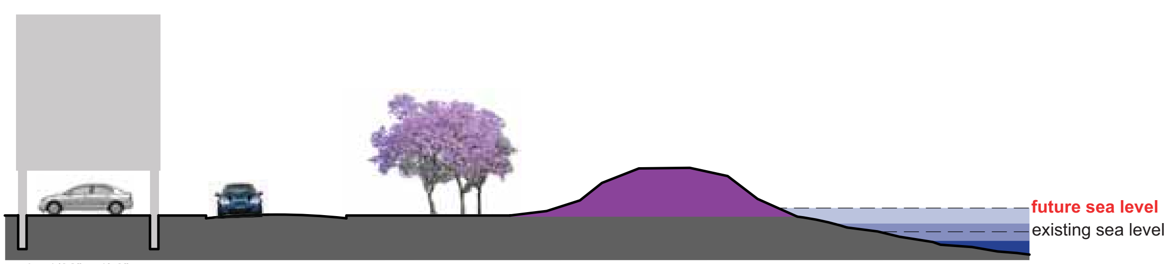
scale: 1/32” = 1’-0”

Existing development exposed to coastal storms and flooding



scale: 1/32” = 1’-0”

Phase 1: Shorefront homes removed and housing elevated for flooding.



scale: 1/32” = 1’-0”

Phase 2: Shoreline buildings removed, dune built up with vegetative coastal buffer

Managed retreat moves human settlement away from the fluctuations of the water-land interface. Structures may be removed or relocated inland as sea level rises and the existing shoreline erodes. Plans for withdrawal from the water’s edge can be incorporated in long-range plans and visions, and include the planned relocation and/or disassembly of valuable existing structures and land uses as well as planned abandonment of less essential structures.

6. CONCLUSION AND NEXT STEPS

Management of the San Diego Bay coastal zone has long been a challenge, due to the complex interaction of physical and socio-economic processes at work. Through coordination with a broad set of public agencies, property owners, and other stakeholders over many decades, the region has created an institutional and legal framework that helps protect important interests, but the outcomes of decision-making are not always ideal. This dynamic will only become more challenging as the pace of sea level rise quickens in the coming years, leading to more frequent and severe extreme flood events as well as a slow and steady trend towards inundation of developed areas and loss of important habitat this century.

The assessments and recommendations presented here represent the best thinking of a large body of regional stakeholders and experts, based on the most current available science. They are a starting point. Going forward, the recommendations are intended as a resource for local agencies as they develop and implement tools for protecting important community assets. In the near-term, opportunities to incorporate these recommendations include the climate action plans under development in the City of San Diego and the Port of San Diego, as well as the regulations and investments directed towards redevelopment of the Chula Vista Bayfront. Over the longer-term, the findings will be helpful in integrating sea level rise adaptation into many of the mechanisms for managing the coastal zone, such as Local Coastal Programs, capital improvement programs, and habitat conservation plans.

While many adaptation actions will be implemented by individual local agencies, regional coordination will be critically important in developing integrated, cost-effective solutions that respond to the interconnectedness of Bay systems and processes. Through renewed support from the San Diego Foundation, ICLEI will continue to convene the project's Public Agency Steering Committee, Stakeholder Working Group, and Technical Advisory Committee through 2012 to move forward with the Comprehensive Strategies that lend themselves to region-wide implementation.

Through the Adaptation Strategy process, regional practitioners have taken the first step towards building resilience to sea level rise by learning how to communicate about the issues, and by starting to identify community vulnerabilities and appropriate adaptation responses. The work to come will be difficult, but it will also present real opportunities to improve quality of life in the region and avoid the significant costs presented by sea level rise on San Diego Bay.

APPENDIX I – VULNERABILITY ASSESSMENT SURVEY QUESTIONNAIRE

The following survey was administered to the Technical Advisory Committee via surveymonkey.com in January 2011.

1. Background Questions

Thank you for taking the time to complete the San Diego Bay Sea Level Rise Vulnerability Assessment Survey. Detailed instructions and supplement information can be found in the packet provided in the email with the link for this survey.

Your responses to the following survey are confidential. ICLEI and the survey partners will not directly quote any of your information without your explicit consent.

1. What is your name?

2. What organization or government do you work for?

3. What is your department and job title within your organization or government?

2. Preliminary Questions

*1. Which of the following systems is your primary focus at your job? (check only one)

- Bay aquatic ecosystems and biodiversity
- Endangered species / critical habitat conservation
- Transitional / nearshore ecosystems and biodiversity
- Upland ecosystems and biodiversity
- Parks, Recreation, and Public Access
- Residential building stock and designated lands
- Commercial / Industrial building stock and designated lands
- Airport operations
- Port - Industrial operations
- Port – Marinas
- Emergency response system – police, fire, hospitals
- Energy facilities
- Flood control and stormwater management
- Hazardous sites
- Potable water supply, treatment, and distribution
- Wastewater collection

Other (please specify)

*2. What geographic scale within the San Diego Bay planning area are you considering when responding to the questions below (Note: We would like you to provide information about the geographic area where you have expertise)?

- San Diego Bay Planning Area (see Figure 1 in the map packet provided in the email)
- Port Lands Only
- San Diego International Airport Operations Only
- The City of Chula Vista
- The City of Coronado
- The City of Imperial Beach
- The City of National City
- The City of San Diego

Other (please specify)

3. Please list any major facilities or components of your system in the planning area (see Figure 1 in the map packet provided in the email) that you are particularly concerned about being impaired by the following impacts of sea level rise:

Flooding	
Erosion	
Salt water intrusion	
Water table rise	
Habitat or species shifts	

3. Vulnerability Assessment - Part 1 - Sensitivity

In Part 1 of this assessment we will be asking you to evaluate the "sensitivity" of your system to the impacts of sea level rise - flooding, erosion, salt water intrusion, water table rise and species / habitat shifts.

Sensitivity here is understood to be the degree to which a system would be impaired by the impacts of sea level rise were the system to hypothetically experience those impacts. Systems that are greatly impaired by small changes in sea levels have a high sensitivity, while systems that are minimally impaired by the same small change in sea level have a low sensitivity.

For example, consider two homes that are built on the same elevation land in areas with equal flood potential – high risk of flooding from still water. The first home is built with its first floor just at the 100 year (1 % chance) flood level. The second is built with its first floor elevated 2 feet above the 100 year (1 % chance) flood level. When a historically high flood event hits the area, the first house is severely damaged and remains uninhabitable for month, while the second home is not impaired at all. Both have the same exposure; however the first has a higher sensitivity level.

Note: Recognizing that some systems could not be exposed under any circumstances to cerain impacts of sea level rise (e.g. the emergency response system could not be impacted by habitat shifts), you are not required to answer these questions for all impacts; however we hope that you will answer these questions from the perspective of hypothetical events and thus answer them for as many impacts of sea level rise as are relevant to your system.

Keeping the above information in mind, please answer the following questions, which will help you to think about the sensitivity of your system.

*1. Are any of the major facilities or components in this system currently impaired by the following impacts (check all that apply):

	Yes	No	Not Sure
Flooding	◯	◯	◯
Erosion	◯	◯	◯
Salt water intrusion	◯	◯	◯
Water table rise	◯	◯	◯
Habitat or species shifts	◯	◯	◯

If you answered "Not Sure" please explain your uncertainty

2. If you answered yes to the questions above, which facilities or components and how are they impaired?

***3. How would you rate the ability of your system to withstand the following impacts?**

	Very low	Low	Medium	High	Very high	Not Applicable
Flooding	◯	◯	◯	◯	◯	◯
Erosion	◯	◯	◯	◯	◯	◯
Salt water intrusion	◯	◯	◯	◯	◯	◯
Water table rise	◯	◯	◯	◯	◯	◯
Habitat or species shifts	◯	◯	◯	◯	◯	◯

4. Please provide additional information on each of the specific ratings that you provided above in Question #3.

***5. Are there additional factors – such as development pressure, budget or weather conditions – that currently cause your system to be unable to meet its demands?**

◯ Yes

◯ No

6. If you answered yes to the question above, please describe the factor(s) that lead to this system inability to meet its demands. Please also describe what demands were not met.

Now we will ask you to evaluate the sensitivity of your system to the impacts of sea level rise. Please use the rating scale below to answer the next question.

Sensitivity Levels	
S0	System will not be impaired by the impact
S1	System will be minimally impaired by the impact
S2	System will be somewhat impaired by the impact
S3	System will be largely impaired by the impact
S4	System will be greatly impaired by the impact

***7. Based on your previous answers and thoughts, what sensitivity level would you give your system for each of the following impacts:**

	S0	S1	S2	S3	S4
Flooding	◯	◯	◯	◯	◯
Erosion	◯	◯	◯	◯	◯
Salt water intrusion	◯	◯	◯	◯	◯
Water table rise	◯	◯	◯	◯	◯
Habitat or species shifts	◯	◯	◯	◯	◯

4. Vulnerability Assessment - Part 2 - Adaptive Capacity

In Part 2 of this assessment we would like you to evaluate the “adaptive capacity” of your system to the impacts of sea level rise - flooding, erosion, salt water intrusion, water table rise and species / habitat shifts.

Adaptive capacity is the ability of a specific system to make adjustments or changes in order to maintain its primary functions even with the impacts of sea level rise. This does not mean that the system must look the same as before the impact, but it must provide the same services.

In addition to adaptive capacity there is the concept of coping capacity, which focuses on a systems ability to quickly return to providing its basic functions following a specific impairment. Having a high coping capacity can lead to a high adaptive capacity.

For an example of coping capacity consider two homes (in this case the home & its owners are the system) built in areas with equal flood potential. Both homes have their base built at the 100 year (1 % chance) flood level. The first home is not designed to react in the event of a flood and is built with materials that cannot tolerate moisture. The second home is designed to pump out water that gets above 1 inch and is built with moisture tolerant materials. When a historically high flood event hits the area, both houses flood. The first house however has water levels that reach nearly 8 inches and due to the moisture begins to mold. It remains uninhabitable for month. The second home starts pumping the water out and because of its moisture tolerance is re-inhabited two days later. Both homes have the same sensitivity however the first has a lower coping capacity.

For an example of adaptive capacity, consider the same two homes. The first is owned by a family with financial resources and with tremendous access to information. The second home is owned by a family struggling financially and with very limited access to information. Both homes will be subject to flooding, but the first home's owners find a program that helps them relocate the house to a safer location, while the second home's owners stay until flooding affects them, and they become displaced by flooding impacts. Both homes have the same sensitivity, but the first has a higher adaptive capacity.

Note: Recognizing that some systems could not be exposed under any circumstances to cerain impacts of sea level rise (e.g. the emergency response system could not be impacted by habitat shifts), you are not required to answer these questions for all impacts; however we hope that you will answer these questions from the perspective of hypothetical events and thus answer them for as many impacts of sea level rise as are relevant to your system.

Keeping this information in mind, please answer the following questions, which will help you to think about the adaptive capacity of your system.

*1. Does your system have core qualities that would allow it to be flexible and adjust in the Short-Term to the following impacts:

	Yes	No	Not Sure
Flooding	◯	◯	◯
Salt water intrusion	◯	◯	◯
Erosion	◯	◯	◯
Ecosystem change	◯	◯	◯
Water table rise	◯	◯	◯

If you answered "Not Sure" please explain your uncertainty

2. If you answered yes above, please describe the characteristics that would enable the system to cope in the Short-Term.

***3. Does your system have core qualities that would allow it to be flexible and adjust in the Long-Term to the following impacts:**

	Yes	No	Not Sure
Flooding	○	○	○
Salt water intrusion	○	○	○
Erosion	○	○	○
Ecosystem change	○	○	○
Water table rise	○	○	○

Explain Uncertainty

4. If you answered yes above, please describe the characteristics that would enable the system to adapt in the Long-Term.

***5. Are there efforts currently underway to make your system more resilient in both the short and long term to the following:**

	Yes	No
Flooding	○	○
Erosion	○	○
Salt water intrusion	○	○
Water table rise	○	○
Habitat or species shifts	○	○

6. If you answered yes above, please describe the specific actions underway to make the system or specific component more resilient.

The examples provided below are intended to help you answer question #7.

	Resource Examples		
	Economic	Environmental	Governance
Low	• No legal authority to raise funds • No strong tax base to call upon • No private sector interest	• No dune system providing storm protection • All habitat is isolated and disconnected from othe natural areas	• No interagency collaboration • No support from higher levels (county, state, etc.) • No public participation
High	• Special fund exists to raise funds • Very strong tax base to call upon • Heavily involved private sector	• Highly functioning dune system regularly provides storm protection • Habitat systems are connected allowing for species and sediment to flow	• Many interagency collaborative processes • Work closely with higher levels (county, state, etc.) • Heavily involved citizenry

***7. What level of resources does your system have in the following areas that will enhance its ability to be flexible and adapt in the long term?**

	Very low	Low	Medium	High	Very high
Economic	○	○	○	○	○
Environmental	○	○	○	○	○
Governance	○	○	○	○	○
Social	○	○	○	○	○
Technology / Infrastructure	○	○	○	○	○

8. Please provide additional information on each of the specific ratings that you provided above in Question #7.

Now we will ask you to evaluate the adaptive capacity of your system to the impacts of sea level rise. Please use the rating scale below to answer the next question.

Adaptive Capacity	
AC0	System will not be able to accommodate or adjust to impact
AC1	System will be minimally able to accommodate or adjust to impact
AC2	System will be somewhat able to accommodate or adjust to impact
AC3	System will be mostly able to accommodate or adjust to impact
AC4	System will be able to accommodate or adjust to impact in a beneficial way

***9. Based on your previous answers and thoughts, what adaptive capacity level would you give your system to the following impacts?**

	AC 0	AC 1	AC 2	AC 3	AC 4
Flooding	○	○	○	○	○
Erosion	○	○	○	○	○
Salt water intrusion	○	○	○	○	○
Water table rise	○	○	○	○	○
Habitat or species shifts	○	○	○	○	○

5. Vulnerability Assessment - Part 3 - Additional Criteria

Thank you very much for taking time to answer these questions. You have completed the required portion of the survey; however we would appreciate your answers to six additional questions below. If you cannot complete this next section please scroll to the bottom and click "next".

For those that do have time, please answer the following questions on a scale of one to ten.

1. What would you say the magnitude of the impairment to your system could be from the flooding scenarios shown in Figures 2 and 3 in the map packet provided in the email.

1 - a very small magnitude impairment
10 - a very large magnitude impairment

Note: Magnitude can be measured in a number of different ways - cost, number of system components affected, number of citizens / species affected, etc. Select a metric that is most meaningful for your system.

	1	2	3	4	5	6	7	8	9	10	NA
Flooding - Low SLR Scenario - Figure 2	○	○	○	○	○	○	○	○	○	○	○
Flooding - Low SLR Scenario - Figure 3	○	○	○	○	○	○	○	○	○	○	○

2. Please provide details on the ratings provided above in Question #1. Specifically, what metric of magnitude did you apply?

3. How evenly distributed amongst the population within the planning area (see Figure 1 in the map packet provided in the email) would you say that impairment of your system could be experienced in the following scenarios.

1 - a very small number of sub-populations experiencing the impairment
10 - almost all sub-populations experiencing the impairment

Note: Sub-populations can be defined in a number of different ways - socioeconomic status, ethnicity, age, species, etc. Select a grouping that is most meaning for your system.

	1	2	3	4	5	6	7	8	9	10	NA
Flooding - Low SLR Scenario - Figure 2	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Flooding - Low SLR Scenario - Figure 3	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

4. Please provide details on the ratings provided above in Question #3. Specifically, how did you define sub-populations?

5. How important would say your system is to the quality of life in the San Diego Bay region?

1 - a very unimportant system
10 - a very important system

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

6. Please provide details on the rating provided above in Question #5. What specific facts did you use to rate the importance of your system.

6. Thank You

Thank you very much for taking the time to complete this survey. We greatly appreciate your participation.

You are officially finished!

1. Are you interested and willing to be quoted directly in the report?

- ◯ Yes
- ◯ No

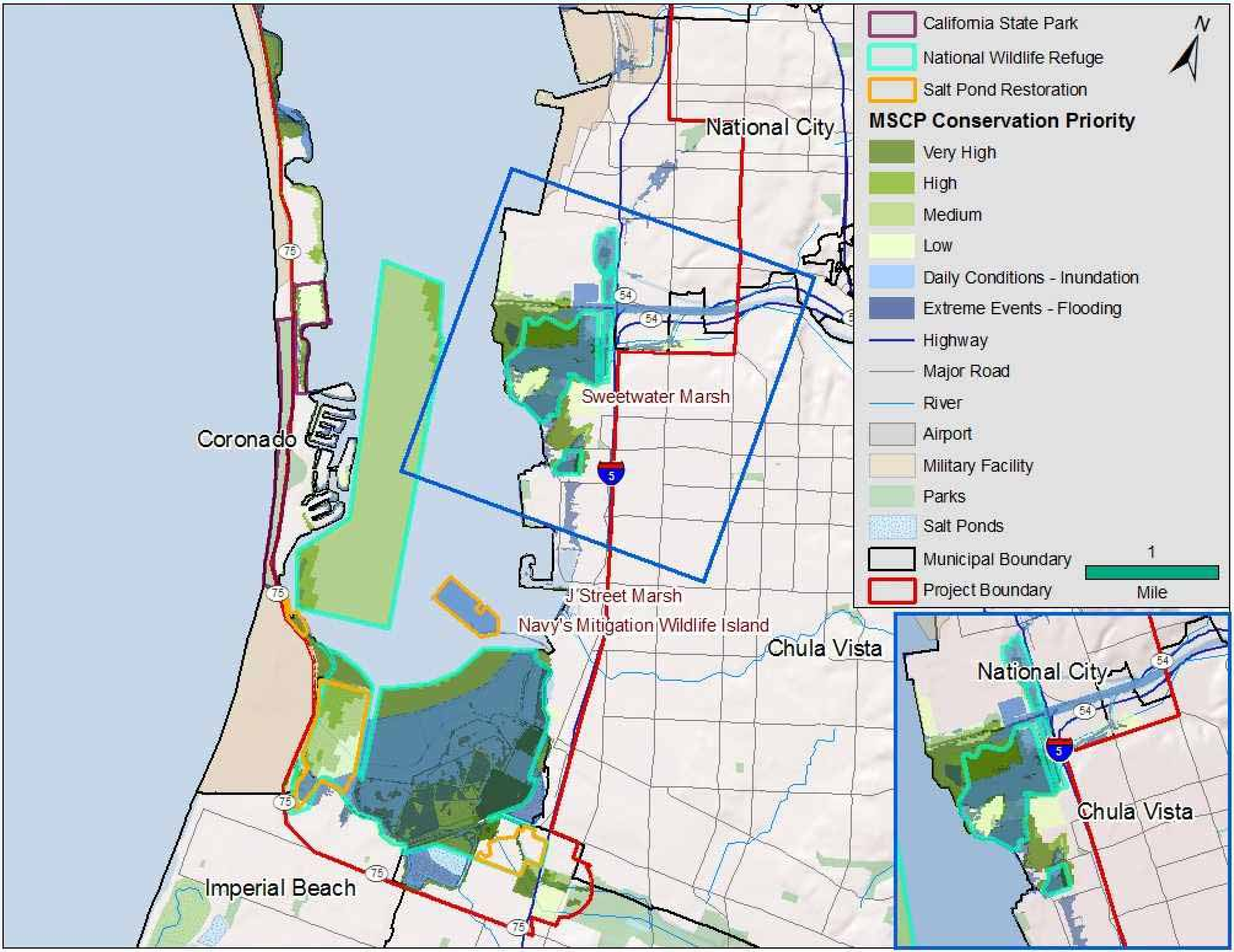
2. If you answered yes to the question above please provide your contact information (name, email and phone number)

Appendix II – Flooding and Inundation Exposure Maps

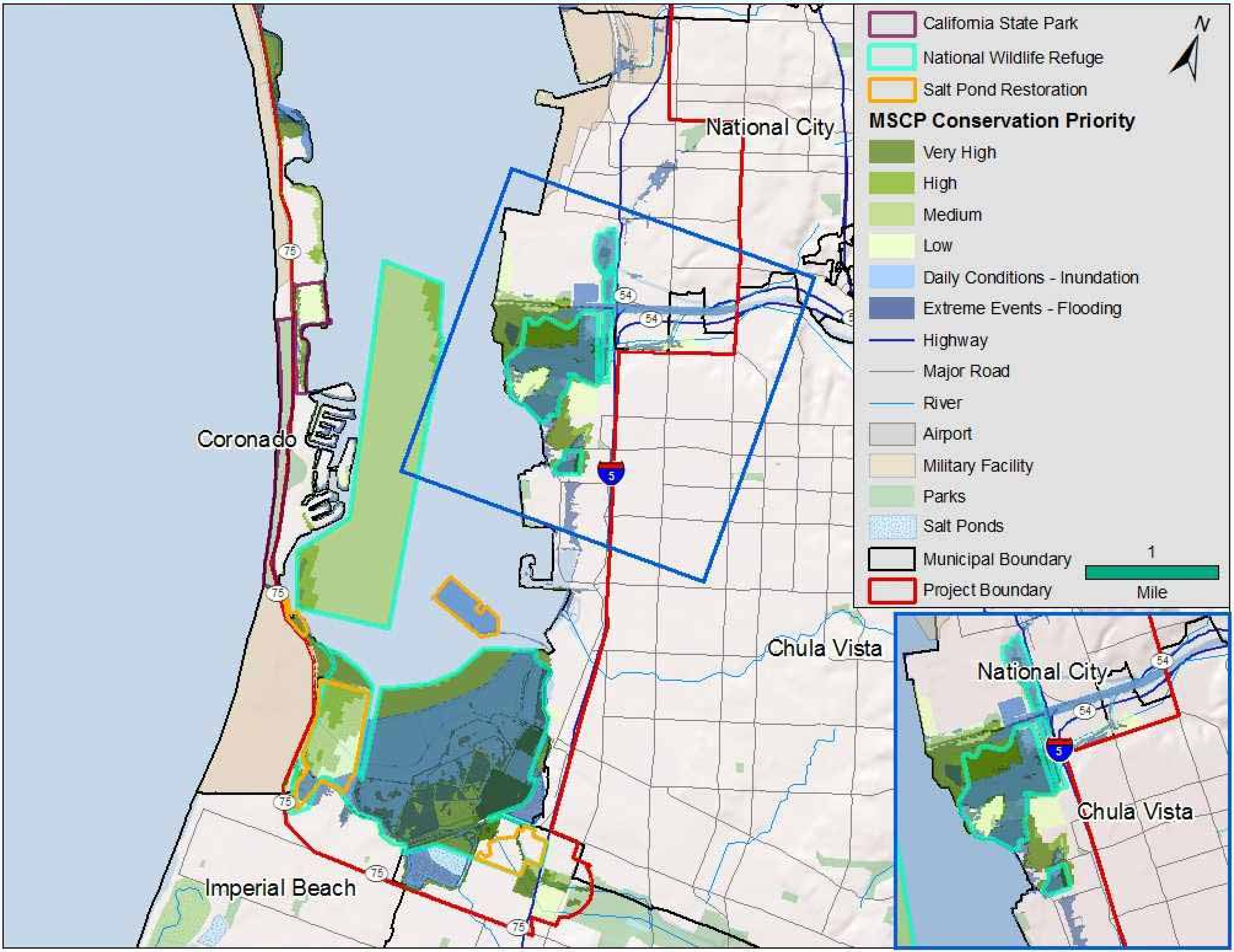
This appendix presents the GIS maps that were generated during the Vulnerability Assessment overlay analysis.

Map 1: Ecosystems - Flood and Inundation Exposure Under 2050 Planning Scenario - North

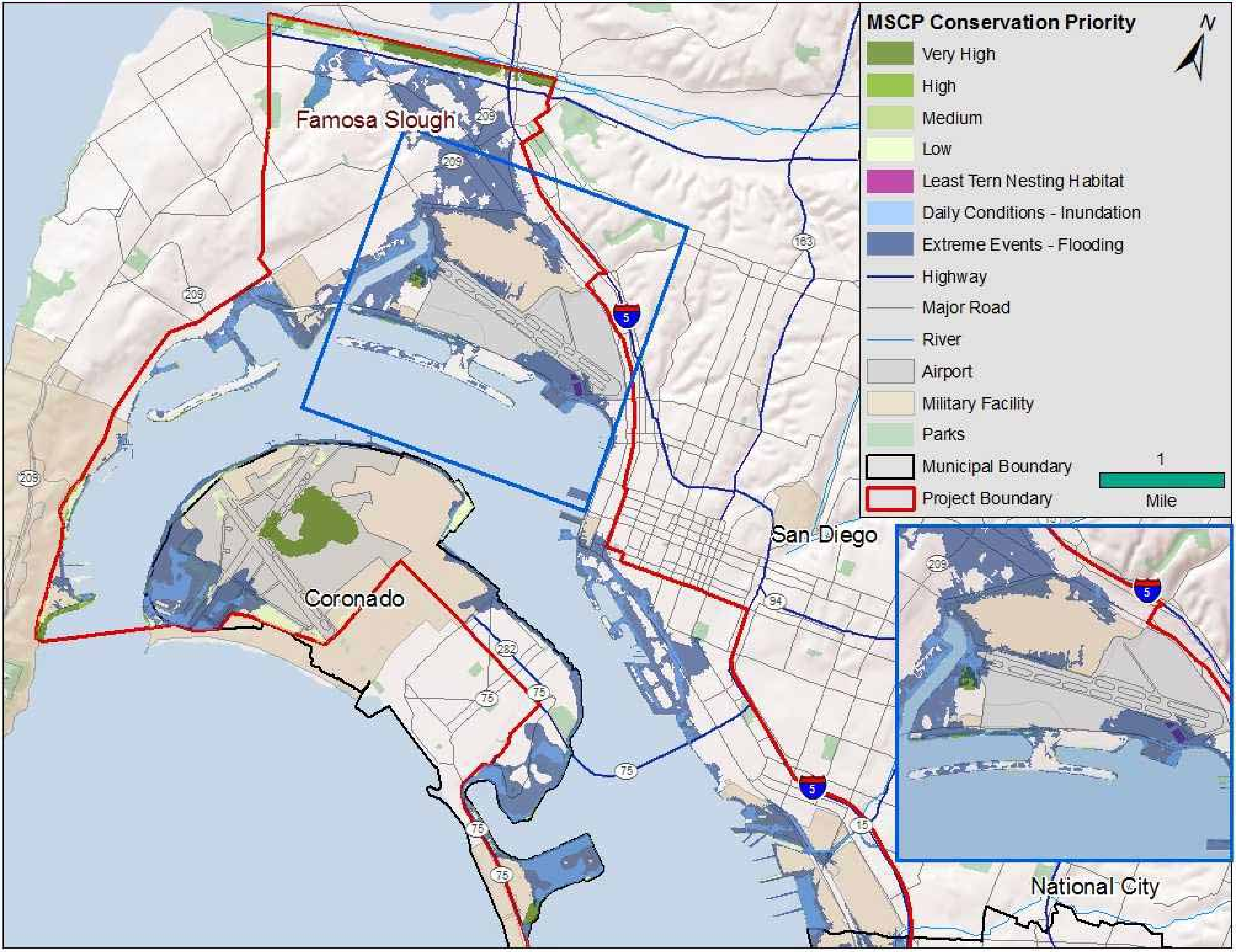
Map 2: Ecosystems - Flood and Inundation Exposure Under 2050 Planning Scenario - South



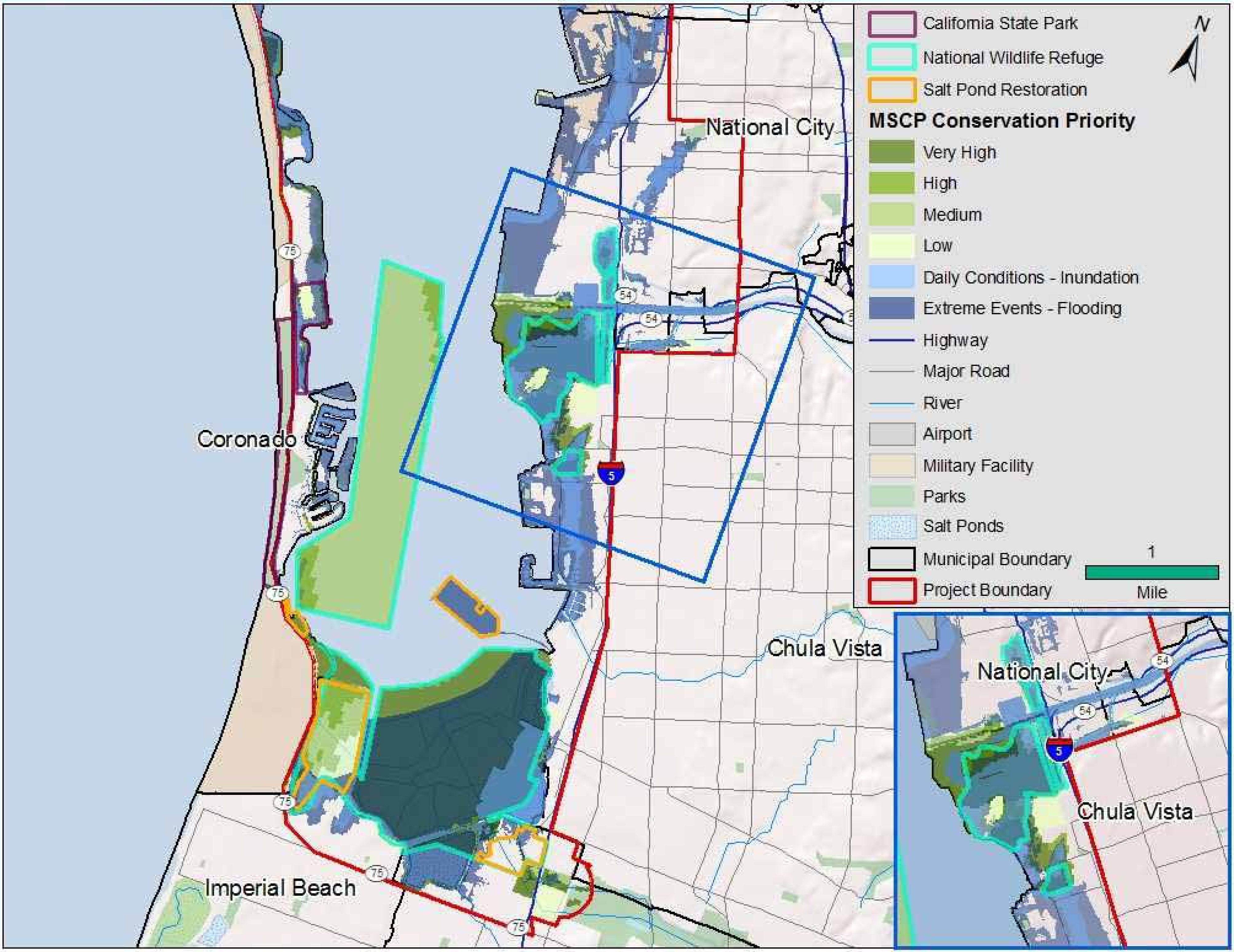
Map 2: Ecosystems - Flood and Inundation Exposure Under 2050 Planning Scenario - South



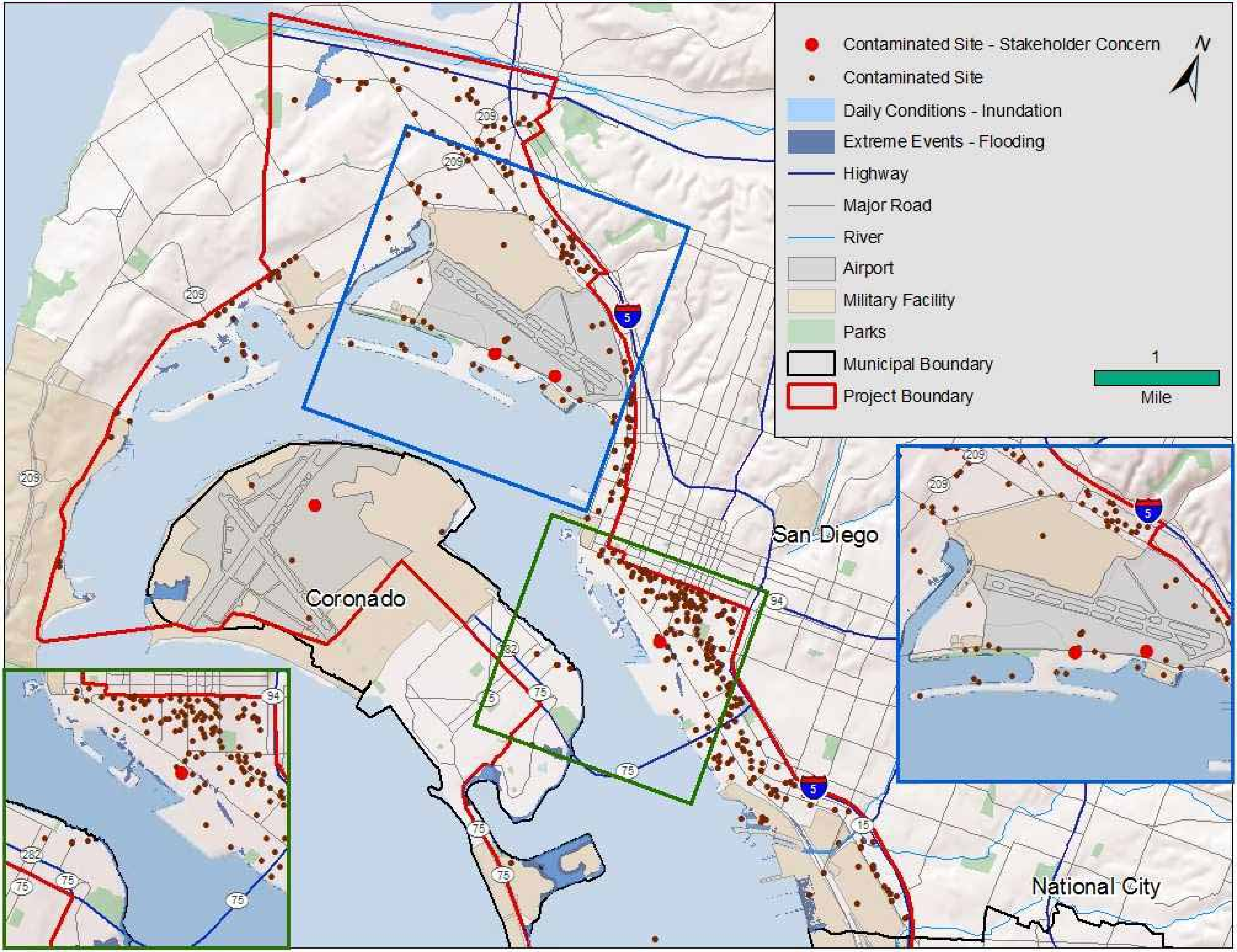
Map 3: Ecosystems - Flood and Inundation Exposure Under 2100 Planning Scenario - North



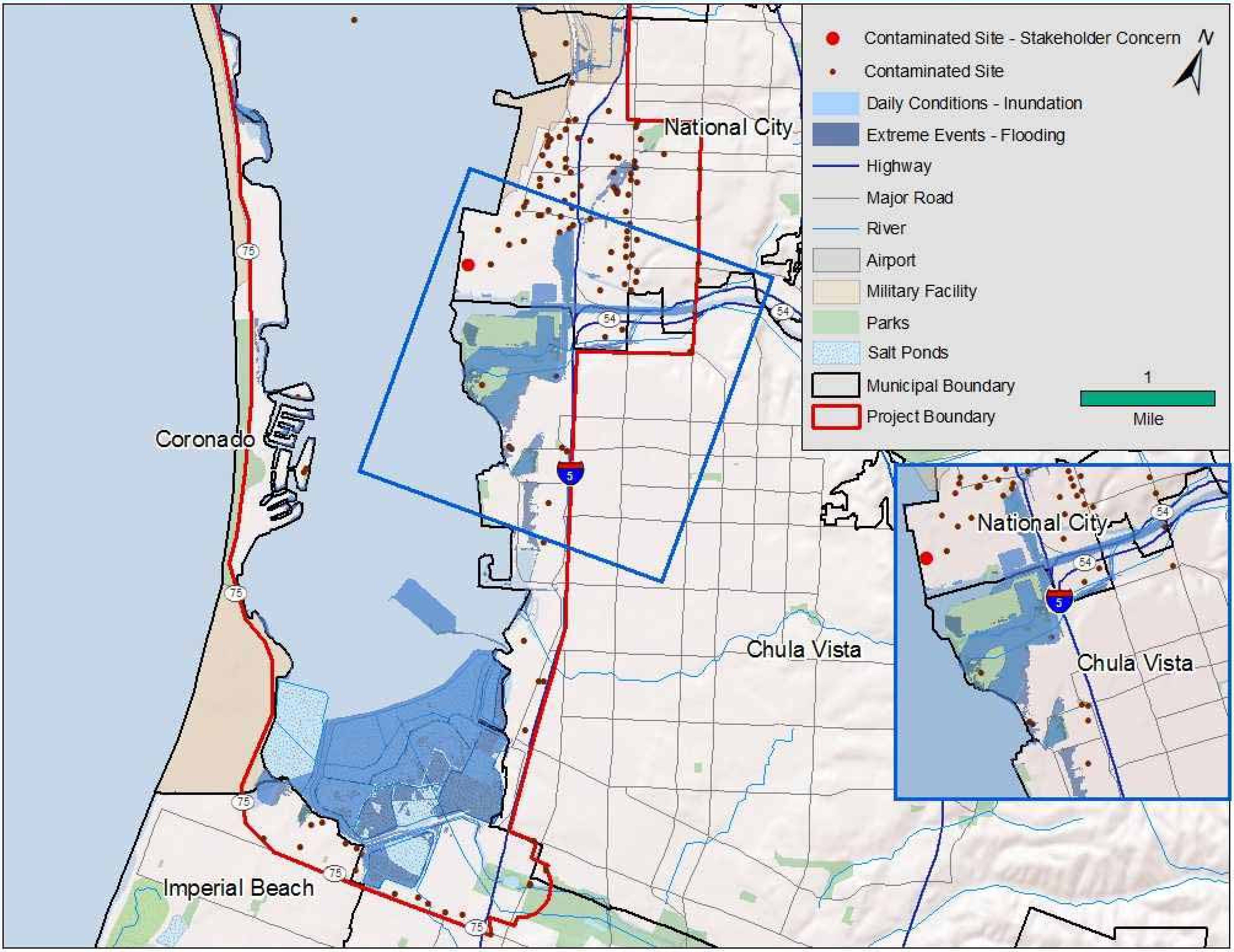
Map 4: Ecosystems - Flood and Inundation Exposure Under 2100 Planning Scenario - South



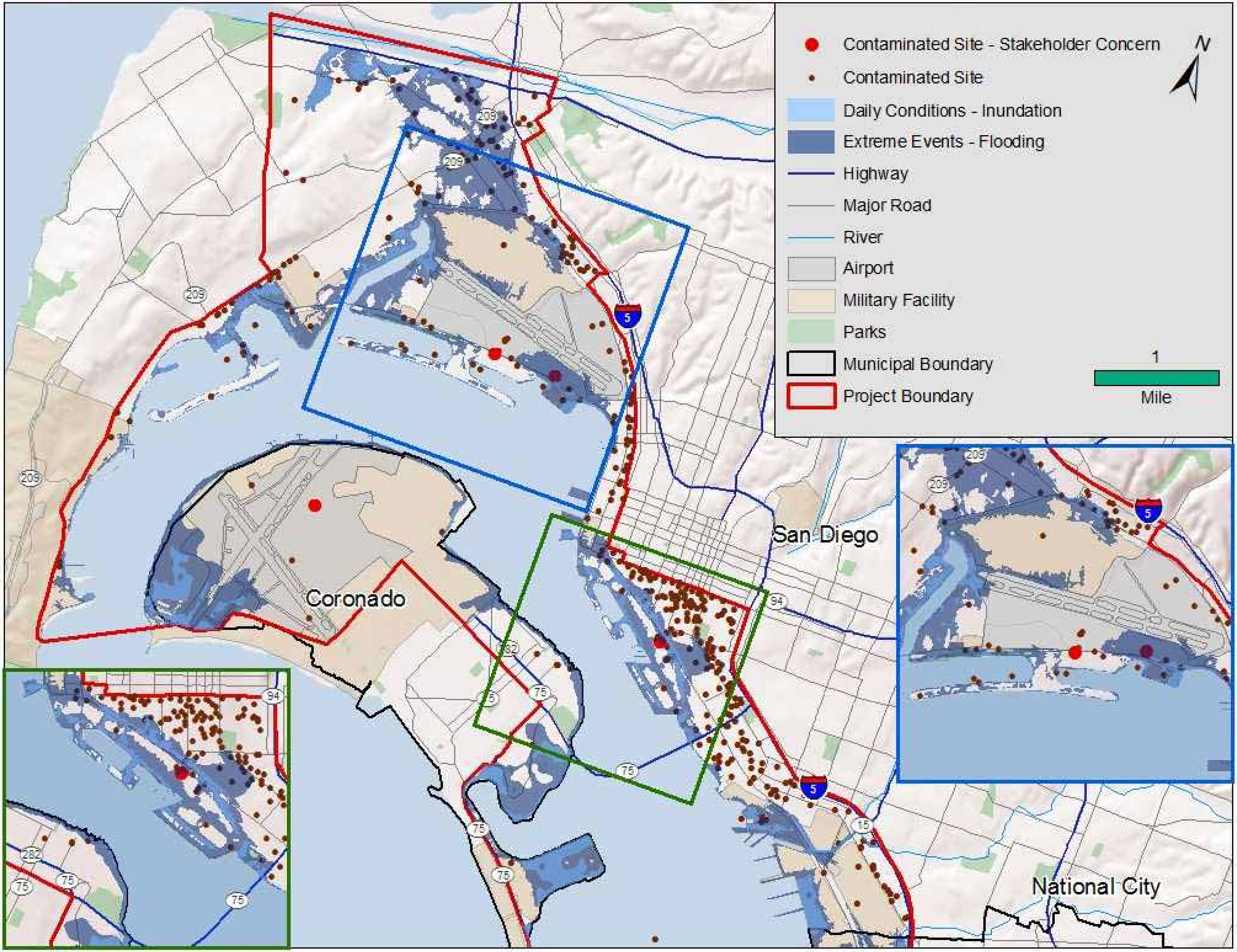
Map 5: Contaminated Sites - Flood and Inundation Exposure Under 2050 Planning Scenario - North



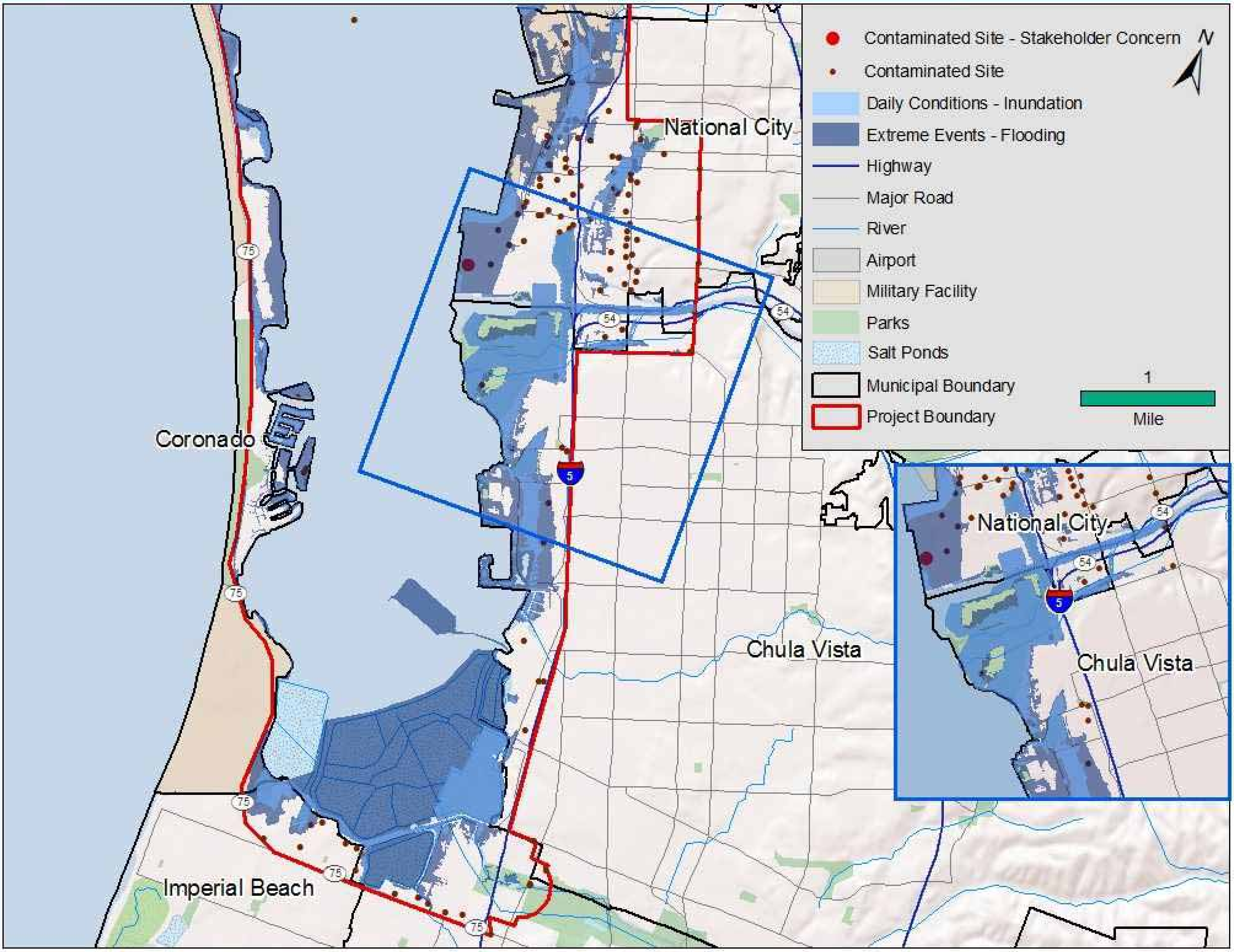
Map 6: Contaminated Sites - Flood and Inundation Exposure Under 2050 Planning Scenario - South



Map 7: Contaminated Sites - Flood and Inundation Exposure Under 2100 Planning Scenario - North

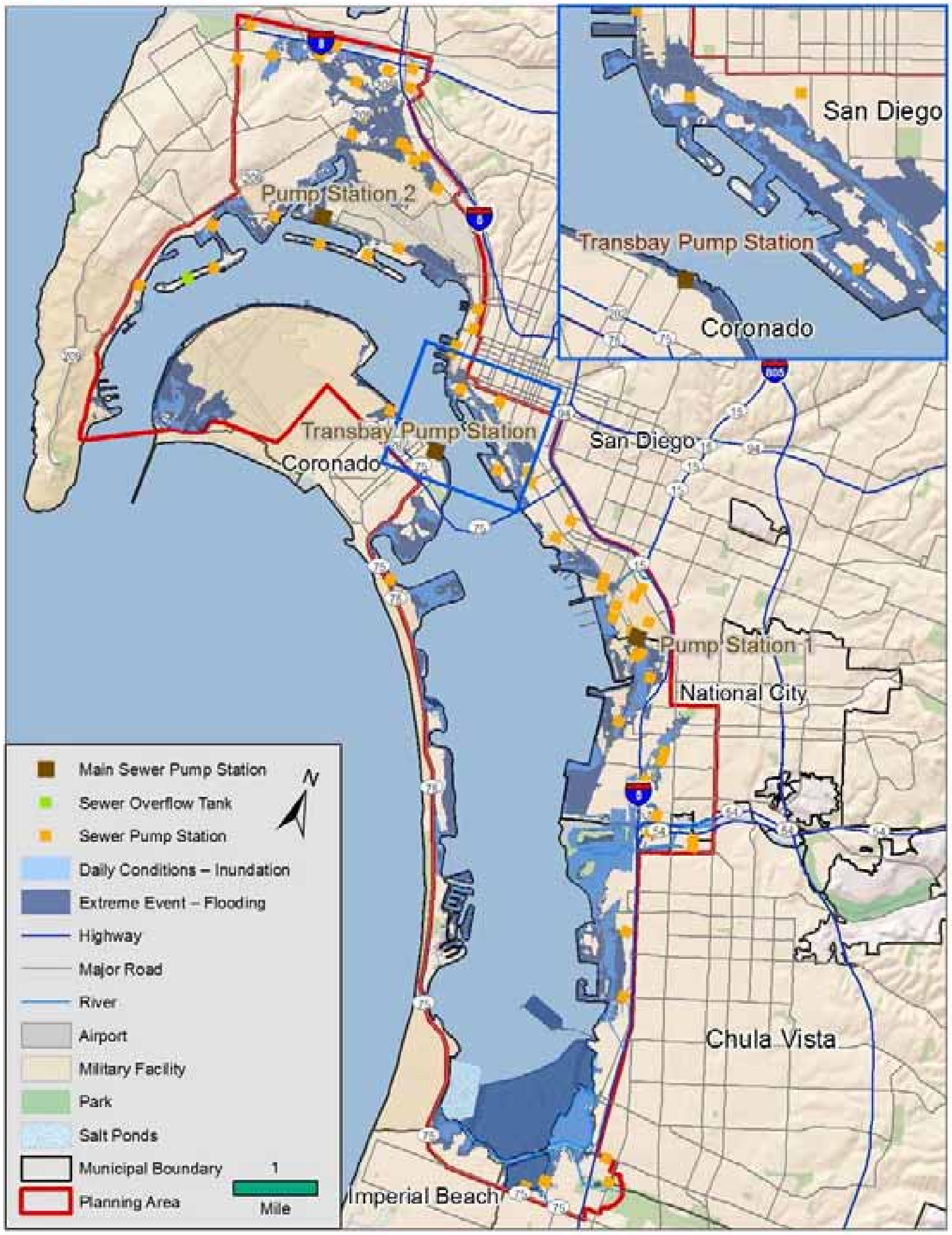


Map 8: Contaminated Sites - Flood and Inundation Exposure Under 2100 Planning Scenario - South



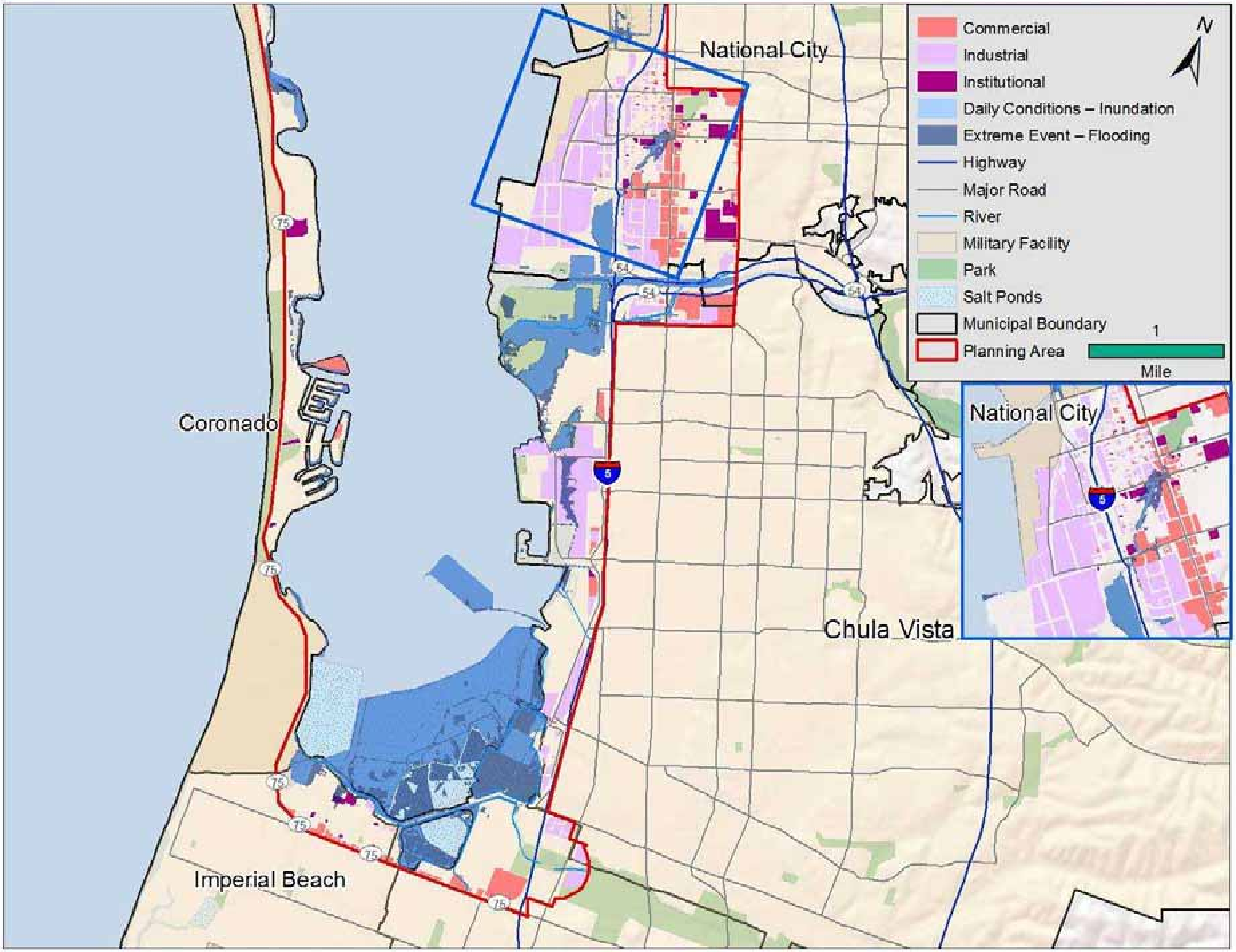
Map 9: Wastewater – Flood and Inundation Exposure Under 2050 Planning Scenario

Map 10: Wastewater – Flood and Inundation Exposure Under 2100 Planning Scenario

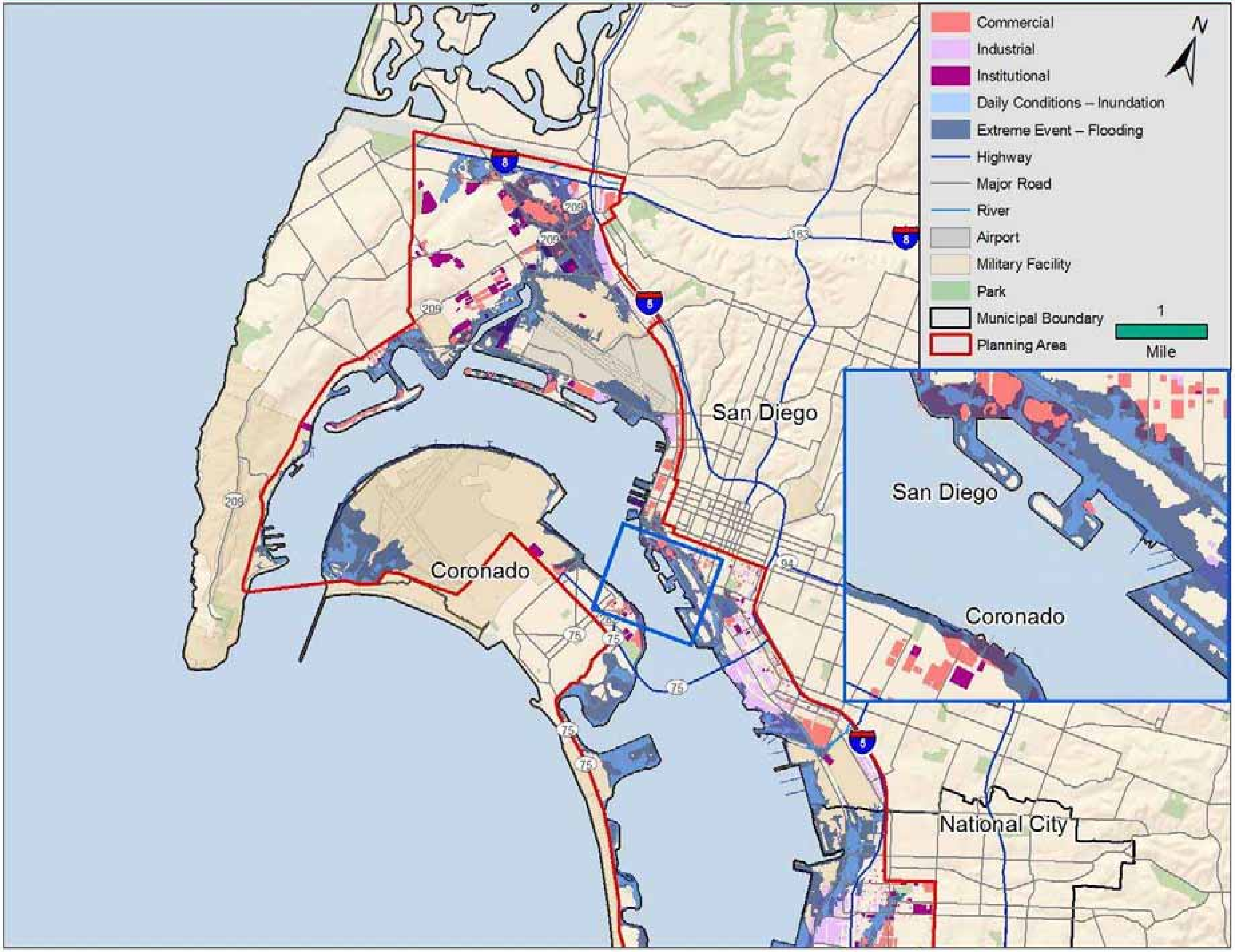


Map 11: Commercial Building Stock – Flood and Inundation Exposure Under 2050 Planning Scenario – North

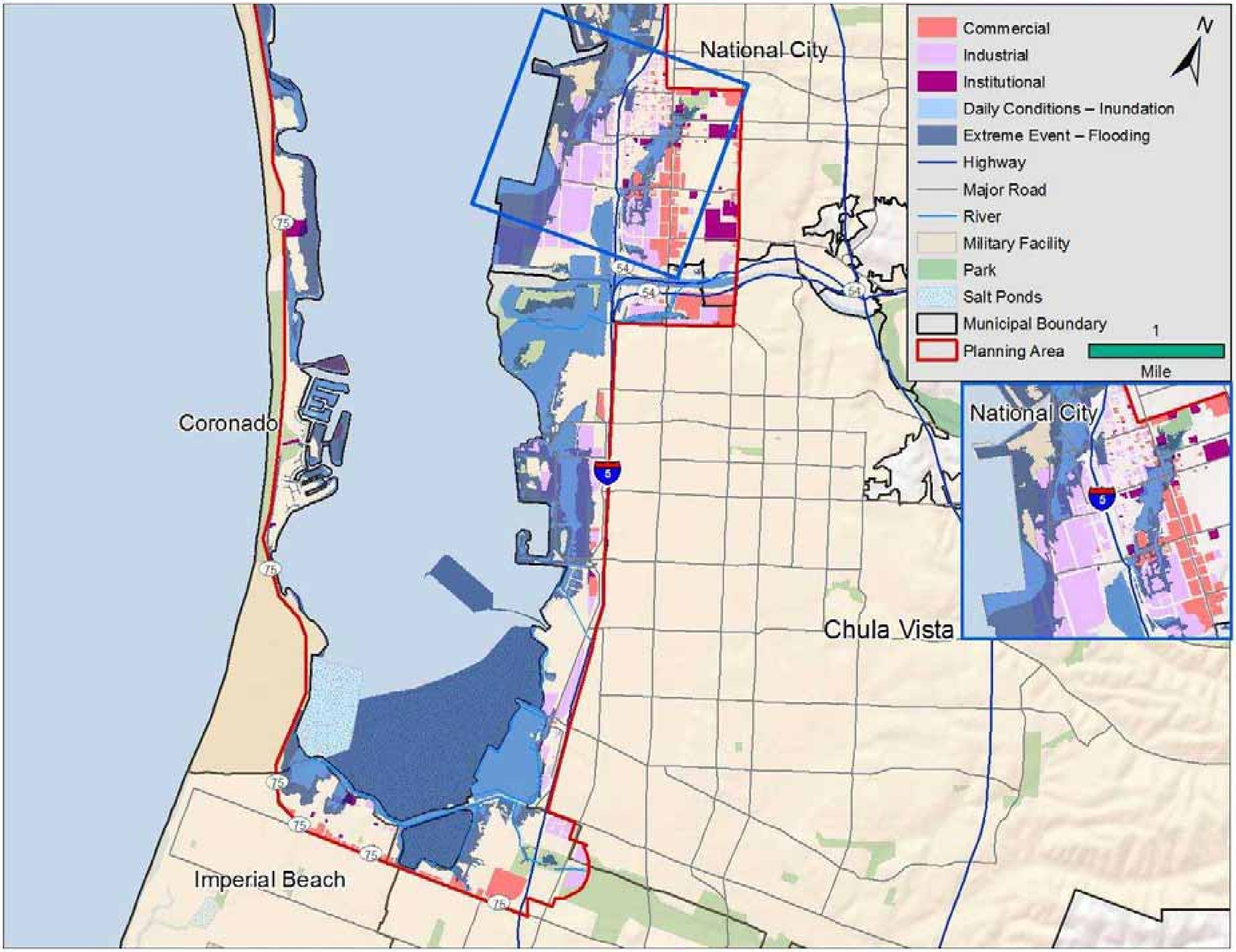
Map 12: Commercial Building Stock – Flood and Inundation Exposure Under 2050 Planning Scenario – South



Map 13: Commercial Building Stock – Flood and Inundation Exposure Under 2100 Planning Scenario – North



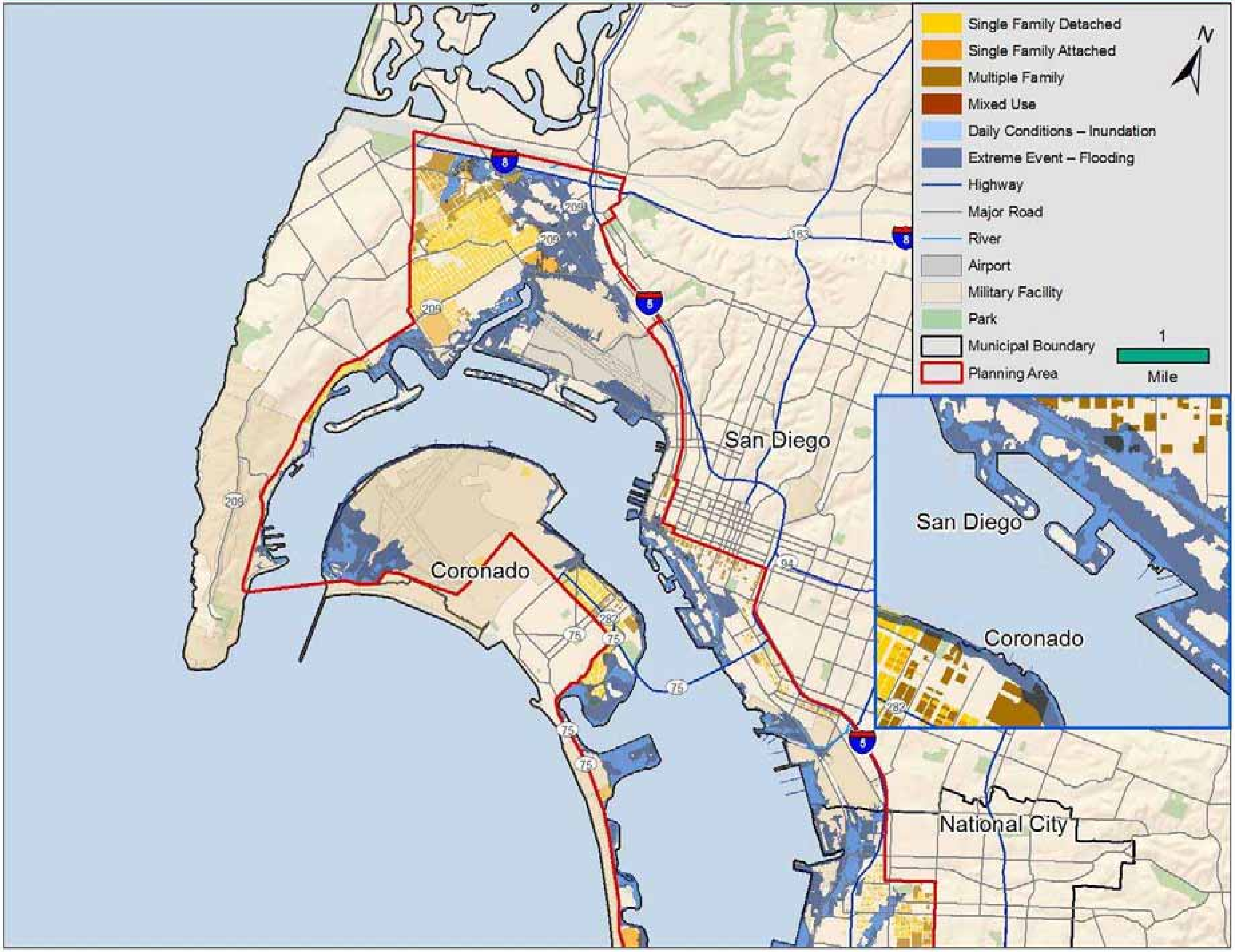
Map 14: Commercial Building Stock – Flood and Inundation Exposure Under 2100 Planning Scenario – South



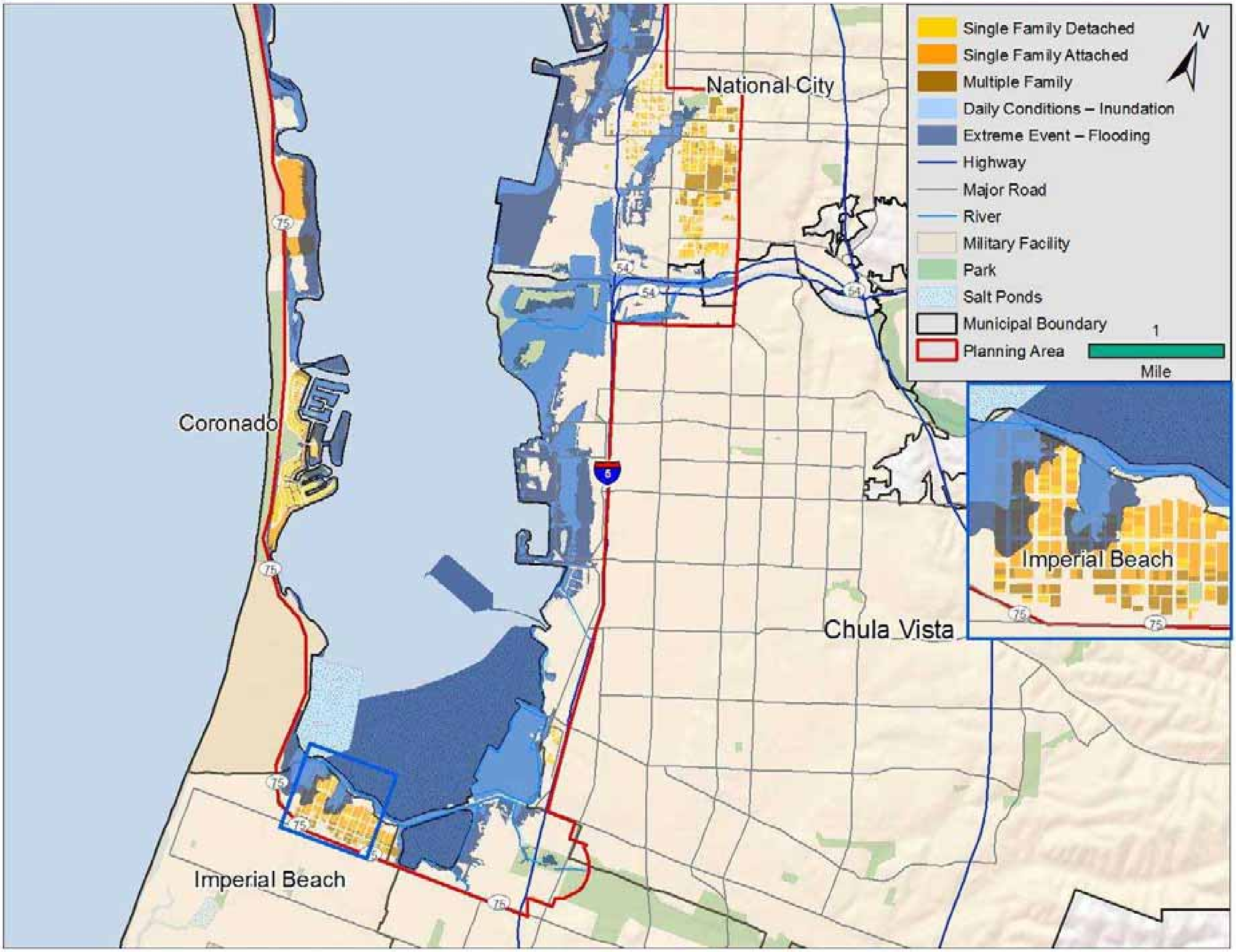
Map 15: Residential Building Stock – Flood and Inundation Exposure Under 2050 Planning Scenario – North

Map 16: Residential Building Stock – Flood and Inundation Exposure Under 2050 Planning Scenario – South

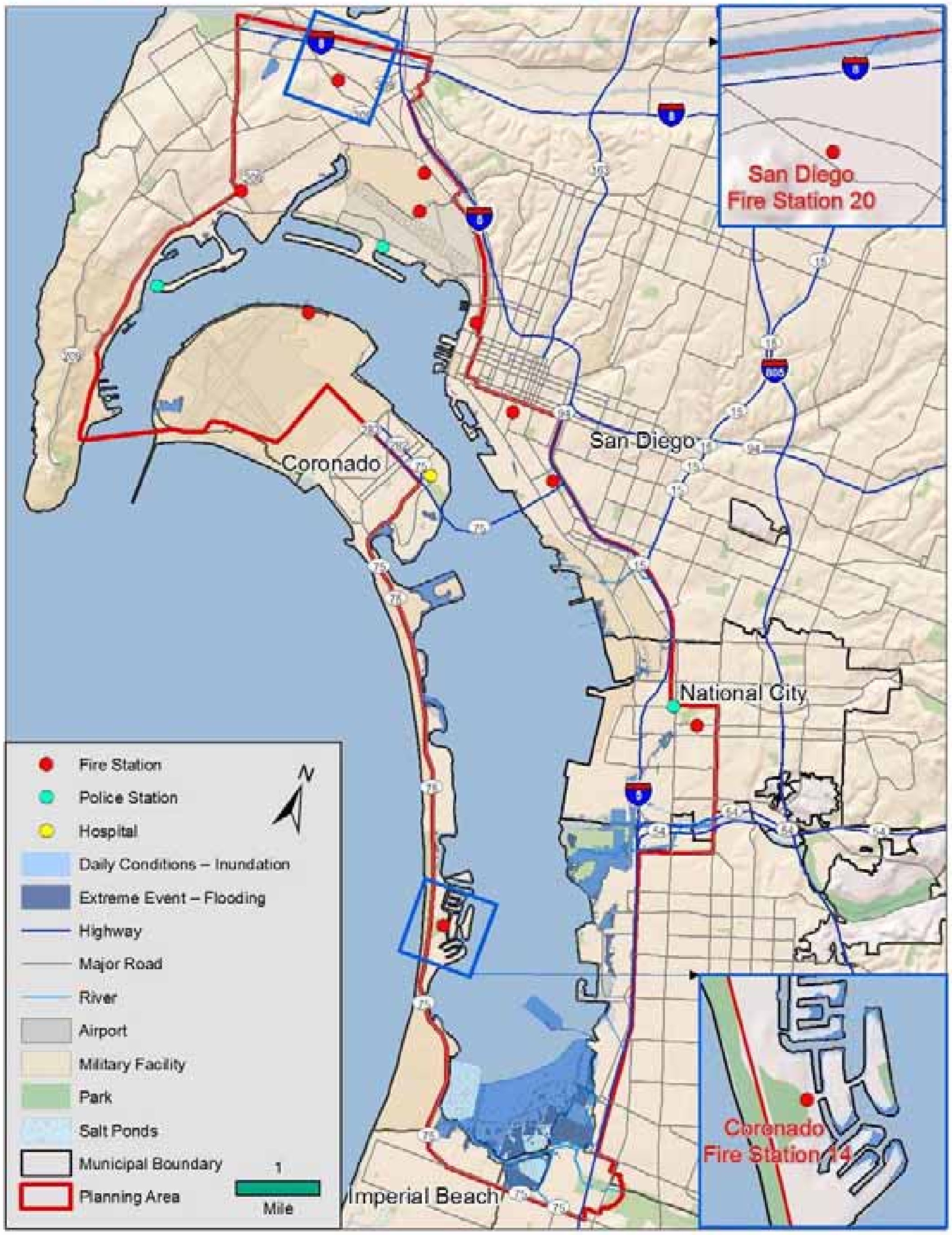
Map 17: Residential Building Stock – Flood and Inundation Exposure Under 2100 Planning Scenario – North



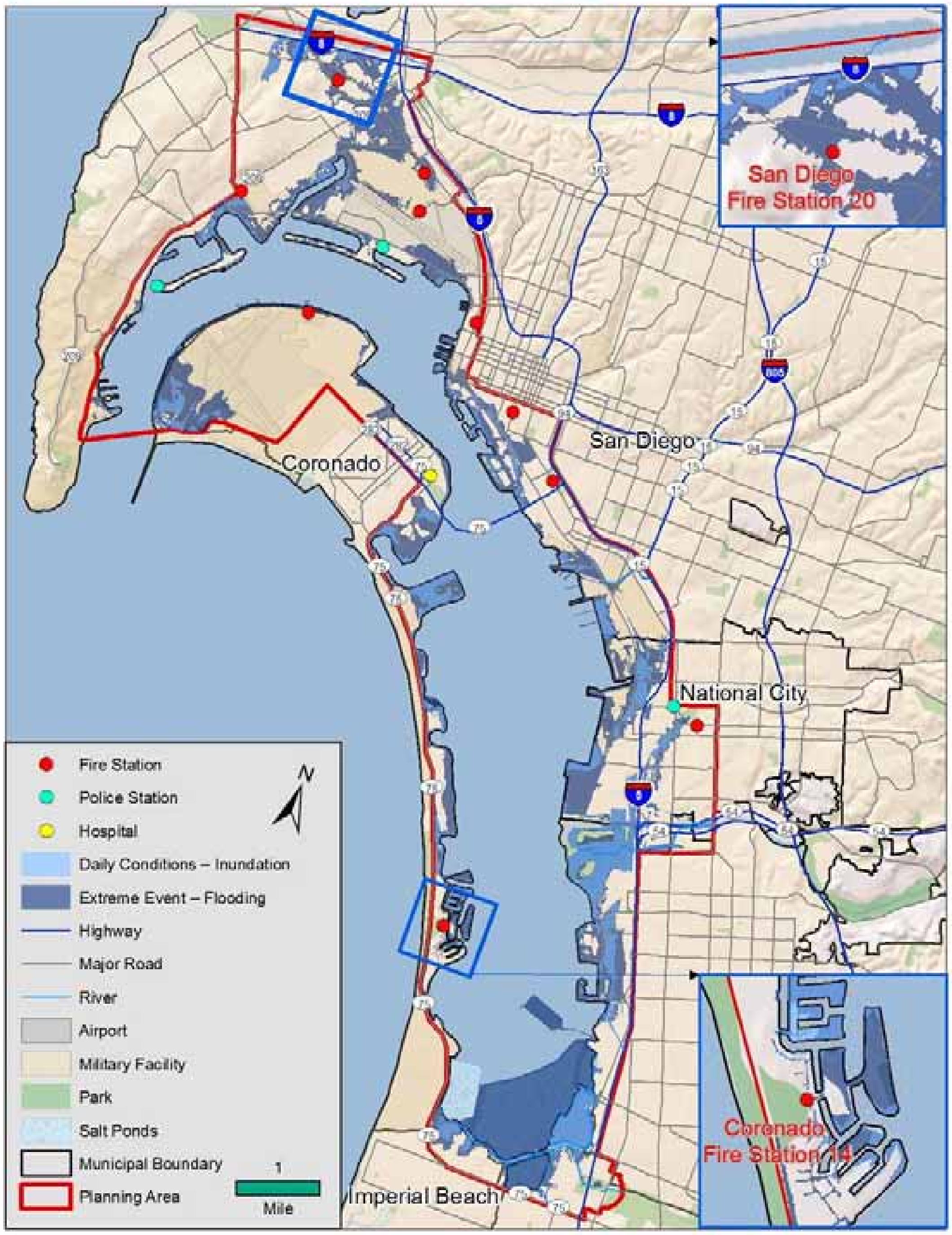
Map 18: Residential Building Stock – Flood and Inundation Exposure Under 2100 Planning Scenario – South



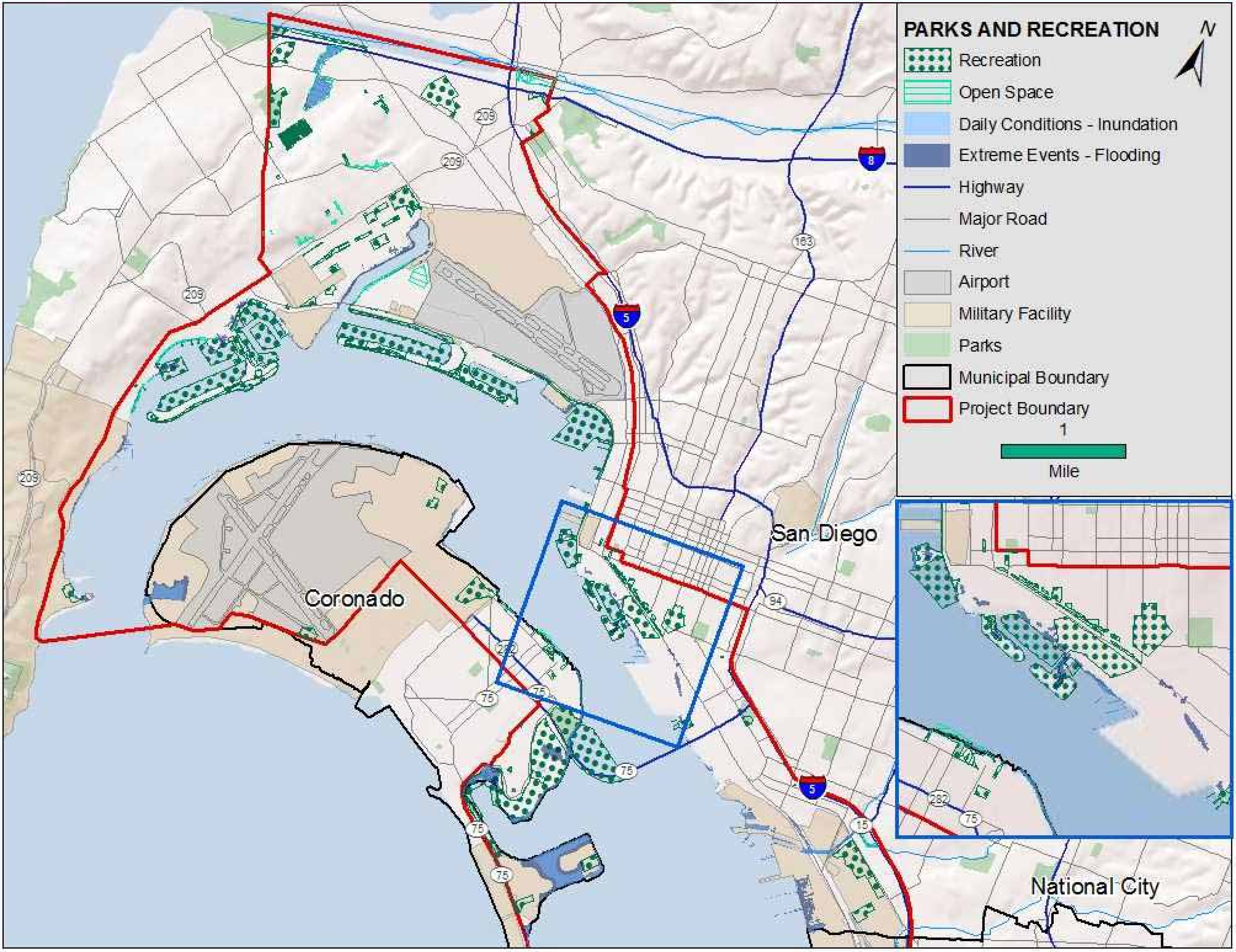
Map 19: Emergency Response Facilities – Flood and Inundation Exposure Under 2050 Planning Scenario



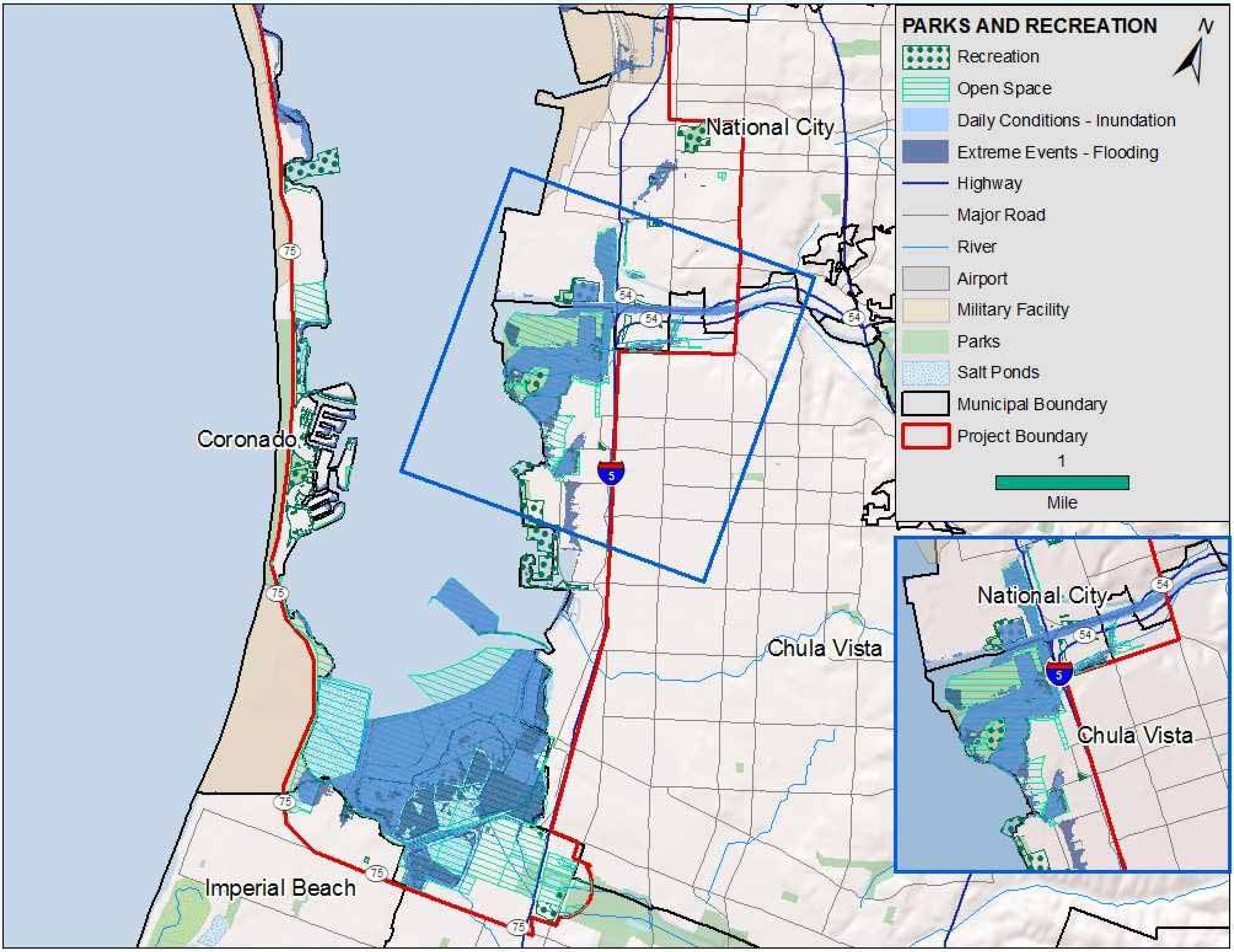
Map 20: Emergency Response Facilities – Flood and Inundation Exposure Under 2100 Planning Scenario



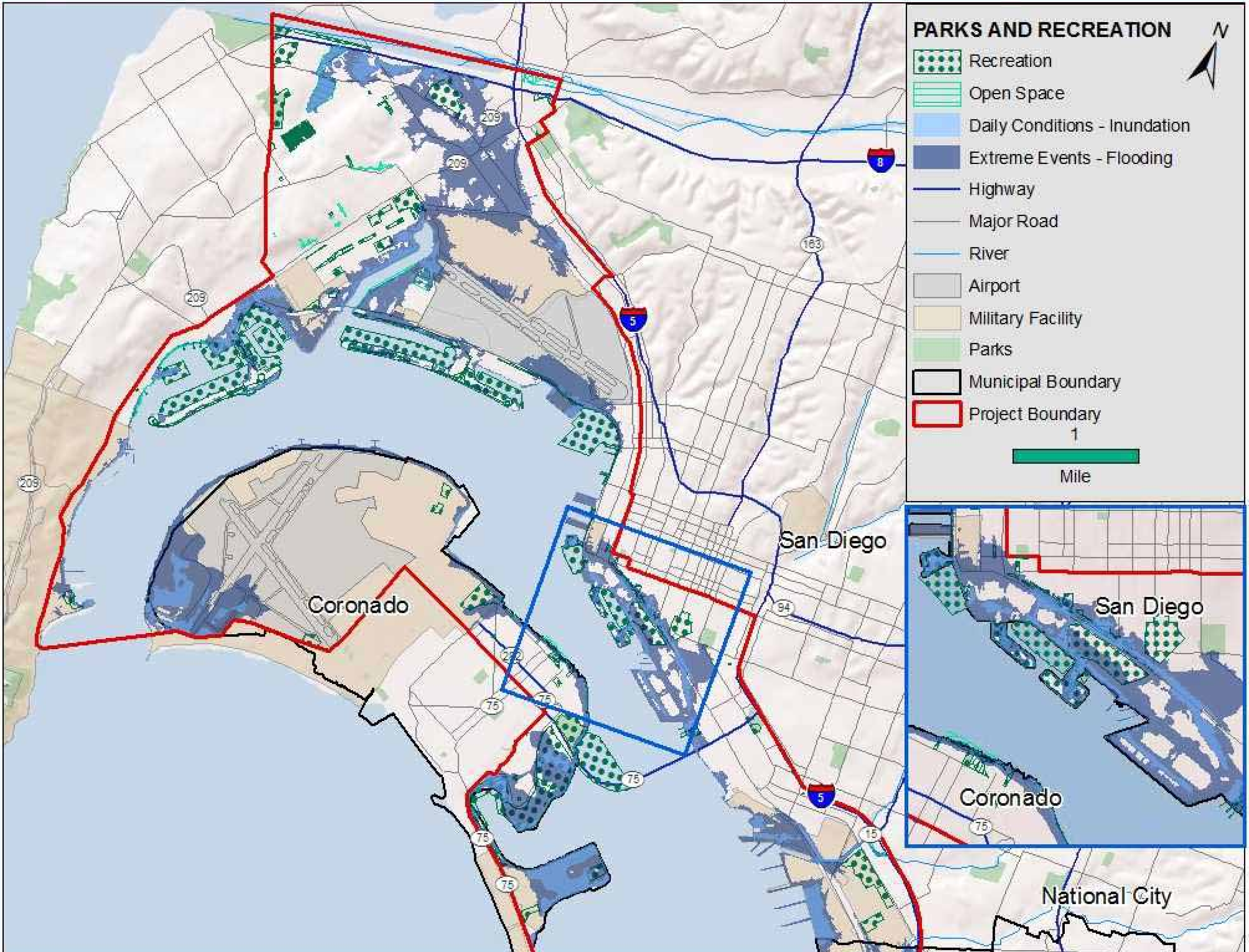
Map 21: Parks and Recreation - Flood and Inundation Exposure Under 2050 Planning Scenario - North



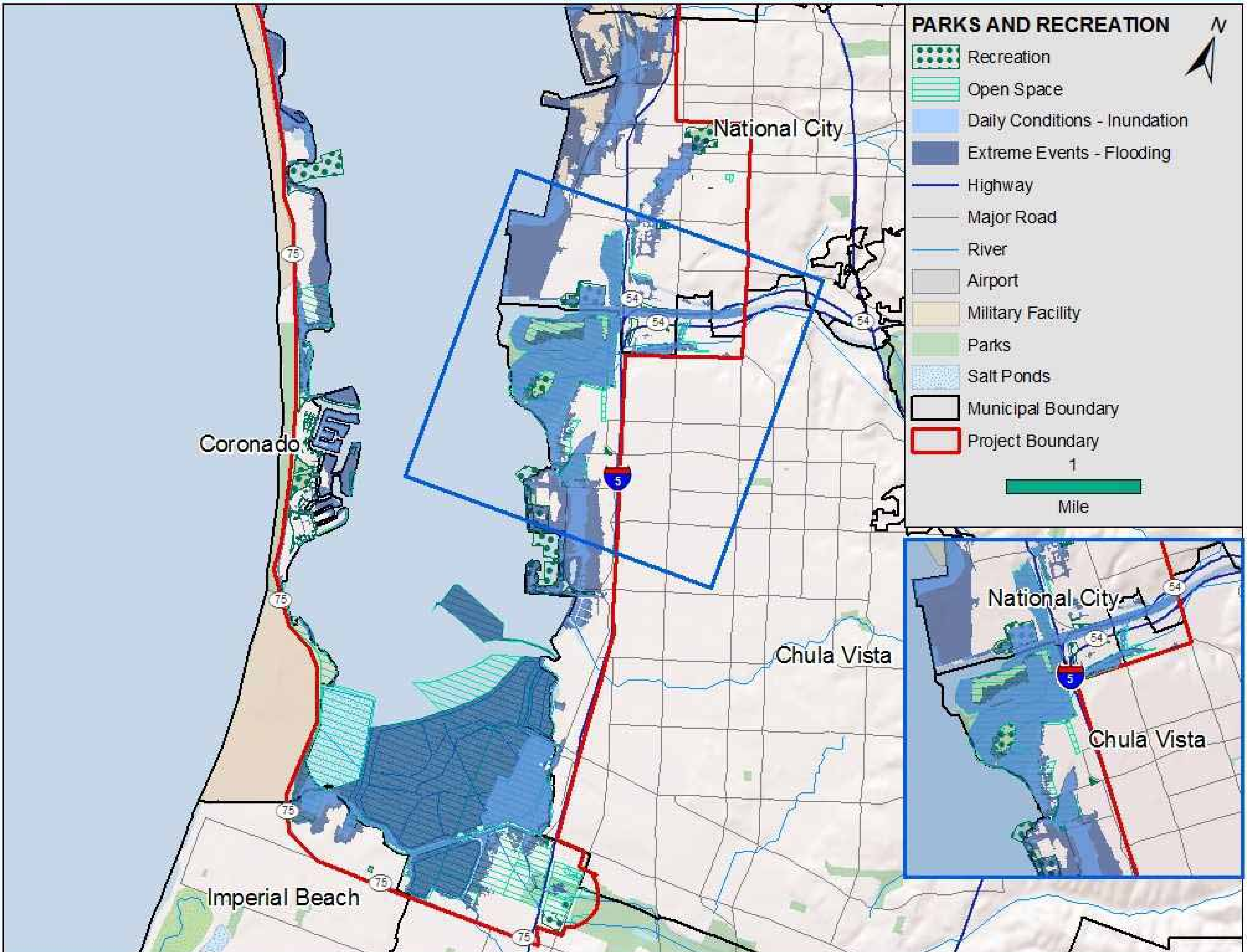
Map 22: Parks and Recreation - Flood and Inundation Exposure Under 2050 Planning Scenario - South



Map 23: Parks and Recreation - Flood and Inundation Exposure Under 2100 Planning Scenario - North



Map 24: Parks and Recreation - Flood and Inundation Exposure Under 2100 Planning Scenario - South



APPENDIX III – TARGETED STRATEGY EVALUATION MATRICES

This appendix presents the Excel-based spreadsheets that were used to evaluate potential targeted strategies. A key to the matrix format can be found on the following page.

EXAMPLE MATRIX

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria: SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Flooding and Inundation		Above-ground water distribution components such as valves, meters, and service points will be vulnerable to flooding.																
Also a Comprehensive Strategy	1	Develop a detailed vulnerability assessment of potable water facilities including future sea level rise impacts for the most at-risk facilities. Evaluate the flood-resistance of specific mechanical equipment in areas vulnerable to future SLR-related floo	+	0	+	0	+	++	+	0	0	0	0	+	0	+	+	8
	2	Update potable water emergency response and maintenance procedures to account for more common and more extensive coastal flooding in vulnerable areas.	+	0	0	0	+	+	+	0	0	0	0	+	0	0	+	7
Water Table Rise		Water distribution systems would be vulnerable if exposed to a rising water table, particularly relating to damage and maintenance of buried mains.																
Also a Comprehensive Strategy	3	Evaluate water table rise scenarios and infrastructure vulnerabilities, in concert with other local jurisdictions, academic researchers, USGS, and other relevant entities. Develop adaptation responses based on vulnerability analysis.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	8

Key vulnerability identified in the Vulnerability Assessment

Targeted strategy addressing the key vulnerability

Evaluation criteria developed by stakeholder group

Sum of evaluation ratings; strategies are listed in **rank** order for each vulnerability

Evaluation rating of how well the strategy meets the criteria (see rating key below)

Evaluation Rating Key

++	Strategy strongly promotes criteria goal
+	Strategy somewhat promotes criteria goal
0	Not applicable or no effect on criteria goal
-	Strategy somewhat conflicts with criteria goal
- -	Strategy strongly conflicts with criteria goal

Bay Sea Level Rise Strategy Evaluation Matrix - Building Stock Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria															Total Rank
			SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	
Flooding and Inundation		Buildings have a low vulnerability to flooding in the 2050 scenario due to limited exposure. They are highly-vulnerable to flooding in the 2100 scenarios as exposure expands to large portions of developed areas.																
Also a Comprehensive Strategy	1	Work with FEMA to improve Flood Insurance Rate Maps (FIRMs) and create additional maps that include future sea level rise.	+	+	0	0	+	++	+	+	0	0	0	+	0	+	+	**10**
	2	In areas vulnerable to projected SLR-related flooding and in the existing 100-year floodplain, consider strengthening floodplain management regulations through participation in the FEMA Community Rating System or through incorporation of more flood-resistant building code provisions.	+	+	0	0	+	++	+	+	0	0	0	0	0	++	0	**9**
	3	In areas vulnerable to projected SLR-related flooding that are not in the existing 100-year floodplain, consider applying NFIP minimum requirements to new development.	+	+	0	0	+	++	+	+	0	0	0	0	0	++	0	**9**
	4	Establish building setbacks from flood lines & ensure that they apply to redevelopment of any buildings destroyed in flooding events.	+	0	+	0	+	+	0	0	+	+	+	0	+	+	0	**9**
	5	Create financial incentives for buildings constructed to higher standards.	+	0	+	0	+	+	+	0	+	0	0	0	0	+	+	**8**
	6	Set higher building code standards - requiring homes to be build above minimum FEMA requirements.	+	0	+	0	+	+	0	0	0	0	0	0	+	++	+	**8**
	7	Gather more specific elevation data creating a better understanding of current base floor building elevations.	++	+	0	0	+	+	+	0	0	0	0	0	0	0	+	**7**
	8	Create a real estate disclosure statement that requires more explicit statements regarding future risks.	+	0	+	0	+	+	+	0	0	0	0	0	0	0	+	**6**
	9	Develop, enhance and distribute outreach and education materials for building owners and tenants in flood prone areas.	+	0	0	0	+	+	+	+	0	0	0	0	+	0	0	**6**
Water Table Rise		Sub-surface structures such as parking garages and basements could be vulnerable to a rising waster table if exposed.																
Also a Comprehensive Strategy	10	Evaluate water table rise scenarios and infrastructure vulnerabilities, in concert with other local jurisdictions, academic researchers, USGS, and other relevant entities. Develop adaptation responses based on vulnerability analysis.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	**6**
Also a Comprehensive Strategy	11	Evaluate geotechnical analyses and dewatering permits to assemble a database of water table interaction.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	**6**

Bay Sea Level Rise Strategy Evaluation Matrix - Wastewater Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria: SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Flooding and Inundation	**A**	Sanitary sewers in low-lying locations will be vulnerable to floodwater inflow which could exceed their capacity, potentially resulting in discharge of wastewater to the Bay.																
Also addresses Wastewater Vulnerability C	1	Ensure that new sewer mains and manholes are sealed against floodwater inflow and groundwater infiltration. Expand programs to reduce inflow and infiltration through rehabilitation of sewer mains and manholes, prioritizing areas where risk of flooding is highest	++	+	0	0	+	+	++	0	0	+	0	+	0	++	++	**13**
	2	Monitor incidences of residents removing sanitary sewer manholes during storm events, and initiate or expand programs to reduce this practice as necessary.	++	+	+	0	+	++	++	0	0	+	0	+	0	0	+	**12**
	3	Update wastewater management plans and capital improvement programs to account for sea level rise-related challenges.	++	+	+	0	+	+	++	+	0	0	0	+	0	+	+	**12**
Flooding	**B**	Surface infrastructure such as major pump stations vulnerable to flooding and inundation.																
	4	Depending on facility design, elevate pump stations and emergency generators as they are rehabitated or in new construction.	+	+	0	0	+	+	++	0	0	+	0	++	0	+	+	**11**
Also a Comprehensive Strategy	5	Develop a detailed vulnerability assessment of wastewater facilities including future sea level rise impacts for the most at-risk facilities, and worked towards a map of these facilities.	++	-	0	0	+	+	++	+	0	0	0	+	0	+	+	**9**
	6	Update wastewater emergency response and maintenance procedures to account for more common and more extensive coastal flooding of vulnerable infrastructure.	+	0	0	0	+	+	++	0	0	+	0	+	0	+	+	**9**
Water Table Rise	**C**	Mains vulnerable to groundwater infiltration, damage, and maintenance challenges if exposed to the water table																
Also addresses Wastewater Vulnerability A.	7	Ensure that new sewer mains are sealed against floodwater inflow and groundwater infiltration. Expand programs to reduce inflow and infiltration through rehabilitation of sewer mains and manholes, prioritizing areas where risk of flooding is increasing d	++	0	0	0	+	+	+	0	+	0	0	+	+	++	+	**11**
Also a Comprehensive Strategy	8	Evaluate water table rise scenarios and infrastructure vulnerabilities, in concert with other local jurisdictions, academic researchers, USGS, and other relevant entities. Develop adaptation responses based on vulnerability analysis.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	**6**

Bay Sea Level Rise Strategy Evaluation Matrix - Stormwater and Flood Control Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria: SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Flooding and Inundation		Storm sewers are very vulnerable to flooding and inundation of Bay drain outfalls due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas, especially during storm events																
	1	Prioritize low-impact development (LID) stormwater practices that encourage infiltration to minimize reliance on storm sewers that could be impaired by SLR.	++	+	+	+	+	++	++	+	+	+	0	+	0	+	+	**16**
	2	Evaluate technologies that can seal off drain outfalls against Bay water inflow during high water events, and install viable technologies on outfalls that could be exposed over the lifespan of the facility due to sea level rise.	++	+	+	0	+	++	++	+	0	0	0	+	0	+	+	**13**
	3	Update stormwater management plans and capital improvement programs to account for sea level rise-related challenges such as flooded Bay outfalls. Include strategic consideration of systemic reconstruction of stormwater facilities in the later-century timeframe.	++	++	+	0	+	+	++	+	0	0	0	+	0	+	+	**13**
	4	Increase capacity of stormwater management facilities to accommodate more common and more extensive coastal flooding.	++	+	+	0	+	++	++	+	0	0	0	+	0	+	+	**13**
	5	Develop a detailed vulnerability assessment of stormwater management at the facility level for the most at-risk facilities, including drain outfalls and areas that could be exposed to localized flooding from Bay water inflow into drains.	++	-	0	0	+	+	++	+	0	0	0	+	0	+	+	**9**
Water Table Rise		Storm drains and BMPs would be vulnerable if exposed to a rising water table, but more information is needed to determine the nature of potential exposure.																
	6	Evaluate water table rise scenarios and infrastructure vulnerabilities, in concert with other local jurisdictions, academic researchers, USGS, and other relevant entities. Develop adaptation responses based on vulnerability analysis.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	**6**

Bay Sea Level Rise Strategy Evaluation Matrix - Potable Water Strategies

Sea Level Rise Impact to San Diego Bay	#	Key Vulnerability / Adaptation Strategy	SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
			Evaluation Criteria															
Flooding and Inundation		Above-ground water distribution components such as valves, meters, and service points will be vulnerable to flooding.																
Also a Comprehensive Strategy	1	Develop a detailed vulnerability assessment of potable water facilities including future sea level rise impacts for the most at-risk facilities. Evaluate the flood-resistance of specific mechanical equipment in areas vulnerable to future SLR-related flooding.	+	0	+	0	+	++	+	0	0	0	0	+	0	+	+	**9**
	2	Update potable water emergency response and maintenance procedures to account for more common and more extensive coastal flooding in vulnerable areas.	+	0	0	0	+	+	+	0	0	0	0	+	0	0	++	**7**
Water Table Rise		Water distribution systems would be vulnerable if exposed to a rising water table, particularly relating to damage and maintenance of buried mains.																
Also a Comprehensive Strategy	3	Evaluate water table rise scenarios and infrastructure vulnerabilities, in concert with other local jurisdictions, academic researchers, USGS, and other relevant entities. Develop adaptation responses based on vulnerability analysis.	++	-	0	0	+	+	0	0	0	0	0	+	0	+	+	**6**

Bay Sea Level Rise Strategy Evaluation Matrix - Transportation Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria															Total Rank
			SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	
Flooding and Inundation		Access provided by local transportation facilities will be vulnerable to surface flooding.																
	1	Evaluate emergency response procedures such as emergency responder access and evacuation route designations for vulnerability to more common and more extensive coastal flooding.	+	+	+	0	++	++	+	+	0	0	0	+	0	0	++	**12**
	2	Design new transportation projects to be resilient to sea level rise. Consider policies that require sea level rise to be factored into the design of all transportation projects and major repairs in areas vulnerable to flooding over the life of the project.	+	0	+	+	+	+	0	0	0	0	0	+	0	++	+	**9**
	3	Monitor changes in design standards relating to drainage, and consider applying floodplain-level standards in areas vulnerable to flooding in the life of the project but that may not be in existing 100-year floodplain.	+	+	0	0	+	+	0	0	0	0	0	0	0	++	+	**7**
	4	Work with SANDAG to evaluate the vulnerabilities of existing regional transportation facilities. Work with SANDAG and Caltrans to consider adaptation in the design of new facilities and in improvements to existing infrastructure in vulnerable areas.	0	0	0	0	+	+	0	0	0	0	0	+	0	+	+	**5**
Flooding		Roads and other facilities could be damanged due to saturated soils and impacts on road substructure and pavement degradation.																
	5	Monitor changes in design standards relating to substructure and materials specification, and consider applying floodplain-level standards in areas vulnerable to flooding in the life of the project but that may not be in existing 100-year floodplain.	+	+	0	+	+	+	0	0	0	0	0	+	0	++	+	**9**
	6	Evaluate where soil saturation from flooding and/or water table rise could pose a risk to existing or new transportation facilities.	+	0	0	0	+	+	0	0	0	0	0	+	0	++	++	**8**

Bay Sea Level Rise Strategy Evaluation Matrix - Emergency Response Facilities Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria: SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Flooding		Two fire stations in Coronado and San Diego are moderately vulnerable to flooding in the 2100 Extreme Event scenario only.																
Also addresses transportation vulnerabilities	1	Evaluate emergency response procedures such as emergency responder access and evacuation route designations for vulnerability to more common and more extensive coastal flooding.	+	+	+	0	++	++	+	+	0	0	0	+	0	0	++	**12**
	2	Gather more specific information about each critical facility and ensure that a regional data base contains key information on flood heights and building elevation levels.	+	0	0	0	+	++	+	0	0	0	0	++	0	0	+	**8**
	3	Set higher standards for all emergency response facilities that could be exposed to flooding during their life span.	+	0	0	0	+	++	+	0	0	0	0	++	0	+	0	**8**
	4	Create regional agreements for equipment sharing and exchanges in order to enhance ability to respond during extreme events.	0	0	+	0	+	++	+	0	0	0	0	++	0	0	0	**7**

Bay Sea Level Rise Strategy Evaluation Matrix - Regional Airport Operations Strategies																		
Sea Level Rise Impact to San Diego Bay	Key Vulnerability / Adaptation Strategy		Evaluation Criteria															Total Rank
			SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	
Flooding and Inundation	Parts of the Airport site will be vulnerable to localized flooding from blocked storm outfalls into the Bay. In the 2100 scenarios, Airport operations will be extremely vulnerable to Bay flooding, particularly from impacts on access roads, future terminals, and portions of the runway/airfield.																	
	1	Evaluate responses for addressing future flooding from the boat channel at the east end of the runway.	++	+	+	0	+	+	0	0	0	0	0	++	0	0	++	**10**
	2	Incorporate sea level rise flood scenarios at SDIA into the Regional Aviation Strategic Plan (RASP) process and the consideration of alternative sites.	++	+	+	0	+	+	0	0	0	0	0	++	0	0	++	**10**
	3	In the SDIA Master Plan, explore potential for reconfiguring airport access away from key roads that may experience significant flooding and are threatened by inundation.	+	+	0	0	+	+	0	0	0	0	0	++	0	+	+	**8**

Bay Sea Level Rise Strategy Evaluation Matrix - Contaminated Sites Strategies

Sea Level Rise Impact to San Diego Bay	#	Key Vulnerability / Adaptation Strategy	SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
			Evaluation Criteria															
Flooding and Inundation		Highly vulnerable to major flooding events as storage tanks in the area could be opened or moved, or motors and pumps could be impaired thus releasing contamination into flood waters or area soils																
	1	In new remediation, ensure that BMPs are designed to be resilient to end-of-century sea level rise.	++	+	+	0	++	++	++	++	+	0	0	+	+	0	+	**16**
	2	Conduct a targeted assessment of specific high-risk contaminated sites, resulting in a map of these sites and utilize findings to prioritize adaptation responses where sites are vulnerable.	++	+	+	0	++	++	++	++	+	0	0	+	+	0	+	**16**
	3	Conduct an improved regional assessment, in conjunction with the Navy, focused on the different types of sites and their specific vulnerabilities to future conditions.	+	0	+	0	++	++	++	++	+	0	0	+	+	0	+	**14**
	4	Deepen collaboration with State, County DEH, and Regional Water Quality Control Board	+	0	+	0	++	++	++	++	+	0	0	+	0	0	+	**13**

Bay Sea Level Rise Strategy Evaluation Matrix - Parks, Recreation, and Shoreline Public Access Strategies

Sea Level Rise Impact to San Diego Bay		Key Vulnerability / Adaptation Strategy	Evaluation Criteria: SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Flooding and Inundation		The system is highly vulnerable to flooding because of location in flood-prone shoreline areas, but adaptive capacity to cope with flooding is higher than for most other systems.																
	1	Prioritize the development of passive, naturalized parks, open space, and habitat land in areas that are vulnerable to flooding, to minimize risk to higher-value infrastructure; to promote public access as shoreline conditions change; and to promote low-impact development stormwater management.	++	+	+	+	+	++	++	+	+	+	++	+	++	+	+	**20**
	2	Develop interpretive signage and installations in shoreline public access areas, describing climate change impacts and responses on San Diego Bay.	+	+	++	0	+	+	+	+	0	0	++	0	+	0	0	**11**
Also a Comprehensive Strategy	3	Evaluate site-specific vulnerabilities, identifying structures such as buildings, docks, and piers that may be at risk. Identify adaptation responses as plans or projects are developed.	+	0	+	0	+	+	0	+	+	0	++	0	+	0	+	**10**

Bay Sea Level Rise Strategy Evaluation Matrix - Ecosystem Strategies

Sea Level Rise Impact to San Diego Bay	#	Adaptation Strategy	SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
Habitat Shift																		
	1	Expand or preserve ***ecological buffers*** around development where feasible to allow for inland migration of wetlands, salt marshes, and other habitat systems	+	+	+	0	+	+	0	0	++	++	+	0	+	0	0	**11**
	2	Develop a decision-making framework for selecting and implementing ***SLR management practices*** such as hard defenses, soft defenses, accommodation, and managed retreat that includes consideration of ecosystem and habitat goals and vulnerabilities.	+	0	+	+	+	+	0	0	+	+	+	0	0	+	+	**10**
	3	Research and identify locations with the greatest potential for landward migration of wetlands	+	+	+	0	+	0	+	0	++	++	0	0	+	0	0	**10**
	4	Expand or adjust conservation areas to enhance the resilience of ecosystems. In the ***acquisition*** of new conservation lands in the San Diego region, consider how ecosystems will change due to sea level rise, prioritizing areas that could evolve into ecosystems threatened by sea level rise elsewhere.	+	+	0	0	+	0	0	0	++	++	+	0	+	0	0	**9**
	5	Evaluate threats to ***habitat connectivity***, and protect habitat corridors to facilitate species shift to viable adjacent habitat as an adaptive response to sea level rise.	+	+	+	0	+	0	0	0	++	++	0	0	+	0	0	**9**
	6	Where feasible, design low-impact stormwater BMPs to also provide habitat.	+	0	0	+	+	0	0	0	++	++	0	0	0	+	+	**9**
	7	Ensure that ecological ***restoration*** projects are designed to be resilient to sea level rise, to the extent feasible.	+	0	+	+	+	0	0	0	++	++	0	0	0	0	0	**8**
	8	Evaluate, minimize and ***mitigate ecological impacts of shoreline hardening projects*** developed in response to sea level rise.	+	0	0	0	+	+	0	0	++	++	0	0	+	0	0	**8**
	9	Pursue research to identify species ranges, ***monitoring habitat shift*** and identifying any emerging conflicts between existing and incoming habitat types.	+	+	+	0	+	0	0	0	++	+	0	0	0	0	0	**7**
Priority for TAC	10	Pursue research studies to further identify ecosystem benefits, especially through ***economic valuation*** of ecosystem services, to aid in cost-benefit analysis of conservation and restoration projects that reduce sea level rise vulnerabilities.	+	+	+	0	+	0	0	0	+	+	0	0	0	0	0	**6**
Priority for TAC	11	***Enhance the SLAMM model*** and perform other assessments that will help to determine the most vulnerable habitat types and locations.	+	+	+	0	+	0	0	0	+	+	0	0	0	0	0	**6**
	12	Strive to create ***habitat mitigation projects*** are resilient to sea level rise. Evaluate how mitigation projects will be affected by SLR and encourage acquisition of upland areas also when analysis indicates that conserved nearshore habitat will be lost to sea level rise.	+	0	+	0	+	0	0	0	++	+	0	0	0	0	0	**6**

Sea Level Rise Impact to San Diego Bay	#	Adaptation Strategy	SC jurisdiction	Existing Programs	Flexibility	Mitigation co-benefit	Econ/Social wellbeing	Public safety	Public health	Environmental justice	Habitat protection	Ecological function	Public access	Critical infrastructure	Community character	Address new development	Address existing communities	Total Rank
			Evaluation Criteria															
Bay Sea Level Rise Strategy Evaluation Matrix - Ecosystem Strategies, cont.																		
Erosion																		
	13	Improve the health of wetlands that provide natural buffers between sediments and subtidal habitat.	0	+	0	+	+	+	0	0	+	+	0	0	0	0	+	**7**
	14	Enhance programs and regulations that protect Bay water quality, to reduce ecological sensitivity to additional SLR-related impacts.	+	?	0	0	+	+	+	0	+	+	0	0	0	0	+	**7**
Priority for TAC	14	Pursue ***research on sediment transport*** dynamics that improves understanding of both erosion and sedimentation. Adjust sediment management practices in response to research findings.	+	0	+	0	+	0	0	0	+	+	0	0	0	0	0	**5**
Flooding and Inundation																		
	15	Promote soft and hard low-impact development (LID) strategies to reduce stormwater runoff.	++	+	+	+	+	++	++	+	+	+	0	+	0	+	+	**16**
	16	Increase capacity of stormwater management systems to accommodate increased flood waters	++	+	+	0	+	++	++	+	+	0	0	+	0	+	+	**14**