

Natural Resources Agency

Safeguarding California: Reducing Climate Risk

An update to the 2009 California Climate
Adaptation Strategy

Public Draft

EXECUTIVE SUMMARY – SAFEGUARDING CALIFORNIA

California and the world's climate are changing, posing an escalated threat to health, well-being, nature, and property. Extreme weather, rising sea levels, shifting snowpack, among other impacts will touch every part of peoples' lives in the next century. Planning key actions now will help us lessen impacts and cope with changes. Many aspects of the environment face historic displacement. In government at every level, we must work together to safeguard our state. And ultimately, each and every one of us needs to take steps to reduce our own impacts and increase our resilience in the future.

The Safeguarding California Plan provides policy guidance for state decision makers, and is part of continuing efforts to reduce impacts and prepare for climate risks. This plan, which updates the 2009 California Climate Adaptation Strategy, highlights climate risks in nine sectors in California, discusses progress to date, and makes realistic sector-specific recommendations.

California is a leader in the global effort to fight climate change. The state is pursuing a broad, integrated strategy to reduce greenhouse gas emissions and build the foundation for a new clean energy economy. While these efforts will reduce the magnitude and impact of climate change, they will not prevent it from occurring. Given the potential impacts and the long-term nature of effective planning, it is only prudent to begin preparing for these impacts. Actions needed to meet these challenges will not be cheap, but will cost far less than taking no action. Every step that we take today helps save valuable resources in the future. To that end, the plan details 11 current efforts already underway.

Right now, more extreme fires, storms, and heat waves are costing lives and property damage. State of the art modeling shows that a single extreme winter storm in California could cost on the order of \$725 billion – with total direct property losses of nearly \$400 billion and devastating impacts to California's people, economy and natural resources. The health and fiscal consequences are dire. Climate change poses a threat not just to lives and health, but the financial resources of governments and the insurance industry.

More broadly – and likely more costly – are rising seas that threaten our coast, while disappearing snowpack in the Sierra Nevada presents new challenges for our state's water management. In the near term, we must take practical, affordable steps to maintain our water, power, and transportation infrastructure, and plan for longer term actions as well.

Below are the nine broad areas impacted by climate change, with real-world, realistic recommendations for actions that we can take today to ensure a better future. In addition, we have included seven strategies that cut across each one of these nine broad areas that can be realistically implemented to help safeguard California.

Safeguarding our Everyday Lives from Climate Change:

- A Changing Water Future: Develop an urban water use plan that reduces reliance on distant, unpredictable sources.

- Keeping the Lights On: Promote development of smart grids that are connected, but localized.
- Cooling California: Promote strategies to keep Californians cool and guard against longer, more frequent heat waves, which are already responsible for a growing number of hospitalizations and deaths.
- Do Better Today, Live Better Tomorrow: By reducing our carbon output today, we can lessen the extent of impacts in the future.

Safeguarding our Natural World:

- Nature Moves with the Climate: As climate patterns shift, so will nature. Providing habitat connectivity and chances for adaptation will help allow species and habitats to survive.
- Help Nature Protect Herself: Improve forest and other habitat resilience.

Safeguarding California – What Science and Lawmakers Can Do:

- Knowing the Real Impacts: Sound science will highlight risks, and help provide a path to solutions.
- Help is on the Way: Assess adequacy of emergency responders.
- Better Together: Collaborate with federal and local government.

Seven Strategies to Safeguard California: Cross Sector Themes

These nine areas touch every part of modern life for people and nature: 1) Agriculture, 2) Biodiversity and Habitat, 3) Emergency Management, 4) Energy, 5) Forestry, 6) Ocean and Coastal Ecosystems and Resources, 7) Public Health, 8) Transportation, and 9) Water. For these nine areas, common themes were identified during the development of the plan. This important identification resulted in identifying seven strategies that cut across all areas that can be acted upon.

- All core functions of government must make the risks Californians face from a changing climate an integral part of their activities.
- Provide risk reduction measures for California's most vulnerable populations.
- Identify significant and sustainable funding sources for investments that reduce climate risks, human loss, and disaster spending.
- Support continued climate research and data tools to inform policy and risk reduction activities.
- Maximize returns on investments by prioritizing projects that produce multiple benefits and promote sustainable stewardship of California's resources.
- Prioritize climate risk communication, education, and outreach efforts to build understanding among all Californians.
- Promote collaborative and iterative processes for crafting and refining climate risk management strategies.

Current Efforts to Prepare California for Climate Risk

Climate change impacts communities and crosses political and jurisdictional boundaries. Cooperation and coordination is essential across a wide variety of factors including: government at all levels (state, federal, tribal, local and regional), businesses, insurers, investors, non-profit organizations, foundations, community groups, and individuals. Fortunately, we already have many examples of progress, including:

- Creation of the Cal-Adapt tool allows visualization of local climate impacts in California
- 2012 California Climate Adaptation Planning Guide is designed for local and regional governments
- 2013 Climate Change Consortium for Specialty Crops sets out impacts and strategies for resilience
- Desert Renewable Energy Conservation Plan (DRECP) is an effort underway to support programmatic development of large-scale renewable energy and the co-equal objective of conservation of the California desert; approximately 22.5 million acres of federal and non-federal California desert land are in the DRECP plan area.
- The State Hazard Mitigation Plan has integrated climate risks since 2007
- Energy efficiency standards have saved Californians more than \$74 billion in reduced electricity bills since 1975, and have helped to foster greater energy reliability
- Urban forestry investments reduce heat island effects and provide air and water benefits
- 2013 State of California Sea-Level Rise Guidance Document is part of California's response
- 2013 Preparing California for Extreme Heat is another part of the response
- 2013 Addressing Climate Change Adaptation in Regional Transportation Plans provides guidance for California's Municipal Planning Organizations and Regional Transportation Planning Agencies
- Construction of four coastal observatories in Eureka, Bodega Bay, Big Sur, and Santa Barbara will help improve flood watch and flood warning information for local emergency responders

Reducing climate risks protect California's people, economy, and natural resources. Investing in action now saves lives and provides long term cost savings; one study found that every dollar spent on a FEMA hazard mitigation grant produced, on average, four dollars of benefits. Implementation of this Safeguarding California Plan will help foster a vibrant and sustainable future for California.

INTRODUCTION

California is taking action to reduce greenhouse gas emissions, but no matter how quickly we reduce those emissions, we will still face increasing impacts from emissions that have already occurred. This means that we must adapt and safeguard California. Bigger and more intense wildfires, floods, storms, and heat waves are already occurring and are likely to become more frequent and more severe. Rising seas threaten our coast and changing precipitation patterns threaten both water supplies and water quality. California faces risks to its people, economy, infrastructure, and natural resources. We need to prepare for these risks, even as we increase our efforts to reduce the emissions that cause climate change, in order to create more resilient and sustainable communities. This Safeguarding California Plan updates the 2009 California Climate Adaptation Strategy.

The 2009 California Climate Adaptation Strategy (2009 CAS), one of the nation's first multi-sector plans for preparing for climate risks, provides an excellent foundation for this update. In California and across the globe, our understanding of climate risks and community impacts continues to evolve, both as a result of improved modeling and direct observation of changing climate conditions and extreme weather events.

California has made critical investments in climate science to help inform policymaking and efforts to prepare for climate risks. The state's third major climate assessment (the Third Assessment), completed in 2012, furthered our understanding of local and statewide climate risks, and improved our understanding of how those risks may interact with the exposure and vulnerabilities of our communities and the response capacity of our natural systems. As a result the Third Assessment has played a significant role in informing this Safeguarding California Plan. California has also developed the Cal-Adapt web-based visualization tool to translate climate data into a usable format for policymakers and local communities. For more information on the Cal-Adapt tool, please see **Box 1: Cal-Adapt—California's Easy Access Tool for Visualizing Local Climate Impacts.**

The state and many local California communities have also started crafting, implementing, and refining management strategies for dealing with new and changing climate conditions, and many insights have been gathered from these efforts. This Safeguarding California Plan updates and builds upon the strategies in the 2009 CAS in light of advances in our understanding of California's climate vulnerabilities and lessons learned.

The Safeguarding California Plan is not meant to replace the 2009 CAS, but to add new recommendations and replace portions of the prior document where new information allows for updating and revision. Except where revisions and new recommendations supercede, the strategies in the 2009 CAS continue to be relevant and are carried forward.

The Safeguarding California Plan is designed as policy guidance for state decision makers. It also highlights gaps in our preparation for climate risks. The update adds a chapter on

Emergency Management and divides the Energy and Transportation section into two distinct chapters. Climate risks often present cross-sectoral challenges, and may require cross-sectoral solutions. As a result, the Safeguarding California Plan identifies cross-sectoral linkages throughout. Each sector chapter features its own recommendations; cross-sectoral strategies are presented in this chapter.

This plan provides a multi-sectoral framework for state efforts to reduce climate risk and is designed to work in conjunction with more in-depth, sector-specific climate planning and risk reduction activities, such as the 2013 State of California Sea-Level Rise Guidance Document and the 2013 Preparing California for Extreme Heat Guidance and Recommendations. The Safeguarding California Plan also fits into a broader suite of coordinated state actions on climate change. For instance, the state is leading the nation in its effort to reduce emissions that cause climate change, and is also supporting local and regional government actions to address climate change.

California's leadership on climate change promotes action to safeguard the state, fosters business innovation, and helps protect the infrastructure and resources necessary to sustain the economy and preserve California's natural legacy. For more information on California business and climate risks, please see **Box 2: Climate Risk and California Business**. Climate change poses substantial risks to California's people, economy, infrastructure, and natural resources. Without meaningful action, California, faces tens of billions of dollars per year in direct costs and exposes *trillions* of dollars of assets to collateral risk, with additional social and human costs. As a point of reference, Hurricane Sandy in 2012, resulted in 147 direct deaths and damage exceeding \$50 billion.¹ Investing in action now can save lives and provide long term savings; one study found that every dollar spent on a FEMA hazard mitigation grant produced, on average, four dollars of benefits.

California faces many risks and challenges, including the following, which are discussed in this Safeguarding California Plan:

- Sea level rise threatens to inundate hundreds of hazardous waste sites in the San Francisco Bay area alone;
- Two-thirds of California's native flora will experience a greater than 80 percent reduction in suitable climate range within a century;
- At least a quarter of the Sierra snowpack, which provides natural water storage for the state, will be lost by 2050;
- Climate change presents serious health risks such as extreme heat, and will have a greater impact on California's most vulnerable populations;
- Cherries, one of the state's most valuable perennial crops, will very likely see significantly declining yields due to warming;
- Climate impacts, such as more extreme weather events, sea level rise, changing temperature and precipitation patterns, and more severe and frequent wildfires, present new risks and uncertainties that will affect all phases of emergency management;

- California’s transportation system is vulnerable to a variety of risks including road washouts, route closures, rail buckling, and sea level rise and coastal erosion impacts on ports and low lying airports, coastal roads and highways, bridge supports, transit systems, and energy and fueling infrastructure;
- Energy transmission and distribution infrastructure are vulnerable both to increased temperatures and to increasing risk of flooding and wildfire; with dozens of California substations at risk of flooding (or partial flooding) due to sea level rise alone; and
- Annual area burned by wildfire is predicted to increase substantially under future climate change scenarios.

Climate change will impact communities and will cross political and jurisdictional boundaries. Coordination will be essential across a wide-variety of actors including: government at all levels, businesses, insurers, investors, non-profit organizations, foundations, community groups, and individuals. Only by working together can the challenges ahead be successfully addressed. Although many significant and important first steps have been taken to implement the 2009 CAS and prepare for climate risks in California, much critical work remains to be done. Funding remains a serious barrier. We need to move from one-time or limited funding sources to significant, sustainable funding sources.

The recommendations in this Safeguarding California Plan are meant to work with existing laws and regulations; however, in order to fully implement actions to prepare for climate risks in California, some laws may need to be amended to better reflect new and changing climate conditions that did not exist when those laws were initially enacted, and new implementing authorities may be needed.

Cross-sectoral Strategies:

- **Support continued climate research and data tools to inform policy and risk reduction activities.**

Executive Order S-13-08 directed the Natural Resources Agency to develop state strategies for preparing for climate risk based on the best known science on climate impacts to California as represented by the California Energy Commission’s (CEC) PIER program. Although the CEC PIER program has not been reauthorized, it will be important for the state to continue to support the development of climate science that supports efforts to prepare for climate risks. While some initial climate vulnerability studies have been undertaken, there are still very significant gaps in the information we have to help craft policies and actions that will safeguard the people, economy, and natural resources of California. For instance, additional information is needed regarding the risk of extreme weather events in California. Scientific research by federal or private organizations may not represent regionally relevant information needed to inform policy decisions or management actions in California, and ‘downscaling’ climate projections for California will be important. Climate change presents novel and evolving risks, and research is needed to develop and evaluate strategies for reducing climate risks. Monitoring of evolving

climate conditions is critical to refining both climate projections and management strategies over time. In light of escalating climate risks and declining budgets for many research institutions, the need for California to continue to fund climate research is more acute than ever.

The Cal-Adapt web-based visualization tool helps translate climate data into a usable format for policymakers and local communities; however, sustained funding over time is needed to maintain the tool and to enhance its functionality to meet the needs of its users. Cal-Adapt is not the only climate visualization tool. Other climate tools are being developed by a variety of state, federal and non-governmental entities. The development of state climate tools should be coordinated and consolidated to the extent possible to optimize expenditures on tool development and to provide users with more streamlined, definitive, planning resources. California climate tools should also be harmonized with, and leverage investments in, federal climate research and tools.

- **Mainstream climate risk considerations.**

State entities need to mainstream climate risk considerations into the activities of all their existing divisions and programs. Climate change is fundamentally altering the environment and context in which state actions occur. If climate risks are to be addressed effectively, climate risk considerations need to be integrated into the design and implementation of all state operations and programs.

It is necessary to build internal capacity for state entities to mainstream climate risk considerations into their activities. Adequate staffing is required. Providing access to and promoting staff participation in climate training activities can also help build capacity. Some state entities have already started to develop these types of programs. State agencies and departments should be provided with the resources to enable climate training for staff. Climate literacy programs should provide both general climate information and content specifically related to the activities and mission of the hosting agency or department. Training should disseminate climate science and climate risk information and empower staff to integrate climate change into their professional responsibilities. The state should develop a standardized curriculum for the general climate information portion of its internal climate literacy program. This standardized curriculum should also be made available as a public resource.

- **Ensure that risk reduction measures provide for California's most vulnerable populations.**

Climate change will have disproportionate impacts on California's most vulnerable populations. Threats to food security, public health and water supplies are just a few of the climate risks that will challenge California's most vulnerable people. Access to information, services and resources affects how climate impacts are experienced. The state's climate policies and efforts to prepare for climate risk should address disproportionate impacts and enhance access to information, services and resources for California's most vulnerable people.

- **Identify significant and sustainable funding sources for investments that reduce climate risks, human loss, and disaster spending.**

Making adequate investments to prepare for near- and longer-term climate risks now can help protect California's people, economy and natural resources. Although needed investments are very substantial, these investments will save lives and provide very significant long-term savings. In order to achieve the needed level of investment, the state will need to work closely with governments at multiple scales (federal, tribal, regional and local) as well as a variety of non-governmental partners. Significant, sustainable funding sources are needed. Innovative risk sharing mechanisms will need to be considered and utilized. Investments must account for time frames needed to realize benefits, changing risk over time, and the life expectancy of any capital investments.

- **Maximize returns on investments by prioritizing investments that produce multiple benefits and promote sustainable stewardship of California's resources.**

Given declining government budgets, the magnitude of potential climate risks to the state, and the significant expenditures needed to prepare California for the risks it faces, expenditures should be designed to maximize returns on investment. Investment priorities should focus on investments that offer climate benefits across multiple sectors and investments that offer other social, economic, and environmental benefits. Interagency coordination will be important to avoid redundancies and optimize resources.

This Safeguarding California Plan discusses a variety of 'green solutions' for addressing climate risks, such as restoring and creating wetlands to guard against flood risks or utilizing forest watershed protection and restoration to enhance water supplies and water quality. Where available, cost-effective green solutions should be utilized. Sustainable stewardship of resources is critical for California's future.

- **Enhance climate risk communication and outreach efforts.**

A high degree of engagement by governments at all levels, the private sector, communities, and individuals is needed in order to effectively prepare for climate risks. This level of engagement is predicated on effective communication of climate risks. The state should develop and maintain a standard set of communication materials regarding climate risks in California, and should provide translated materials for non-English speaking communities. Those materials should be made available online and through outreach efforts. Outreach efforts should be focused on increasing public awareness and increasing community engagement in preparing for climate risks. Funding will be needed to support adequate outreach efforts.

- **Promote collaborative processes for crafting climate risk management strategies.**

Climate risks in California are substantial, cross many jurisdictional boundaries, and are growing over time. Effective preparation for climate risks will require engagement by governments at all levels (state, federal, tribal, local and regional), businesses, insurers, investors, non-profit organizations, foundations, community groups, and individuals. Collaboration should promote information sharing, including sharing best-practices and working together on climate research and monitoring, coordinating action, and leveraging scarce resources. For an example of this type of collaborative work, please see **Box 3: The Alliance of Regional Collaboratives for Climate Adaptation.**

California has more than 100 federally recognized tribes and the largest Native American population of any U.S. state. The Brown administration renewed its commitment to coordination with Native American tribes when Governor Brown signed Executive Order B-10-11, with the intent of strengthening communications and collaboration between California state government and Native American tribes. The state will continue implementation of this direction as it works to foster strong working partnerships with tribal nations and lead efforts to better coordinate with tribes on preparing for climate risks.

As more information about changing climate risks and impacts is developed, management strategies should be refined to reflect best-available science. Iterative and flexible management approaches that can incorporate evolving information will be critical.

Box 1

Cal-Adapt—California’s Easy Access Tool for Visualizing Local Climate Impacts.

With a proliferation of climate research tools and resources over the past five years, it has become increasingly difficult to identify definitive sources of aggregated climate data for planning purposes. The state of California plays an important role in helping to develop regionally relevant climate research to support policy and planning efforts. Implementation of many actions to enhance community resilience will happen at the local and regional levels, and the state is committed to working cooperatively with local and regional governments to support their efforts to prepare for climate risks. Recognizing that climate data must be translated into a usable format and that having numerous sources of climate data can be difficult to navigate, the state created a tool called Cal-Adapt; a web-based climate planning tool where you can quickly find information to help visualize impacts associated with climate change at the local level.

Cal-Adapt addresses one of the major challenges facing planners who are working to enhance community resilience in the face of climate risks: a scarcity of tools and definitive sources located in one easy access location that can provide regionally relevant information. Designed in response to a recommendation in the 2009 California Climate Adaptation Strategy, Cal-Adapt was specifically designed to support planning activities and provide public information on

climate impacts and risks in the state. Cal-Adapt provides visualization tools and easy access to important data sets specific to California. The user friendly platform provides a convenient and effective way to explore climate impacts and vulnerabilities. Since its release, the website is being used by local and regional entities to find out how the climate may change in their jurisdictions, and these partners have been providing the state with useful feedback about the functionality of the tool.

Cal-Adapt was originally developed with funding from the California Energy Commission's Public Interest Energy Research program. Limited funding has been identified to support a tool update in 2014. The goal of the 2014 update will be to refresh the data sets incorporated in the Cal-Adapt tool and make the tool more responsive to the needs of local decision makers. However, as climate change projections and observations continue to evolve, planning efforts become increasingly sophisticated, and implementation of local climate plans moves forward, it will become increasingly important to continually maintain and enhance this tool to ensure it reflects best available knowledge.

Box 2

Climate Risk and California Business

Climate change poses significant risks to businesses including supply chain disruptions, destruction of business assets, and interruption of distribution networks. By taking action to reduce climate risks, California can support a resilient and prosperous business community.

Businesses are important partners for the state with respect to preparing for climate impacts. For instance, as discussed in the Emergency Management section of this document, the insurance industry provides important risk sharing mechanisms that can work in tandem with government policies to reduce climate risk. Institutional investors can adopt investment practices that encourage positive climate action.² Companies help create markets for ecosystem services.³ Businesses and industry groups can encourage the development of climate policies and raise awareness about climate change issues.⁴ And, as discussed elsewhere in this document, innovative technologies, materials, and design can improve energy efficiency, reduce heat island effects, and reduce risks from the changing climate.

Box 3

The Alliance of Regional Collaboratives for Climate Adaptation

The Alliance of Regional Collaboratives for Climate Adaptation (ARCCA) was formed in early 2012 to address the emerging impacts of climate change, including extreme storm events, heat waves, droughts, and sea level rise. ARCCA brings together Regional Collaboratives -- from San Diego, Los Angeles, the San Francisco Bay Area, and Sacramento -- that are coordinating and supporting local climate partners in projects to enhance public health, protect natural systems, build economies, and improve the quality of life in all communities. The mission of ARCCA is two-fold, to enhance cooperation and best practices sharing between regions and work more effectively with the State in its development of climate adaptation plans, policies and programs.

OCEAN AND COASTAL ECOSYSTEMS AND RESOURCES

INTRODUCTION

The policy guidance in this chapter is meant to help inform state decision makers regarding ocean and coastal issues when preparing for climate risks.³³⁵ Three quarters of California's 38 million people live near our iconic 1,100 miles of coastline and San Francisco Bay's additional 500-mile³³⁶ shoreline. Because of this geographic reality, a vast number of people can potentially be impacted by the ocean through rising sea levels brought on by climate change and direct impacts of human activities. A rising sea brought on by climate change puts vital infrastructure at risk. This includes roads, highways, bridges, commercial and residential buildings, sewage treatment plants, gasoline pipelines, power plants and power grid infrastructure, several of the busiest ports and airports in the world, and even emergency facilities like hospitals. Sea-level rise, coastal storms and erosion are also impacting natural and recreational assets such as beaches and tidal wetlands that are valued by Californians as part of the attraction of living in and visiting the coast and bay regions. That is why a multitude of federal, state, regional and local entities are working together to educate and advise decision makers on methods to prepare and plan for these large-scale, multi-decade changes. In order to lower vulnerability and exposure to economic losses and public health and safety risks, it is critical that California take actions now to ensure resilient communities.

While less visible, the impact of runoff, pollution, and carbon absorption on the ocean is a real and timely threat to waters that provide an abundance of seafood to not just our state, but places all over the world. What's more, the threat of fouling our waters isn't just a local one – it is a global crisis that can only be addressed through both local actions and work on all scales to reduce the pollution that is causing higher temperatures and changes in ocean chemistry.

Actions to address these threats have already started. California is tackling carbon pollution through a suite of climate policies to reduce greenhouse gas emission pursuant to the California Global Warming Solutions Act of 2006 (Assembly Bill 32 or "AB32"). Some progressive local and regional governments and state agencies have been working on innovative shoreline management plans including managed retreat (discussed further below) and investments in tidal wetlands which can provide cost-effective flood protection. The State has also developed guidance for incorporating sea-level rise, storms and shoreline change into planning and decision making for projects in California. Continued investments in climate-smart Ocean and coastal management can help protect the public health and welfare of Californians and bolster the resiliency of natural resources on which our communities depend.

More than forty years ago, grassroots environmental activism led to California passing some of the nation's first and strongest coastal management laws. These laws established that the coast and bay shoreline are important natural resources for the benefit and enjoyment of all of the people of California and that "it is the policy of the State to preserve, protect, and where possible, to restore the resources of the coastal zone for the enjoyment of the current and succeeding generations". California's commitment to protection of our shared coastal resources is at the heart of California's Coastal Management Program which has been hailed as a national and international model for coastal resource management. The state agencies who make up the Coastal Management Program include the Coastal Commission, San Francisco Bay Conservation and Development Commission and the Coastal Conservancy. All three of these state agencies are engaged in significant projects that integrate consideration of climate change into decision-making and providing leadership for reducing risks and preparing for changing conditions.

Many different entities play an important role with respect to protecting and managing California's ocean and coastal ecosystems and resources. Understanding the jurisdictional scope of these entities is important for a robust discussion of continued steps needed to adequately prepare for climate impacts to help in identifying management gaps or determining which agency should take specific actions in the future. The key state agencies for management of coastal and ocean resources are listed at the end of this chapter, in Box 55Box 46. In addition, coastal assets and infrastructure are under the purview of various federal, state, regional and local agencies, and there are significant coastal assets under private ownership and management. As further discussed in various chapters throughout this plan, local governments have primary responsibility for land use planning and local infrastructure and play a key role in emergency management efforts; thus they have an important role with respect to California's ocean and coastal ecosystems and resources. Management and planning for climate impacts requires a high degree of coordination.

The 2009 California Climate Adaptation Strategy identified the following guiding principles for decisions on actions to address the impacts from climate change in the ocean and coastal regions:

- California must protect public health and safety and critical infrastructure.
- California must protect, restore, and enhance ocean and coastal ecosystems, on which our economy and well-being depend.
- California must ensure public access to coastal areas and protect beaches, natural shoreline, and park and recreational resources.
- New development and communities must be planned and designed for long-term sustainability in the face of climate change.
- California must look for ways to facilitate adaptation of existing development and communities to reduce their vulnerability to climate change impacts over time.
- California must begin now to adapt to the impacts of climate change. We can no longer

act as if nothing is changing.

As described later in this chapter, the state plans on engaging in a public process to review these guiding principles and integrate them into a framework for improved action to reduce risks and support vibrant, healthy coastal and bay communities and natural landscapes.³³⁷

This chapter on ocean and coastal ecosystems and resources is organized as follows:

- Climate change impacts on ocean and coastal ecosystems and resources;
- Highlights of steps taken to date and success stories;
- Actions needed for safeguarding ocean and coastal ecosystems and resources;
 - Better understanding of climate impacts on ocean and coastal ecosystems and resources;
 - Improve management practices for coastal and ocean ecosystems and resources and increase capacity to withstand and recover from climate impacts;
 - Better understanding of evolving trends that may impact ocean and coastal ecosystems and resources; and
 - Information Sharing and Education.
- Box 55 – California Ocean and Coastal Ecosystems and Resources (description of state entities that play an important role with respect to California’s ocean and coastal ecosystems and resources).

CROSS REFERENCES: While this section of the Safeguarding California Plan raises many topics relating to ocean and coastal resources, some of these topics are further described within the context of cross-related sections of this Plan. For instance, sea-level rise impacts relating to transportation infrastructure are further discussed in the Transportation section of this document. Flood hazard preparation is further discussed in the Emergency Management section of this document. Sea-level rise as the cause of salt water intrusion into drinking water supplies is further discussed in the Water section of this document.³³⁸ Sea-level rise impacts on energy infrastructure are discussed in the Energy section of this document. Toxic releases, floods and other public health issues related to sea-level rise are further discussed in the Public Health section of this document. Climate impacts on ocean and coastal ecosystems are also discussed in the Biodiversity and Habitat section of this document.

Climate Change Impacts on Ocean and Coastal Ecosystems and Resources

Climate change presents new threats to ocean and coastal ecosystems and resources including, but not limited to, sea-level rise, extreme events, and ocean acidification.

Sea-level Rise, Storms and Erosion: Infrastructure and Property Damage, Permanent Submersion of Coastal Lands, Toxic Releases, and Risks to Water Supply

Climate change is causing global average temperatures to increase. This warming trend causes sea-level rise in three ways: 1) the oceans are warming, which causes sea water to expand, increasing ocean volume, 2) glaciers on land are melting and transferring water to the oceans, and 3) sea ice is melting.³³⁹

According to a 2012 report by the National Research Council³⁴⁰, for the California coast south of Cape Mendocino, sea level is projected to rise approximately 5 to 24 inches by 2050 (relative to 2000) and 17 to 66 inches by 2100³⁴¹. Communities, public and private property, infrastructure, natural habitats (including wetlands and marshes), coastal agriculture³⁴², and important cultural resources will be at increased risk from storm surges and flooding, permanent inundation and erosion. [See Box 47: Rising Seas Threaten California's Coastal Past] The risks to California's economy, its people, and its natural resources are substantial; and populations that are socially and economically vulnerable will bear a disproportionate burden. As discussed in the NRC study, it is the combination of sea-level rise and extreme events that are most likely to cause significant damage in the near term. As one example, the map in Box 48 shows the companies just in the Silicon Valley that are located in areas vulnerable to projected sea-level rise by the end of the century.³⁴³

Box 47

Rising Seas Threaten California's Coastal Past

by Molly Samuel (used with permission)



A site with evidence of more than 1,000 years of occupation is eroding due to high tides

hitting the base of the cliff. (Photo: Mike Newland)

On a sunny day earlier this summer at Point Reyes National Seashore, I scrambled behind Mike Newland as he clambered across gullies and bushwhacked through thigh-high lupine. Once we got to the spot he was aiming for, on the edge of a sandy beach-side cliff, he stopped and started to pick through shells and stones.

“You can see, we’ve got sort of a handful of little guys here, popping out of the ground,” he noted. “Some of these that we’re going to see, they weren’t here a year ago, when I came here last time.”

Newland, an archaeologist at Sonoma State University and the president of the Society for California Archaeology, was hunting for Native American artifacts, clues about what life was like in coastal California before Europeans arrived. It was easy for him to find them; wind, rain and tides have eroded these cliffs and exposed the ancient trash piles and stone tools.

This site and these cultural resources — some of them a thousand years old or more — might not be around for much longer. These pieces of California’s history are in danger of disappearing as the Pacific Ocean claws at the base of this cliff. Sea level rise is accelerating the problem.

It’s not just that the tides will be higher. The cliffs are so soft, they could recede hundreds of feet back, with just a few feet of sea level rise.

“You know, this isn’t just gonna be a matter of, the ocean’s going to pop up and cover it up and then we can get back to it later,” Newland said. “These sites are toast. And we’re essentially losing them all at once.”

Nick Tipon, a retired high school teacher and member of the Federated Indians of Graton Rancheria, whose territory includes Point Reyes, said he became aware of the extent of the erosion several years ago.

“In one part of the park, there’s a layer of soil that indicates human habitation in that spot, and sticking out from the side of a cliff was a human skull,” he said. When human remains are disturbed or exhumed, tribal policy is to rebury them as close as possible to where they were found. “So then we thought, ‘How far inland do we have to go away from the cliff to find stable soil? So we don’t have to do this 100 years, 200 years again? So that literally our ancestors can rest in peace?’”

Newland says there is evidence that people have lived in California for at least 11,000 years, and the soft sandstone cliffs on the coast have always been susceptible to erosion. Traditionally, Tipon said, the tribe would have let the ocean take burial sites, since it was

a natural process. But now, with two million or so people visiting the park every year, they can't leave human remains exposed.

Meanwhile, climate change threatens to expose more of them. A tide gauge in the nearby Golden Gate has recorded eight inches of sea level rise in the past century. Scientists' project it could rise three feet in the next.



Just looks like a rock, right? Archeologist Mike Newland says, "This is a crypto-crystalline silicate cobble that was broken by native peoples, probably to get material for making stone tools. It comes from a high-risk site along the western edge of Point Reyes National Seashore." (Photo: Mike Newland)

Point Reyes contains more than 120 Coast Miwok settlement sites. (The Federated Indians of Graton Rancheria includes both the Coast Miwok and the Southern Pomo people.) The National Park Service works closely with Native Americans to protect graves and other important objects or sites. And the Park Service supports and conducts climate research and has programs to help mitigate and adapt to changes coming to the parks. But Mark Rudo, a National Park Service archaeologist, said the Park Service isn't prepared to deal with the scale of the threat that sea level rise presents.

"At the same time that we're trying to figure out what the impacts are, we're also trying to identify what we can do about them, so it's not an easy situation to work in," he said. It's a special challenge with archaeological sites. While it may be possible for natural resources, plants and animals, to migrate, Rudo pointed out that cultural resources, like archaeological sites that remain in the ground, can't be moved, even with help. "We're stuck," he said. "We can't hide or run away from the problem, or adapt to it."

But the park does have help measuring the extent of the problem. Newland is recruiting archaeologists from all over the state in a volunteer effort to survey sites along the coast in Marin, Monterey, San Diego and Del Norte Counties, and he hopes to continue expanding the project, to study the thousands of sites up and down the California coast.

"We have to be honest. Most of the sites are going to be destroyed," he said. "But we should at least know what we're going to lose. That's my goal." At Point Reyes alone, Newland has found that 54 of the 160 sites he studies are in danger of being erased in the next century, and most of the others face some level of threat from other climate change impacts. And he emphasized, this is going to be a problem everywhere. "We are in the process of losing all of our maritime sites as a species. Every place that we've launched off to go explore the world through the ocean is now at risk," Newland said.

Tipon, who's a tribal liaison to the parks, said they'll have to decide what to try to protect on a case-by-case basis, but he's less concerned about any given object than with people and culture. And that won't be washed away as easily.

“One of the questions I get asked a lot when I give speeches is, ‘How long have your people been here?’ And I go, ‘Well, you know, the archaeologists say that it’s 3,000 years, 7,000 years, 11,000 years,’” he said. “But the cultural response is: we’ve been here forever. So how long are we going to be around? We will be here forever.”

Molly Samuel joined KQED as an intern in 2007, and since then has worked at KQED as a reporter, producer, director and blogger. Before becoming KQED Science’s Multimedia Producer, she was a producer for Climate Watch. Molly has also reported for NPR, KALW and High Country News, and has produced audio stories for The Encyclopedia of Life and the Oakland Museum of California. She was a fellow with the Middlebury Fellowships in Environmental Journalism and a journalist-in-residence at the National Evolutionary Synthesis Center. Molly has a degree in Ancient Greek from Oberlin College and is a co-founder of the record label True Panther Sounds.

Sea-level rise will result in the inundation of some beaches; for gently sloping beaches, the general rule of thumb is that 50 to 100 feet of beach width will be lost for every foot of sea-level rise. Beaches and bluffs also will be exposed to greater and more frequent wave attack, due to the elevated seas as well as to a possible increase in the frequency and severity of storm waves. When the means of protecting existing structures involves building sea walls or other “hard armoring” of the coast, there will be an inevitable additional loss of beaches as a result. This is because shoreline protective devices halt the landward migration of the back of the beach, and continued flooding of the seaward beach results in a reduction in beach width, and its eventual loss entirely. The loss of beaches due to armoring and sea-level rise will in turn result in loss of public beach access, tourism losses, losses of marine mammal haul-out area and sandy beach habitat, and loss of beach buffering capacity against future bluff erosion.³⁴⁴ By virtue of California’s sovereignty, the public owns all of the coastline three nautical miles from what is known as “the mean high tide line.”³⁴⁵ The California Constitution mandates that these lands are held by the State in trust for the people and public access is a key part of that mandate. As sea levels continue to rise, there may be jurisdictional shifts over areas of the California coast line; areas that were once beaches will become submerged lands and strategies will need to be developed to protect public access.

As noted in the Transportation section of this document, sea-level rise and coastal erosion also threaten ports and low lying airports, roads and highways, bridge supports, transit systems, and energy and fueling infrastructure. This has major implications not only for critical emergency evacuation routes and public health, but also for goods movement and the economy. For further discussion of these issues, please see the Transportation and Water section of this plan.

Sea-level rise and extreme events also threaten water supply and delivery, through salt-water intrusion into fresh water sources and through impacts to the Sacramento-San Joaquin Delta. Saltwater intrusion in groundwater supplies is caused by the landward and upward movement of sea-water and is further discussed in the Water section of this document. The waterways in the Delta are at sea level and are affected by ocean tides. The Delta consists of a network of channels and sunken “islands” that cover—together with Suisun Marsh—about 1,300 square miles. This combination of islands and channels support not only water supply conduits, but also other important infrastructure elements: major arteries of the state’s electrical grid; natural gas fields, storage facilities, and pipelines; highways and railways; and shipping channels, all surrounded by an increasingly urban landscape. Inundation and higher flood risk associated with sea-level rise and storm events might affect operations of the Central Valley Project and State Water Project, impacting water supply and delivery. Communities within the Delta are at high risk from sea-level rise; the Surging Seas study by Climate Central showed that with four feet of sea-level rise, Stockton has the largest total exposed population in the state and Sacramento is the city with the fifth largest exposed population. This same study concluded that the counties with the largest total exposed populations included the following Delta counties: San Joaquin (2nd), Sacramento (5th), and Solano (10th).

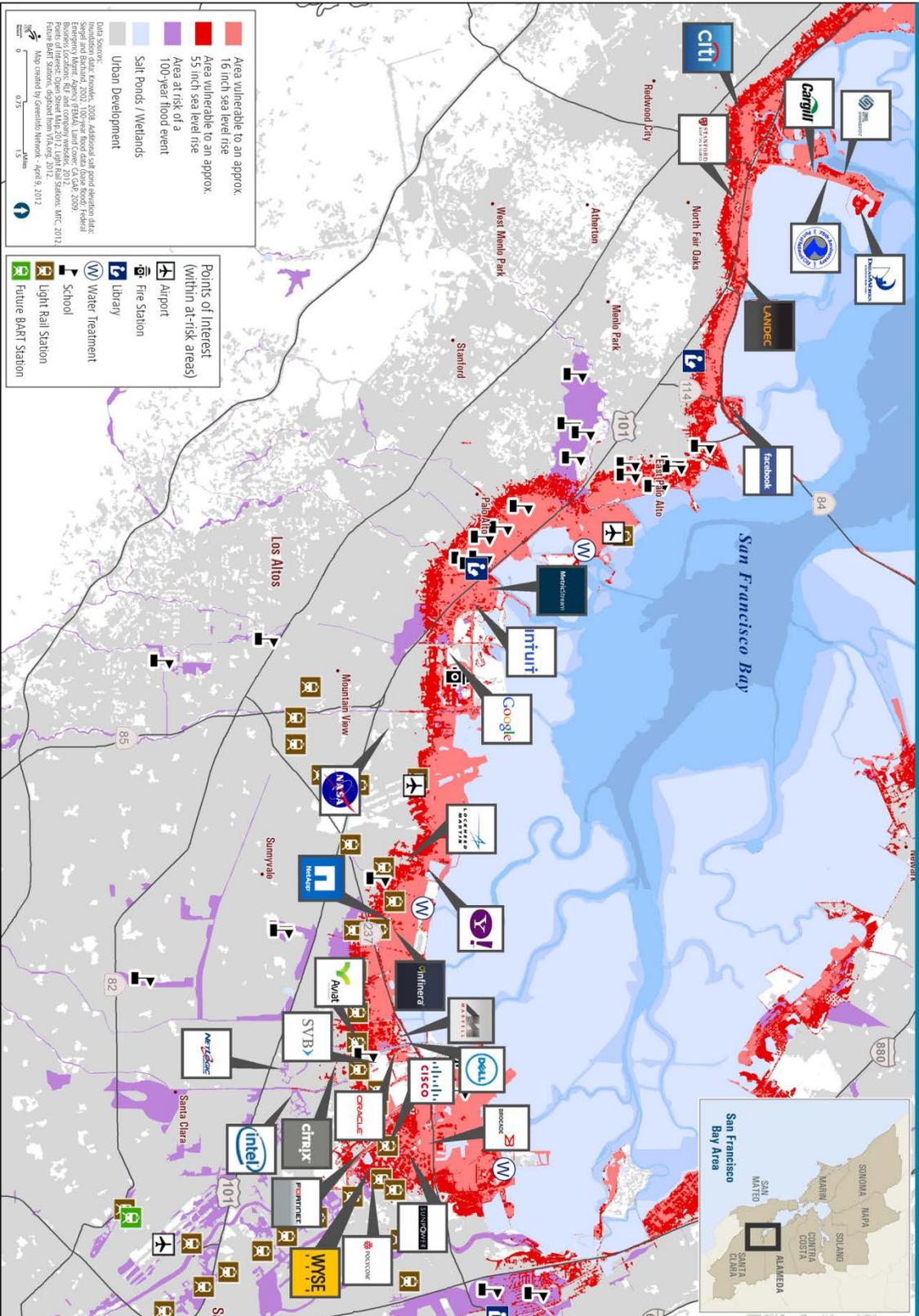
Sea-level rise and coastal erosion also threaten other infrastructure and property including wastewater treatment and storm water management facilities³⁴⁶, hospitals, schools, and homes and businesses. For more on the state's hospital preparedness program, please see the discussed in more detail in the Public Health chapter. Sea-level rise presents very significant fiscal risks.³⁴⁷

The presence of facilities or land containing hazardous materials in coastal areas susceptible to either flooding or permanent inundation presents toxic exposure risks for human communities and ecosystems. Hazardous materials can contaminate flood waters, drinking water supplies, buildings and property, and ocean-based food sources. For more information on public health risks from climate change, please see the Public Health section of this document. A 2009 CEC PIER funded study evaluated sites containing hazardous materials at risk from sea level rise in California.³⁴⁸ The study evaluated a range of sites monitored by the U.S. Environmental Protection Agency for hazardous materials including: "Superfund" sites and brownfields (regulated under the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]), hazardous waste generators, facilities required to report emissions for the Toxic Release Inventory, facilities regulated under the National Pollutant Discharge Elimination System, and facilities with permits under Title V of the federal Clean Air Act for hazardous air pollutants. In 2009, 130 such sites were already located in high flood risk areas, but with a 55- inch sea level rise, the high risk flood area along the California coast will expand - and the number of sites at risk will increase 250% - with an estimated 330 hazardous waste facilities and sites at risk.³⁴⁹ A more recent 2013 report from the Adapting to Rising Tides ("ART"), a project led by the San Francisco Bay Conservation and Development Commission that worked collaboratively with local governments to "field test" planning to be resilient to sea level rise found that there were eight types of contaminated lands within the ART San Francisco Bay Area sea-level rise study area alone, primarily concentrated in Oakland and Emeryville; these lands include two Federal Superfund sites, 450 leaking underground storage tanks, 112 Department of Toxic Substances Control (DTSC) sites and 24 active and closed landfills.³⁵⁰

Flood Risk and Sea Level Rise – South Bay

Economic Impact, San Francisco Bay Area

Map Courtesy of the California Water Foundation



Imagining California's Future Coastline - California King Tides Initiative

A “king tide” is a popular term used to describe a phenomenon that occurs when the orbits and alignment of the Earth, moon, and sun combine to produce the greatest tidal effects of the year.³⁵¹ King tides are a normal occurrence several times a year in coastal areas.

Because king tides can reach 6 or 7 feet, they are useful for envisioning future everyday water levels expected to occur as a result of climate-driven sea level rise. King tides can cause flooding and can be particularly damaging if coupled with storms and strong waves.

Coastal communities around the world including communities in Australia, British Columbia, and in a variety of U.S. states, have begun documenting king tides in photographs to inspire action to reduce coastal hazards and impacts from sea-level rise. The California King Tides Initiative is such an initiative and engages citizens to photograph king tides, or the highest winter tides, along the entire California coast, including bay areas.³⁵²



Vista Del Mar, December 24, 2011 by Cassidy Teufel. Photo courtesy of California King Tides Initiative – license to use this photograph does indicate an endorsement of this document.

“Wetlands” - Nature’s Flood Protection

Wetlands are transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is often covered by shallow water during some parts of the year. There are many types of wetlands, but some major categories of wetlands include: tidal wetlands, freshwater wetlands, and freshwater forested wetlands (including meadows).³⁵³ Sea-level rise will result in changes to some coastal ecosystems, including by converting some freshwater wetlands into more salty tidal wetlands by changing the elevation of the freshwater- saltwater interface.³⁵⁴

It is now understood that wetlands not only provide habitat for fish, birds and other species, but wetlands also play an important role in water quality, water supply, flood control, and, in some cases, aid in the storage of greenhouse gas emissions. Wetlands absorb and filter pollutants that could otherwise degrade ground water or the water quality of rivers, lakes, and estuaries. Some wetlands recharge aquifers that provide urban and agricultural water supplies. Wetlands also absorb and slow flood waters, reducing the size and destructiveness of floods.³⁵⁵

In the past, the function of wetlands was poorly understood and such lands were viewed as marginal, unproductive lands or breeding grounds for mosquitos and malaria. As a result, many wetlands were drained, filled, and converted to other uses. Estimates of wetlands that historically existed in California range from 3 to 5 million acres. The current estimate of wetland acreage in California is approximately 450,000 acres; this represents an 85 to 90 percent reduction - the greatest percentage loss in the nation.³⁵⁶ The World Bank has estimated that the drainage of 1,800 km² (about 450,000 acres) of wetlands in the Sacramento – San Joaquin Delta alone has released some 0.9 GtCO₂ (Giga tons, or billion tons of carbon dioxide), a mass of about one quarter of the total above ground pool of carbon in Californian forests, over the last century.³⁵⁷

A 2013 report by the Bay Institute³⁵⁸, an environmental organization, studied the potential for integration of tidal marshes in to multi-purpose shoreline management regimes in the San Francisco Bay Area in the light of expected climate impacts. According to the study, hybrid levees which fortify traditional earthen levees in The San Francisco Bay with tidal marsh restoration are not only extremely cost effective, they offer many additional benefits. Because plant root systems in marshes expand over time, the marsh can function as a “self-maintaining levee” which grows vertically over time and can help the entire system keep pace with sea-level rise assuming marsh restoration efforts are initiated in a timely way. Tidal marshes also provide significant flood protection benefits by reducing destructive wave energy during storms, and marshes provide significant habitat benefits as well.

As further discussed below, there are some exciting projects underway to restore

wetlands to aid future generations in coping with climate change stressors like impacts to water quality, changing water availability, and increased threat of floods. See South Bay Salt Pond Restoration Project description below and DWR's Twitchell Island Project in the Biodiversity and Habitat section describing how wetlands can reduce subsidence in the Delta and in turn reduce pressure on levees that can lead to levee failure and flooding. Many more opportunities for additional wetlands protection and restoration work still exist.

Box 51

Flood Insurance

The availability of private flood insurance is extremely limited, since private sector insurance companies have long viewed the risk of flood events as uninsurable.³⁵⁹

The National Flood Insurance Program (NFIP), established in 1968, is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses. Participating in the NFIP is based on an agreement between communities and the Federal Government. The program is administered by FEMA and provides flood insurance protection to property owners, renters, and business owners in communities that participate in the program.³⁶⁰ Homes and buildings in "high-risk" flood areas with mortgages from federally regulated or insured lenders are required to have flood insurance. High-risk flood areas have a 1% or greater chance of flooding in any given year, which is equivalent to a 26% chance of flooding during a 30-year mortgage. (See Box 21: "What is a 100-Year Storm or a 100-Year Flood" in the Emergency Management section of this document.) However, homes and buildings in moderate-to-low risk areas file over 20% of NFIP claims and receive one-third of disaster assistance for flooding. (Disaster relief is further discussed in the Emergency Management section of this document; as noted in that section, disaster relief funds, when available, must generally be repaid with interest.)³⁶¹ Although NFIP collects over \$3 billion dollars in premiums annually³⁶², in four of the past eight years, claims will have eclipsed premiums - in 2005, the year of Hurricanes Katrina, Rita and Wilma, claims totaled \$17.7 billion.³⁶³

In July 2012, The Biggert-Waters Flood Insurance Reform Act was signed into law, reauthorizing NFIP through 2017, and instituting some premium reforms and provisions for updated flood mapping.³⁶⁴ The intent behind the 2012 reforms was, in part, to ensure more accurate assessment of flood risk so that investment in infrastructure and real property that is or will be underwritten by the Federal Government is not based on flawed or outdated hazard analysis. The 2012 reforms authorized increasing insurance premiums based on the new risk assessments in an effort develop a solvent fund source that could reliably respond to flood disasters. As part of the 2012 reforms, a new Technical Mapping Advisory Council, made up of federal, state, and local experts, was formed to review current flood hazard risk mapping standards and to recommend new standards to FEMA based on evolving new scientific and technological data. FEMA is

required to report annually to Congress on how it is acting on those recommendations and whether it has deferred action on any recommendation.³⁶⁵ As of November 2012, NFIP debt was approximately \$20 billion, no principal has been paid on the debt since 2010, and premiums are not likely to generate sufficient funds to repay the debt.³⁶⁶

According to the Congressional Research Service, although the full economic cost of Hurricane Sandy, which occurred in October 2012, will not be known for years - NFIP payouts are estimated to be between \$12 billion and \$15 billion. “In the immediate aftermath of Sandy, this amount quickly exceeded the \$4 billion in cash and remaining borrowing authority from the Treasury Department [for NFIP]. By January 2013, the NFIP had processed more than 140,000 claims for Sandy-related damages totaling about \$1.7 billion. To protect the financial integrity of the NFIP and ensure that the NFIP has the financial resources to cover its existing commitments following the devastation caused by Sandy, the Obama Administration requested that Congress pass legislation to increase the NFIP’s borrowing authority. On January 4, 2013, Congress passed, and the President two days later signed into law, H.R. 41 to provide a \$9.7 billion increase in the NFIP’s borrowing authority, from \$20.725 billion to \$30.425 billion, to pay flood claims related to Hurricane Sandy.”³⁶⁷

The U.S. Government Accountability Office (GAO) has added limiting the federal government’s fiscal exposure to climate change to its 2013 list of high-priority areas.³⁶⁸ As of August 2012, California had 260,000 NFIP policies in force, representing coverage of \$68 billion of assets.³⁶⁹

Repetitive Loss

Structures built and rebuilt in flood prone areas may be vulnerable to being damaged or destroyed multiple times; in many areas, climate impacts will increase the likelihood of such ‘repetitive loss’. In 2004, a program was instituted to try to reduce the repetitive loss of structures insured under NFIP. The Severe Repetitive Loss (SRL) grant program provides Federal cost-share funding for States, Territories, and Federally-recognized Indian tribes for strategies for addressing existing properties subject to repetitive loss and preventing the building of new structures in areas prone to repetitive loss.³⁷⁰

As further described below, some California coastal communities are already developing, new innovative approaches to managing the many risks of sea level rise. (See Highlights of Steps Taken to Date: Innovative Shoreline Management in California and accompanying Box 54: Innovations in Shoreline Management in California) As noted below, additional work remains to reduce the risk of loss of life and property.

In addition to these planning efforts, the California Environmental Quality Act (CEQA) requires environmental impact reports “evaluate any potentially significant impacts that could result from locating development in areas susceptible to hazardous conditions (e.g., floodplains, coastlines, wildfire risk areas) as identified in authoritative hazard maps, risk

assessments or in land use plans addressing such hazards areas.”³⁷¹ If there are potentially significant direct and indirect impacts to the environment as a result of locating a project in high risk areas, these impacts must be considered and where feasible, mitigated.

For more information on insurance and climate risks, please see Climate Change and Insurance in the Emergency Management section of this document.

In addition to sea-level rise and its associated impacts, there will be additional impacts to ocean and coastal ecosystems and resources. These include changes in temperature, more extreme weather, potential increases in water contamination, ocean acidification and hypoxia. These impacts are further described below.

Changes to ocean function affecting global climate regulation & more extreme weather

As noted above, oceans play a key role in the global climate system, storing and moving heat and carbon, and also playing an important role in the water cycle. Ocean circulation is central to global climate regulation (and is also important to the distribution of nutrients in the ocean), and is influenced by a number of factors, including temperature and salinity. Climate models generally predict that there will be large changes to ocean circulation as a result of continued greenhouse gas emissions and associated temperature changes and ice sheet melting (which affects ocean salinity).³⁷²

For every 1-degree C (1.8 degrees Fahrenheit) rise in temperature, the amount of moisture that the atmosphere can contain rises by 7 percent; the increased moisture in the atmosphere means more rain, and climate models predict that there will be more extreme rain events.³⁷³ But precipitation is not spread evenly around the globe, and some places might actually get less precipitation than they used to get due to shifts in air and ocean currents.³⁷⁴ Extreme storm events coupled with sea-level rise will intensify flooding risks, salt water intrusion and erosion³⁷⁵ and could also negatively impact coastal tourism.

More Extreme Weather: Increase in Pollution Runoff & Ocean Water Contamination

As noted above, sea-level rise may lead to flooding, especially when coupled with extreme storm events, and flooding may lead to water pollution. Extreme storm events may also increase pollution run off from urban, suburban and rural lands (e.g. oil, pesticides, litter, nitrogen fertilizers, etc.). Polluted storm water runoff in ocean water can cause serious public health problems including earaches, sinus problems, diarrhea, fever and rashes,³⁷⁶ as well as illness, death and reproductive failures in marine species.³⁷⁷ Runoff of fertilizers can also result in algae blooms; algae blooms can produce toxins or deplete oxygen levels in ocean water; this may cause illness or death in marine species, including fish and shellfish species that are consumed for food.³⁷⁸

Extreme storm events may also increase releases of raw sewage into marine environments either due to accidental spills from aging, cracked, and leaking sewer systems or due to

overflows of untreated or partially treated wastewater from combined sewer systems.³⁷⁹ Salt water draining into sewer lines as part of extreme weather flooding may poison the biological systems at treatment plants and result in further releases of sewage.³⁸⁰ Accidental spills and overflows can contain untreated human and industrial waste, toxic materials, and debris; this can, in turn, cause serious public health risks and ecological damage.³⁸¹

As further discussed below, enhanced monitoring, infrastructure relocation, repair or redesign (including use of green infrastructure), continued work to control sources of land-based pollution, and public health risk communications programs will be important to address these issues.

Ocean Acidification

The chemistry of the world's oceans are changing as increasing carbon dioxide, and other waste gasses from human activities, are absorbed into the surface water. This results in a decline in pH, a process known as ocean acidification. Ocean acidification is considered a global threat to marine ecosystems, and has the potential to impact various economic sectors (e.g. fisheries, aquaculture, tourism) and coastal communities in California, and may also have indirect effects on food security and biodiversity. The current rate of ocean acidification is unprecedented over the past hundreds of millions of years; similar past events have been accompanied by major marine extinctions.³⁸² While oceanic uptake of carbon dioxide from the atmosphere provides a valuable service to human societies by moderating the severity of climate change, it is having a profound long-term impact on marine chemistry and biology.³⁸³

In addition to atmospheric gas absorption, small-scale processes like nutrient runoff into coastal waters from land-based sources can lead, through biological processes, to especially low pH (and hypoxic – see section below) water at very local scales.³⁸⁴ The coastal regions off the west coast of North America are also strongly influenced by seasonal upwelling, a natural process that brings carbon dioxide-rich, offshore waters to the surface ocean. With decades of human inputs of carbon dioxide to the atmosphere, the water that upwells now (which has been out of contact with the atmosphere for approximately 50-100 years), has even lower pH than in the past, resulting in localized “hotspots” of ocean acidification around upwelling regions. For example, the acidification conditions in upwelling-driven northern California coastal waters in 2008 were similar to what are predicted to occur in open-ocean surface waters in 2050.³⁸⁵

Many biological processes, such as growth, reproduction, and survival of many species are affected by shifts in seawater pH.³⁸⁶ For instance, with increasing ocean acidification, many calcifying organisms have difficulty forming and maintaining their shells and skeletons (See Box 11: Ocean Acidification; Implications for Biodiversity in the Biodiversity and Habitat section of this document.) Calcifying organisms such as coral reefs, shellfish

and zooplankton are among the first to experience impacts, and early life stages of marine organisms may be particularly vulnerable. However, there is significant variation in the sensitivity of marine organisms, and a growing body of evidence to suggest some species may have the capacity to adapt to future ocean chemistry.

There is potential for ocean acidification to impact wild fisheries that are of great economic importance to California. The first direct impact on humans may be through declining harvests and fishery revenues from shellfish and their predators.³⁸⁷ (See Box 52: First Person Narrative: Seeing is believing: shellfish growers confront ocean acidification.) Overall, marine crustaceans (crab, lobster, shrimp) appear broadly tolerant to the seawater acidification expected by 2100. Urchins may be more sensitive to acidification due to the vulnerability of their early stages, though new research indicates they may be able to adapt. Fished species are also embedded in marine food webs that are sensitive to changes in environmental conditions. Evidence suggests that the demographics, size, and nutritional content of some species can change in response to changing carbonate chemistry; these effects are likely to influence food web structure and function. The abundance of fished species can vary as the food web changes. A project linking spatially and temporally explicit ocean chemistry forecasts from regional ocean models with scenarios of the response of species in the California Current ecosystem to acidification will be completed in December 2015.³⁸⁸

Box 52

FIRST PERSON NARRATIVE: Seeing is believing: shellfish growers confront ocean acidification

By Mark Wiegardt [used with permission]

“My family has been farming Pacific oysters for five generations. We know good and bad seasons are normal. But we never dreamed that the seawater itself would start killing our oysters in their first days of life.

At that age, oysters, clams and mussels are tiny and vulnerable. That’s why scientists and shellfish farmers learned to rear young shellfish in tanks until they are hardy enough to survive, when they are then transferred to the wild. At the Whiskey Creek Shellfish Hatchery in Oregon, we sell larvae by the tens of millions to growers up and down the West Coast. When wild oysters have a bad reproductive season, a handful of hatcheries like ours have kept farms in business. The tasty shellfish end up on dinner plates all over the country—perhaps even yours.

But in 2007, batch after batch of oyster larvae died in our tanks. Our business was on the verge of bankruptcy. Shellfish growers feared they would be next; without seed, a farm can last only a few years. Nobody knew what was clobbering the young oysters.

Alan Barton, an oceanographer by training and manager at Whiskey Creek, solved the

mystery. He knew the fish in his home aquarium tank were sensitive to changes in water chemistry, so he began measuring pH in the water we pumped into our hatchery from the ocean. When the acidity was high, our larvae died.

I was skeptical at first – how could the very water we depend on now bring us to our knees? But scientists from Oregon State University and the National Oceanographic and Atmospheric Administration (NOAA) confirmed Barton’s insights. Their findings appear in a new scientific paper³⁸⁹ published last week.

Thanks to this experience, I’ve learned that our business is on the front line of what scientists call ocean acidification. Carbon dioxide from smokestacks, tailpipes and chimneys is pumped into the air and absorbed by the ocean, reacting with the sea water and making it more corrosive. The scientists have showed us that the acid resulting from increasing fossil fuel emissions combines with natural acid in the deep, carbon-rich water that upwells along the Pacific Northwest. The combination kills young oysters.

Lately some writers are looking for ways to dismiss ocean acidification as no big deal. I wonder how good these experts are at keeping tiny young oysters alive in corrosive water. This isn’t theory or speculation—this is happening right now, to my livelihood. And it’s not just one business. In Washington alone, the shellfish industry employs 3,200 people and is worth \$270 million to the state’s economy.

At Whiskey Creek, we’ve learned that when you’re fighting to save your business—and your seafood supplies— it helps to know what you’re up against. We now carefully monitor the acidity of the water, and avoid spawning oysters when carbon dioxide concentrations are high enough to kill them; we also treat the water to reduce its acidity. This has enabled us to stay in business for now.

But there are other signs of concern. Barnacles and wild mussels used to clog our pipes so fast that we had to replace them three times every summer. Now the pipes barely need cleaning; a worrying sign that changes in ocean chemistry impacts more than oysters.

We need more states to learn from those of us on the front lines of ocean acidification. The governor of Washington recently convened an expert panel of scientists, stakeholders and policymakers to advise the state’s leaders on how to understand, mitigate and adapt to acidification. That’s a good beginning and it’s a model that other states can follow, to address ocean acidification head on.”

Mark Wiegardt and his wife Sue Cudd run the Whiskey Creek Shellfish Hatchery near Tillamook, Oregon

Expansion of Areas of Low Oxygen (“Hypoxic”) Waters

Hypoxia (low oxygen levels) can have profound effects on marine ecosystems leading to large-scale die-offs, local damage to fisheries, and long-term loss of biodiversity. While some areas of hypoxic waters – particularly in deep ocean waters – are natural and important parts of marine ecosystems, climate change and other human activity may now expand hypoxic waters into areas closer to the ocean surface.³⁹⁰ Multiple factors may contribute to this phenomenon:

- Increasing sea-surface temperatures results in less oxygen taken up at the ocean surface and hinders mixing into the deeper ocean.
- Nutrient inputs into coastal waters, including nitrogen (both from air pollution emissions and water pollution runoff from land), can lead to especially hypoxic and acidified water at very local scales.

Expanding hypoxic zones have been occurring off the California coast during the past 20 years.³⁹¹ Effects on marine species and ecosystems include altered microbial processes, changes in predator-prey dynamics, and shifts in the abundance and accessibility of commercially and recreationally fished species. Increases in the frequency, duration, intensity, and spatial extent of rapid intrusions of hypoxic waters are also likely; and tracking these events and their impacts will be important.³⁹²

HIGHLIGHTS OF STEPS TAKEN TO DATE AND SUCCESS STORIES

In the last five years, there has been significant action on many scales to address climate impacts to ocean and coastal resources. Almost all coastal and bay counties are involved in some level of climate-related planning initiatives and efforts, some more broadly focused than others. There are a number of guidance documents, modeling and mapping, vulnerability assessments, and funding opportunities that are emerging in tandem with regional climate change collaboratives that support research, monitoring, and implementation at multiple scales including local, regional, and state wide efforts. Some actions with wide-ranging policy impacts that have been taken by the State are highlighted below.

Sea-level Rise Studies Funded by the California Energy Commission’s Public Interest Energy (PIER) Program - PIER was not reauthorized in 2011, but during its existence, it helped to fund a number of critical studies relating to sea-level rise in California. In addition to the August 2009 report on anticipated sea-level rise scenarios for California discussed above, there was also a companion report entitled *The Impacts of Sea Level Rise on the California Coast* which identified vulnerabilities and cost impacts of anticipated sea-level rise. That report included demographic analysis that indicates large numbers of Californians are at risk from impacts of sea-level rise, including low-income households and communities of color. The report also found nearly \$100 billion (in year 2000 dollars) worth of property, measured as the current replacement value of buildings and contents, at risk from a 100-year flood event with a 55 inch sea-level rise if no actions are taken -

with an overwhelming two-thirds of that property concentrated on San Francisco Bay and the majority of the at-risk property is residential.³⁹³

Follow-up PIER studies produced reports on The Impacts of Sea Level Rise in the San Francisco Bay,³⁹⁴ Characterizing Uncertain Sea Level Rise Projections to Support Investment Decisions,³⁹⁵ Impacts of Predicted Sea Level Rise and Extreme Storm Events on the Transportation Infrastructure in the San Francisco Bay Region,³⁹⁶ City of Santa Barbara Sea Level Rise Vulnerability Study,³⁹⁷ and Coastal Flooding Projections: 2000-2100.³⁹⁸

2012 Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future - National Research Council Report (“NRC report”) - California Executive Order S-13-08 directed state agencies to plan for sea-level rise and coastal impacts, and it also requested the National Academy of Sciences to establish a committee to assess sea-level rise to inform these state efforts. The states of Washington and Oregon, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey joined California in sponsoring a study to evaluate sea-level rise in the global oceans and along the coasts of California, Oregon, and Washington for 2030, 2050, and 2100. The results of the study were released in 2012, and have informed California’s Sea-level Rise Guidance Document (described below).

2013 State of California Sea-level Rise Guidance Document - The Coastal and Ocean Working Group for the California Climate Action Team (CO-CAT) has developed guidance for incorporating sea-level rise projections into planning and decision making for projects in California. The guidance document recommends scenario-based planning and decision-making aimed at reducing risk.

Sea-level Rise Resolution - On March 11, 2011, the OPC unanimously adopted a Sea-Level Rise Resolution to support state agency integration of sea-level rise into decision-making. Outreach was conducted to over 45 state agencies, commissions, and other governmental bodies and entities implementing projects or programs using state funding or on state property, including on lands granted by the Legislature. It was urged that consideration of the risks posed by sea-level rise are incorporated into all decisions regarding areas or programs potentially affected by sea-level rise. The work of integrating of sea-level rise considerations has begun at entities like the Sacramento-San Joaquin Delta Conservancy, the Strategic Growth Council, and other entities named in this document; however, additional integration is still needed.

Guidance on Incorporating Sea Level Rise in Transportation Project Planning – These types of guidance documents developed by Caltrans are further described in the Transportation section of this document.

First-of-its-kind Statewide Network of Marine Protected Areas - On December 17, 2012, 19 Marine Protected Areas (MPAs) became effective in the Northern California coastal

region, completing the nation’s first statewide coastal system of marine protected areas. The key agencies leading MPA development and oversight are CDFW, FGC, OPC, State Parks, and Parks and Recreation Commission.

The coastal portion of the statewide network of MPAs now includes 119 MPAs of varying designations, five recreational management areas and 15 special closures, that combined cover approximately 16 percent of all open coast state waters. Approximately half of California’s new or modified MPAs are multiple use areas, with the remaining in no-take areas. The MPAs were developed to be consistent with California’s landmark Marine Life Protection Act (MLPA), the first statutory mandate of its kind in the nation. The MLPA required that California’s MPAs be redesigned based on the best available science, with identified goals and objectives, and with the advice and input of stakeholders and experts to create a statewide network.

The north coast MPA regulations include a provision for federally recognized tribal members to continue harvesting and gathering fish, kelp and shellfish as they have been doing since time immemorial. The provision will allow non-commercial take to continue where there is a record of ancestral take by a specific tribe, consistent with existing regulations, in MPAs other than State Marine Reserves.

Because climate impacts such as ocean acidification, changing ocean temperatures, rising sea levels, and changes in oxygen levels are compounding other stressors on marine and coastal habitats such as pollution and overfishing - MPAs are increasingly recognized as a key tool for aiding marine and coastal habitats. MPAs are also important areas for continued scientific research on climate impacts on marine and coastal ecosystems.

OceanSpaces is an online community that has been developed to steward and share MPA monitoring data and results, and better facilitates communication among the diverse audiences interested in the health of California’s ocean.³⁹⁹

[See Box 53: Aerial photo sequence below by Charles C. Benton of restoration images from 2008 – 2010; used with permission.]

Box 53

South Bay Salt Pond Restoration Project - Under the leadership of Senator Dianne Feinstein, the South Bay Salt Ponds were purchased in 2003 from Cargill Inc. Funds for the purchases were provided by federal and state resource agencies and several private foundations. The 15,100 acre purchase represents the largest single acquisition in a larger campaign to restore 40,000 acres of lost tidal wetlands to San Francisco Bay. CDFW, California State Coastal Conservancy, and the U.S. Fish and Wildlife Service conducted a four-year public process to design a restoration plan for the property. The final plan was adopted in 2008 and the first phase of restoration started later that year. This large restoration effort is designed to establish a thriving wetland ecosystem, provide a critical natural buffer against the effects of climate change and sea-level rise, and provide carbon

storage benefits.

South Bay Salt Pond A21 Plateau



Installation of Equipment to Aid Flood Monitoring and Forecasting DWR's Enhanced Flood Response and Emergency Preparedness program and NOAA's Hydrometeorology Test bed program and have collaborated in a \$25 million project to improve monitoring and forecasting of "atmospheric rivers" (or the powerful winter systems, sometimes called "pineapple express" storms) that are responsible for most of California's major floods. Construction of four coastal observatories in 2013 – in Eureka, Bodega Bay, Big Sur, and Santa Barbara – will improve flood watch and flood warning information that can be provided to local emergency responders. The Western States Water Council has called for West-wide of expansion of this 21st century observing system for extreme precipitation, recognizing the value of what has been installed in California and the potential for additional West Coast offshore observations to further improve forecasting capability.

California Coastal Commission - Local Coastal Programs (LCPs) are basic planning tools used by local governments to guide development in the coastal zone, in partnership with the Coastal Commission. LCPs are submitted to the Coastal Commission for review for consistency with California Coastal Act requirements. The Coastal Commission is working with local governments to address climate change through LCPs and planning to reduce risks from climate change. Recent certified LCPs that have incorporated policies to minimize risks from sea-level rise impacts include Dana Point, Marina Del Rey, and Redondo Beach. The Coastal Commission is in the process of developing more specific guidance for addressing sea-level rise and other climate change related land use and coastal resource protection issues into LCPs. In addition, the Ocean Protection Council has approved \$2.5 million in grant funds for local governments to update LCPs to address sea-level rise and as of June 2013, the Conservancy, OPC, and Coastal Commission are in the process of administering the new grant program. In addition, Governor Brown and California Legislature approved an augmentation of \$4 million to the fiscal year 13-14 budget of California Coastal Commission (\$3 million for state operations and \$1 million grant to local governments) for local governments and the Coastal Commission to prepare, update, amend and review Local Coastal Programs including an emphasis on climate

change issues. The Coastal Commission is working with the Administration to provide information to support long-term funding to address the critical need to update LCPs and include climate change adaptation. Continued funding for this work is necessary to be successful.

Bay Conservation & Development Commission-Sea Level Rise Vulnerability Assessments

The San Francisco Bay Conservation and Development Commission was one of the first coastal management agencies in the country to work collaboratively with the U.S. Geological Survey and the PIER program to prepare regional vulnerability assessment to rising sea levels that included evaluating public policy implications and identification and adoption of enforceable policies regarding resilience to sea level rise as part of its permitting process.

California Current Acidification Network (C-CAN) is a collaboration of interdisciplinary scientists, resource managers, industry and others from local, state, federal, and tribal levels dedicated to advancing understanding of ocean acidification and its effects on biological resources of the U.S. west coast.

The West Coast Ocean Acidification and Hypoxia Science Panel - California and Oregon have signed a Memorandum of Understanding to jointly sponsor a high-level science panel to help address the issue of ocean acidification and hypoxia. The panel will provide state-level decision makers with the knowledge needed to evaluate and develop action plans for these complex issues. The science panel will also identify the research and monitoring needed to contribute to a West Coast-wide assessment of ocean acidification and hypoxia, and address information and data gaps critical to resource management decisions.

Monterey Bay Shoreline Management Planning

The Monterey Bay National Marine Sanctuary (MBNMS) is a federally-protected marine area offshore of California's central coast and encompasses 276 miles of shoreline. The Sanctuary must authorize and can place conditions on any Coastal Commission permit for sea wall or "armoring" projects below mean high tide. MBNMS convened a workgroup in 2003 with representatives from the Coastal Commission, U.S. Geological Survey, Caltrans, California Department of Boating and Waterways, U.S. Army Corps of Engineers, and scientists from local institutions to develop an action plan for a proactive, holistic, regional approach to coastal armoring. The plan includes a pilot program to investigate and assess environmentally sound alternatives to coastal armoring.⁴⁰⁰

Box 54

INNOVATIONS IN SHORELINE MANAGEMENT IN CALIFORNIA

Managed retreat at Surfer's Point

The Surfers' Point Shoreline Managed Retreat project is an effort in the City of Ventura to remove infrastructure near the coast and restore the natural beach. The project will

provide more beachfront area for recreational use and function as a natural storm buffer. The California State Coastal Conservancy helped plan and fund the construction of this project. Other important project partners that worked with the City were Surfrider Foundation, State Parks, Ventura County Fairgrounds, and the Coastal Commission. Federal transportation funding helped construct the project. The project is a comprehensive response to severe shoreline erosion in the face of sea-level rise. The project is in the City of Ventura and involved relocating a bike trail, parking lot and other access amenities away from the shoreline and restoring the beach and sand dunes.

Pacifica State Beach Managed Retreat, Beach and Estuary Restoration

Coastal erosion at Linda Mar State Beach threatened critical infrastructure and oceanfront property; while at the same time flood hazards from nearby San Pedro Creek caused periodic flood damage to the City of Pacifica. A managed retreat strategy was developed and implemented through a partnership of agencies, including the California State Coastal Conservancy, City of Pacifica, community groups, scientists and engineers. The project aimed for a combination of managed retreat and estuary restoration goals to reduce the coastal flood hazards. It is one of the first beaches to utilize managed retreat as a method of shoreline protection. In addition to sand replenishment (also called “beach nourishment”), it has restored habitat for four threatened and endangered species and enhanced public access with expanded trails and parking lots.

San Francisco Bay Living Shoreline-Nearshore Linkages Project

Living shoreline projects utilize a variety of structural and organic materials to stabilize and reinforce the shoreline, minimize coastal erosion, and maintain coastal processes while protecting, restoring, enhancing, and creating natural habitat for fish and aquatic plants and wildlife.⁴⁰¹ An innovative pilot project was constructed in the San Francisco Bay in 2012 to test the implementation of living shorelines as an adaptive method to provide habitat functions and values, as well as cope with sea-level rise and other environmental changes related to climate change. The project includes a comparison of multiple techniques to restore critical eelgrass and native oyster habitat at two sites. The California State Coastal Conservancy is leading this project which was designed and implemented through a multi-agency partnership.

ACTIONS NEEDED FOR SAFEGUARDING OCEAN AND COASTAL ECOSYSTEMS AND RESOURCES

Better Understanding of Climate Impacts on Ocean and Coastal Ecosystems and Resources

(1) Further Vulnerability Assessments and Cost Analyses

Additional vulnerability assessments and cost analyses are needed to fully assess California’s risks to climate impacts and appropriate responses to reduce those risks. Every community potentially impacted by sea-level rise will need to prepare vulnerability and cost assessments that include but are not limited to consideration of recreational and environmental losses to

the evaluation of cumulative and synergistic impacts, the importance of hazard avoidance, and the importance of adequately accounting for the environmental and recreational costs and benefits of strategies. Appropriate resources are needed for local governments and communities to not only prepare vulnerability assessments and cost analyses but also for the training and tools to apply the results to adaptation planning and implementation. Specifically, local vulnerability assessments are needed at scales that enable and inform planning and project implementation. The State has already invested significant resources to conduct and support vulnerability and cost assessments across sectors and a sampling of additional needs are listed below. An Adaptation Planning Guide for local and regional governments has also been developed.⁴⁰²

- a) Water Supply, Wastewater and Stormwater: An assessment of the state's wastewater and stormwater facilities is needed to identify vulnerabilities of aging infrastructure and system capacities in light of more extreme weather events and sea-level rise projections in the NRC report and as incorporated into the OPC's guidance to state agencies on planning for sea-level rise. Any such assessment should include cost analysis of system upgrades and cost analysis of potential public health, environmental, and property damage. Funding for the assessment would be needed.
- b) Hazardous Waste Sites and Facilities: An assessment is needed for toxic release vulnerabilities from the state's hazardous waste facilities and hazardous waste sites in light of more extreme weather events and sea-level rise projections in the NRC report. The assessment should include recommendations for addressing vulnerabilities, including cost analysis of recommendations and cost analysis of potential public health, environmental, and property damage. Funding for the assessment would be needed.
- c) Underground Storage Tanks (USTs): An assessment is also needed to address toxic release vulnerabilities from the state's USTs, not just in coastal areas, but also in inland areas susceptible to flooding. This need is further described in the Water section of this document.
- d) Energy and Transportation Infrastructure: Additional needs with respect to vulnerability studies for energy and transportation infrastructure are described in the Energy and Transportation sections of this report.
- e) Cumulative and Synergistic Impacts: As noted above, ocean acidification, changing ocean temperatures, rising sea levels, and changes in oxygen levels are compounding other stressors on ocean and coastal habitats and resources such as pollution and overfishing. Development of ocean renewable energy projects, and other offshore energy development, may also present new stressors on ocean and coastal habitats and resources. The cumulative impact, and any synergistic dynamics among the stressors, is not well understood, and the potential implications for commercial fish and shellfish species and human health are also not fully understood. A more robust scientific understanding of cumulative and synergistic impacts, accompanied by a science-informed trade-off analysis framework, is critical to supporting innovative management techniques that are responsive to the new, and rapidly changing, marine conditions.

Further, there is a need for OPC to continue supporting data layers within the California Geoportal to underpin decisions that will be made by permitting agencies. Funding support to enable studies of such cumulative and synergistic impacts is needed.

- f) **Economic Costs to Californians** As noted above, there have been some studies to date of the economic impacts of sea-level rise to some California communities, and there has been some study of potential impacts from more extreme weather events. However, more information about the cost of expected climate impacts is needed to inform and evaluate management options. Funding support to enable such studies is needed.
- g) **Marine Species and Ecosystems.** See Biodiversity and Habitat section of this document for information regarding the need for a comprehensive, state-wide vulnerability assessment for marine species and ecosystems in California.

For more information on California climate vulnerability assessments to date please see the California Climate Change Portal
http://www.climatechange.ca.gov/climate_action_team/reports/climate_assessments.html and the various sections of this document.

(2) Continued Modeling Scientific models are tools used to generate predictions and explanations. Models must be built, tested for accuracy, and revised.⁴⁰³ Models add greatly to our understanding of the possible outcomes from and consequences of changes to a system.

Along the coast, the main drivers of change will be changing water conditions (water level, waves, storms, extreme events, acidification, or temperature), and changes to the shoreline (sediment supplies, addition or removal of structures, development patterns). Models may be used to predict changes in the California shoreline, expected storm surges, pollution inputs, estuarine and near shore impacts, and sediment movement in coastal areas in the era of climate change. Modeling is important to examining the full extent of consequences associated with various sea-level rise projections along with storm wave conditions and the dynamics at coastal inlets. Continued development and refinement of models for climate impacts on California's ocean and coastal ecosystems and resources will be important. Funding to support such work will be needed.

(3) Continued Support and Investment in Monitoring Efforts

Monitoring changes to biological, chemical and physical processes is critical to continue advancing knowledge of climate impacts on coastal and marine ecosystems and resources and to support informed management responses that incorporate the best-available science on changing ocean and coastal conditions. Partnerships to enable funding and staffing of these efforts will be important. The Ocean Protection Council (OPC), in partnership with the Ocean Science Trust and the OPC's Science Advisory Team, will lead a process to identify priority monitoring needs to improve management of ocean and coastal resources under a changing climate. This process will address topics such as:

- a) Ongoing monitoring and assessment of coastal inundation damages, for purposes of statewide flood planning;
- b) Monitoring of offshore meteorological parameters and wave heights to obtain data for storm surge modeling and meteorological forecasting; and
- c) Estuarine monitoring for changes to wetlands, sediment, changes in salinity, etc.

Improve Management Practices for Coastal and Ocean Ecosystems and Resources and Increase Capacity to Withstand and Recover from Climate Impacts

(1) Hazard Avoidance for New Development

In order to minimize the adverse effects of sea-level rise and storms, it is important to carefully consider decisions regarding areas vulnerable to flooding, inundation and erosion. The state should not build or plan to build, lease, fund, or permit any significant new structures or infrastructure that will require new protection from sea-level rise, storm surges or coastal erosion during the expected life of the structure, beyond routine maintenance of existing levees or other protective measures, unless there is a compelling need consistent with the public trust doctrine and existing law (*e.g.* coastal-dependent marine terminals or

marinas that must necessarily be sited in areas at risk). If the state is building or planning to build, lease, or permit structures that will require additional new expenditures for sea-level rise protection during the expected life of the new structures, the state should ensure that the project proponent:

- a) Minimize risks through siting, design and engineering;
- b) Identify viable funding sources for building, monitoring and maintaining the new sea-level rise protections;
- c) Ensure that any new protections must consider how risk changes over time and ensure that actions to reduce risk in the short-term do not increase risk in the long-term; and
- d) Design protection in a manner that maximizes conservation of natural resources and public access.

As discussed in the Emergency Management section of this document, it is important to note that actions to reduce risk in the near term (such as developing protections for near-term sea-level rise) may encourage development patterns that actually increase risk in the longer term. Development must be carefully considered in light of local vulnerabilities, principles laid out in this section, and any recommendations resulting from the OPC-Led Process for Coordinated Action described below.

(2) Encourage Innovative Design of New Structures/Infrastructure in Areas Vulnerable to Sea-level Rise

Where there is a compelling need for structures and infrastructure in areas susceptible to sea-level rise, storm surge and erosion, best available material science and structural design should be utilized to minimize pooling water on roadways, ensure maximum durability and public safety, and otherwise incorporate expected impacts into building plans.⁴⁰⁴ The State should propagate relevant design standards for engineering and construction in areas susceptible to sea-level rise, storm surge and erosion and priority should be given to development of green or nature-based infrastructure when appropriate. Efforts in other states affected by hurricanes (Florida, Georgia, Louisiana, etc.) should be studied to illuminate the potential impacts of severe storms in California.

(3) Enhance Integration of Climate Risk Considerations, Including Extreme Weather Events and Sea-Level Rise, into Emergency Management Activities

For a discussion of the integration of climate risks considerations into emergency management activities, please see the Emergency Management section of this document.

(4) OPC-Led Process for Coordinated Action Informed by Science Needs Assessment

Although there is a lot of work in California to address sea-level rise, coastal storms and erosion, the urgency of the situation requires more active management and coordination to understand what is working on local, regional and state levels that can be expanded and to leverage resources and better integrate work in an on-going manner. The OPC will lead an inclusive, collaborative, science-based process to inventory existing actions to reduce risks from sea-level rise, storms and erosion and to collaborate with others to improve the

capacity of entities at multiple scales to more effectively act to reduce these risks. OPC will work with the California Coastal Zone Management Agencies (Coastal Commission, BCDC and Coastal Conservancy), the state coastal land owners (State Lands Commission, Department of Parks and Recreation) and other state entities and with consultation with local land use planning authorities, tribes, federal partners, and other stakeholders.

This process will involve activities such as:

- Conducting a science needs assessment in partnership with the CA Ocean Science Trust and the OPC's Science Advisory Team to identify key information needs and the opportunities for existing and new science to inform management and reduce risks.
- Engaging state partners to assess progress and future plans and leverage resources.
- Engaging non-state entities working on many scales to learn what is working, what could be expanded and what else needs to be done.
- Collaborating with FEMA, NOAA, USGS and the Army Corps of Engineers and state agencies such as the Coastal Conservancy, Coastal Commission, BCDC and the Department of Water Resources on improving mapping of areas at risk of flooding due to sea-level rise, storms and shoreline change.
- Bring resources and expertise to assist the State Lands Commission, Coastal Commission and others address the issue of changing boundaries between public trust lands and private lands.
- Providing resources on funding sources and mechanisms for supporting actions to understand and reduce risks on many scales.
- Describing a range of tools that can be utilized to reduce risk while maximizing conservation of natural resources and public access, consistent with the public trust doctrine.
- Supporting state agencies to have the capacity to take effective action.
- Improving coordination and sharing of information needed to leverage resources and improve consistency and effectiveness.

The OPC will consider how to support innovative practices including managed retreat and use of natural processes and habitats to reduce risk from flooding, inundation and erosion; and will also address expected impacts to public access and use of beaches, trails and recreational areas along the coast.

(5) Support Pilot Projects for Innovative Shoreline Management Techniques

Particularly during the OPC-Led Process described above, the state should continue to support local and regional governments and other entities implementing innovative shoreline management projects. Pilot project may provide valuable insights into best practices for managing shorelines in the era of rising sea levels and storm surges.

(6) Continue to Study and Support Investment in Cost-Effective Green Infrastructure to Reduce Flood Risk and Stormwater Runoff and to Maximize Associated Co-Benefits

As noted above, there can be significant cost savings and co-benefits associated with the use of green infrastructure, such as wetland restoration and urban forestry, to improve water quality and flood protection. Co-benefits may include greenhouse gas reductions that can reduce the pace and scale of climate impacts, habitat for wildlife, and improved air quality. For example, wetlands have the potential to reduce subsidence in the Delta, thus reducing pressure on levees which in turn reduces risk of levee failure and flooding. *See DWR's Twitchell Island Project in the Biodiversity and Habitat section for more information.*

(7) Addressing Climate Impacts in Local Coastal Programs and General Plan Guidelines

Under existing law, Local Coastal Programs (LCPs) and General Plans are key tools for addressing sea-level rise, storms and shoreline change. The Coastal Commission is in the process of developing more specific guidance for addressing sea-level rise and other climate change related land use and coastal resource protection issues into LCPs. Continued investments to update LCPs is necessary since most LCPs currently do not include plans for reducing risk from sea-level rise. In addition, the Governor's Office of Planning and Research (OPR) will also be providing a 2013 update to its General Plan Guidelines (GPG 2013). The GPG 2013 will be a resource for decision-makers, planners, and the public for the development and implementation of local general plans. The GPG 2013 will include advice on how general plans can address needed preparation for climate impacts.⁴⁰⁵

(8) Support and Continue Progress Toward a More Integrated Ecosystem Approach to Management of Ocean Resources

Ocean acidification, changing ocean temperatures, rising sea levels, changes in oxygen levels, changes in ocean circulation, more extreme weather events, and cumulative and synergistic impacts, are rapidly changing marine habitats. Species ranges, species interaction, reproductive success, and many other variables are shifting. There is need to move away from a focus of only looking to management approaches that focus on single-species management. A more integrated approach might include the tenets of ecosystem management, a process that aims to conserve major ecological services and restore natural resources while meeting the socioeconomic, political and cultural needs of current and future generations. While recognizing the importance of a more integrated approach, it is important to recognize that managers will continue to work within the confines of existing regulatory requirements, laws, and responsibilities as they relate to single species.⁴⁰⁶ A more integrated approach will be better suited to highly dynamic changing variables. For instance, the Pacific Fishery Management Council is developing an ecosystem-based approach to managing fish stocks in the offshore waters of Washington, Oregon, and California. Ecosystem-based management as defined by the Council "recognizes the physical, biological, economic, and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition."⁴⁰⁷ The Pacific Fishery Management Council is one of eight regional fishery management councils established by the Magnuson Fishery Conservation and Management Act of 1976.⁴⁰⁸ In addition, the Delta Reform Act of 2009 adopted an ecosystem approach to restoring the Delta, along with the co- equal goal of improving statewide water supply reliability.⁴⁰⁹

(9) Continued Development of State Sediment Master Plan and Sediment Management Activities

The Coastal Sediment Management Working Group (CSMW) is a collaborative taskforce of state, federal, and local/regional entities, chaired by the U.S. Army Corp of Engineers South Pacific Division and the California Natural Resources Agency.⁴¹⁰ The CSMW is developing a comprehensive state Sediment Master Plan (“SMP”) for the conservation, restoration, and preservation of valuable sediment resources along the coast of California. Sediment includes materials such as gravel, sand, silt and clay formed by natural erosion such as precipitation, wind, and stream flows. Humans have substantially altered natural sediment transport processes within California’s coastal watersheds, reducing storm protection, habitat and recreation along the coast. The goal of the SMP is to reduce shoreline erosion and coastal storm damages, provide for environmental restoration and protection, increase natural sediment supply to the coast, restore and preserve beaches, maintain or improve coastal access, improve water quality along coastal beaches, and optimize the beneficial use of material dredged or excavated from ports, harbors, wetlands, and other sediment sources.⁴¹¹ For instance, the types of hybrid levees discussed in Box 50: “Wetlands” - Nature’s Flood Protection” would utilize dredged sediment from nearby flood control channels for marsh restoration. That dredged sediment is currently disposed of in landfills.⁴¹² Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (LTMS) Program is implemented by state, federal and local partners, including the Bay Delta Conservation and Development Commission (BCDC). BCDC is working, in part with the CSMW, to prepare sediment management plans that integrate the successful Long Term Management Strategy for dredging with flood control planning, wetlands restoration and other aspects affecting sediment processes throughout the San Francisco Bay system.⁴¹³

(10) Water Management Responsive to Saltwater Intrusion Issues

For information about saltwater intrusion and water management activities, please see the recommendations for continuing to mainstream climate considerations into water management in the Water section of this document.

Better Understanding of Evolving Trends that May Impact Ocean and Coastal Ecosystems and Resources

(1) Better understand the impacts and opportunities associated with offshore renewable energy development

Renewable energy development helps to reduce greenhouse gas emissions from fossil fuel use and can help reduce the pace and scale of climate impacts on ocean and coastal ecosystems and resources. Marine renewable energy has the potential to play a role in meeting California’s renewable portfolio standards and energy demand; however, marine renewable energy development can also have some negative impacts on coast and ocean ecosystems and resources including noise and light pollution and impacts on avian and other flying species. In response, the California Marine Renewable Energy Working Group; is an interagency group chaired by the California Ocean Protection Council was formed with the following goals:

- Address uncertainties in regulatory processes for marine renewable energy projects

- in California;
- Address the information needs of state agencies and stakeholders to inform potential impacts and user conflicts with marine renewable energy projects; and
 - Facilitate the development of agreements and joint state-federal committees to improve coordination of state and federal permitting processes.

As noted above, it will be important to understand the benefits and impacts of ocean renewable energy development in the larger context of other expected climate impacts and traditional stressors on ocean and coastal ecosystems and resources.

(2) Support Reform of Federal Flood Insurance Program

As noted above, there were \$68 billion of California assets insured under the Federal Flood Insurance program as of August 2012. However, continuing issues with respect to the financial integrity of NFIP may pose serious threats to the economic well-being and health of Californians. The State should support appropriate continuing reform of NFIP and implementation of the 2012 Biggert-Waters Flood Insurance Reform Act⁴¹⁴ while engaging in risk communication efforts and other efforts described in this chapter.

Information Sharing and Education

(1) Invest in Risk Communication Efforts, Emphasizing Disclosure of Risks that Have Not or Cannot Be Addressed in an Economically Feasible Manner⁴¹⁵

The State should invest in efforts to raise public awareness and understanding of sea-level rise and accompanying risks of flooding, erosion, infrastructure and property damage, and permanent submersion of coastal lands, salt water intrusion, toxic releases and other public health impacts. The state should also invest in efforts to raise awareness of the limitations of flood insurance and disaster relief, and the costs associated with response and recovery efforts associated with various anticipated sea-level rise impacts. Finally, the state should invest in efforts to raise awareness regarding options to protect new and existing structures and infrastructure from sea-level rise; awareness raising efforts should include discussion of any relevant benefits from employing green infrastructure, cost estimates, awareness and support for protecting vulnerable communities, and funding sources for protective measures. For example, California State Parks are one important venue to communicate risk and disseminate information. There are 114 coastal units in the State Park System – encompassing some 340 miles of the coast, and including coastal portions of State Parks, State Recreation Areas, Natural Reserves, and State Beaches. In 2011, 34 million visitors attended coastal parks. Each of those visitors presents an opportunity to communicate about climate change.

(2) Improve Maps and Tools and Provide Training to Incorporate Best-Available Climate Science into Planning and Operation and Management Decisions for Assets at Risk from Sea-level Rise

As sea-level rise projections and storm surge projections continue to be refined, maps and tools reflecting those projections must be developed and updated to support flood management planning, hazard planning, capital investment and development decisions. Training in the use of these maps and tools must also be provided so that best available knowledge about expected impacts can be fully integrated into routine governmental decision making, for instance for land use planning, transportation planning and operation and management, and the siting and operation and management of energy infrastructure.⁴¹⁶

(3) Sustainability Modeling Tools for Fishery Managers

Utilizing data collected from monitoring efforts, and best available understanding of cumulative and synergistic impacts from climate and other stressors, sustainability modeling tools should be developed to assist fishery managers. These tools should be consistent, to the extent it serves the State, with relevant ecosystem-based management approaches propagated by the Pacific Fisheries Management Council as described above. California's network of MPA's provide scientist with an unprecedented opportunity to utilize and create tools to assess trends in oceanographic conditions that fishery scientists and managers may then use to determine the effects of these changing conditions on fisheries.

(4) Public Health Risk Communication Efforts

As noted above, climate impacts to ocean and coastal ecosystems and resources have numerous public health implications. Flooding, permanent inundation, and more extreme weather events may cause: toxic exposures from USTs and hazardous waste sites and facilities, increased pollution from stormwater and wastewater systems, contamination of fish and shellfish, and serious property damage including damage to transportation and energy systems and critical infrastructure including hospital facilities. In-situ instrumentation will help provide better data to inform needed beach closures to limit health risk exposures and consumption advisories. CDPH and SWRCB already have programs in place that could be used for these continuing public health risk communication efforts.

Box 55

California Ocean and Coastal Ecosystems and Resources

Given the myriad facets of California's ocean and coastal assets, many different state entities play an important role with respect to California's ocean and coastal ecosystems and resources. Understanding the jurisdictional scope of these entities is important for a robust discussion of continued steps needed to adequately prepare for climate impacts.

California Coastal Commission (Coastal Commission) was established by voter initiative in 1972 (Proposition 20) and later made permanent by the Legislature through adoption of the California Coastal Act of 1976. The California Coastal Commission works in partnership with coastal cities and counties and is committed to protecting and enhancing California's coast and ocean for present and future generations. It does so through careful planning and regulation of environmentally-sustainable development, rigorous use of science, strong public participation, education, and effective intergovernmental coordination. The Coastal

Commission works in partnership with local governments to develop local land use plans and implementing ordinances, or Local Coastal Programs. The plans are developed by local governments and certified by the Commission, and are a key mechanism for addressing sea-level rise and other climate change impacts at the local level throughout the state.

California Department of Fish and Wildlife (CDFW) established in 1927, is the state agency designated to protect, maintain, enhance, and restore California's marine and terrestrial ecosystems and species for their intrinsic and ecological values. CDFW is also responsible for the diversified use of fish and wildlife including recreational, commercial, scientific and educational uses. CDFW also prevents, prepares for, and responds to spills of oil and other deleterious materials, primarily in the marine and coastal environment.

California Department of Parks and Recreation (California State Parks or CSP) is a trustee agency responsible for managing 114 coastal parks that cover over 340 miles of the California coast. Those parks include state beaches with amenities such as campsites and picnic areas, as well as coastal rivers, estuaries, and dune systems, many protected as natural preserves and state wilderness areas. State Parks also provide access to state marine parks and other marine protected areas. In 2011, 34 million people visited state beaches and other coastal parks. CSP's Division of Boating and Waterways (DBW), is responsible for planning, developing, and improving facilities on state-owned and state-managed properties, and funds applied research on coastal waves, beaches, sea level, and climate change. CSP's mission is to provide for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity and its most valued natural and cultural resources while also providing opportunities for high-quality outdoor recreation.

California Department of Public Health (CDPH) was established on July 1, 2007, through enactment of SB 162, which vested responsibility for public health programs in CDPH. CDPH assists local health agencies in addressing microbiological contamination of beaches and recreational waters.

California Department of Toxic Substances Control (DTSC) which began as a unit within the Department of Health Services in the early 1970s, protects California's people and environment from harmful effects of toxic substances through the restoration of contaminated resources, enforcement, regulation and pollution prevention.⁴¹⁷

California Department of Transportation (Caltrans) with origins dating back to 1895, is the state agency responsible for transportation planning, construction, and maintenance of the State Highway system. Caltrans oversees significant transportation infrastructure located in coastal areas, including highways and bridges.

California Department of Water Resources (DWR) established in 1956, is responsible for managing and protecting California's water resources and supplies. DWR includes a Division of Flood Management, established in November 1977, and has been instrumental in

working on Enhanced Flood Response and Emergency Preparedness.

California Energy Commission (CEC) established in 1974, is the state's primary energy policy and planning agency. As further discussed in the Transportation and Energy sections of this document, the CEC aids in planning and managing energy resources that may be vulnerable to climate impacts including sea-level rise.

California Fish and Game Commission (FGC) established in 1870, is a Commission comprised of five members, appointed by the Governor and confirmed by the Senate. The Commission formulates general policies for the conduct of CDFW, but also has general regulatory powers, including deciding seasons, limits and methods of take for sport fish. The Commission also has responsibilities for invasive species; establishing/regulating use of Marine Protected Areas (MPAs); listing/delisting threatened and endangered species under the California Endangered Species Act; prescribing terms and conditions for issuance of licenses/permits by CDFW; and revoking or suspending privileges of those that violate California Fish and Game laws and regulations.

California Ocean Protection Council (OPC) was established in 2004 pursuant to the California Ocean Protection Act. OPC is tasked with the following responsibilities: coordinating activities of ocean-related state agencies to improve the effectiveness of state efforts to protect ocean resources within existing fiscal limitations; establishing policies to coordinate the collection and sharing of scientific data related to coast and ocean resources between agencies; identifying and recommending to the Legislature changes in law; and identifying and recommending changes in federal law and policy to the Governor and Legislature.

California Ocean Science Trust (OST) is a nonprofit 501(c)(3) public benefit corporation established pursuant to the California Ocean Resources Stewardship Act of 2000 (California Public Resources Code Sections 36970-36973. OST's mission is to advance a constructive role for science in decision-making by promoting collaboration and mutual understanding among scientists, citizens, managers, and policymakers working toward sustained, healthy, and productive coastal and ocean ecosystems.

California State Lands Commission (SLC) The California State Lands Commission was created in 1938 and serves the people of California by managing and protecting over 4 million acres of sovereign land, including the beds of California's navigable rivers, lakes and streams, and the State's tide and submerged lands. The Commission's jurisdiction extends along the State's over 1,100 miles of coastline and offshore islands from the ordinary high water mark, as measured by the mean high tide line, except where there is fill or artificial accretion, to three nautical miles offshore. The Commission also has oversight authority over legislatively granted public trust lands, which includes the lands and waterways underlying California's major ports. All lands under the Commission's jurisdiction, granted or ungranted, are state assets held in trust for the benefit of the people of California and subject to the protections of the common law Public Trust Doctrine. The Commission also manages energy and mineral resource development and use under approximately 130 oil,

gas, geothermal and mineral leases covering more than 95,000 acres of State-owned lands. The Commission is responsible for preventing oil spills by providing the best achievable protection of the marine environment at the State's 58 marine oil terminals through ensuring compliance with the State's Marine Oil Terminal Engineering and Maintenance Standards. Further, the Commission administers the State's Marine Invasive Species Program⁴¹⁸ and in that capacity is responsible for preventing or minimizing the release of invasive species in California waters from vessels that are 300 gross registered tons and above.

California Technology Agency (formerly the Office of the State Chief Information Officer) was established in 2007 and is a cabinet-level agency responsible for the approval and oversight of all state information technology projects, including Geospatial Information Systems (GIS) and the State of California Geo-Portal.⁴¹⁹ The California Geo-Portal includes maps of Marine Protected Areas, nautical charts, OPC's coastal viewer, and links to MarineBios an interactive map for users to visually explore marine and coastal spatial planning data held in the California Department of Fish and Wildlife, Marine Region, Geographic Information System.

Delta Protection Commission (DPC) The mission of the Delta Protection Commission is to adaptively protect, maintain, and where possible, enhance and restore the overall quality of the Delta environment consistent with the Delta Protection Act, and the Land Use and Resource Management Plan for the Primary Zone. This includes, but is not limited to, agriculture, wildlife habitat, and recreational activities. The goal of the Commission is to ensure orderly, balanced conservation and development of Delta land resources and improved flood protection.

Delta Stewardship Council (DSC) was created in legislation to achieve the state mandated coequal goals for the Delta. "'Coequal goals' means the two goals of providing more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Since the waterways in the Delta are at sea level and are tidally influenced, and since many Delta islands are at or below sea level, the coastal effects of climate change will also affect resources within the Delta.

San Francisco Bay Conservation and Development Commission (BDC) is a state agency that was created by the California Legislature in 1965 with the charge of minimizing future unnecessary filling of the Bay and promoting its wise use and improving public access along its shoreline. BCDC has developed an extensive climate change adaptation program. Recent projects include new policies to address sea-level rise; a collaborative scientific study to characterize ecosystem services provided by wetlands and develop strategies to improve wetland resilience; and a collaborative project with NOAA to work with several local governments and special districts to identify the potential Bay-related impacts of sea-level rise and storms adaptation approaches that address identified vulnerabilities. BCDC is also working with the Association of Bay Area Governments collaborative planning and

implementation process to develop a comprehensive regional resilient shorelines strategy that addresses rising sea level and storms as well as earthquakes.

State of California Coastal Conservancy (SCC) SCC, established in 1976, is a state agency that purchases, protects, restores, and enhances coastal resources, and works to provide access to the shore. SCC works in partnership with local governments, other public agencies, nonprofit organizations, and private landowners to develop plans and implement projects that protect and enhance coastal and marine habitats. In 2012, the Legislature specifically authorized the SCC to address the impacts of climate change including but not limited to extreme weather events, sea-level rise, storm surge, beach and bluff erosion, salt water intrusion, and other coastal hazards that threaten coastal communities, infrastructure, and natural resources.

State Water Resource Control Board (SWRCB) and nine **Regional Water Quality Control Boards (Water Boards)** were created in 1949. SWRCB protects water quality by setting statewide policy and supporting the pollution control programs administered by the Water Boards. The Ocean Unit of the SWRCB is responsible for the development of the California Ocean Plan and other significant regulatory documents for bays and estuaries. The Water Boards administer programs related to ensuring that beaches are safe to swim by regulating the discharge of waste and supporting the monitoring of coastal watershed and beach health. As further described in the Transportation section of this document, SWRCB's Underground Storage Tank (UST) Program protects public health and safety and the environment from releases of petroleum and other hazardous substances from tanks.

Governor's Office of Emergency Services (OES) OES is responsible for the coordination of overall state agency response to major disasters in support of local government. The Agency is responsible for assuring the state's readiness to respond to and recover from all hazards and for assisting local governments in their emergency preparedness, response, recovery, and hazard mitigation efforts. OES includes the Public Safety Communications Office.

Coastal assets and infrastructure are under the purview of various federal, state, regional and local agencies, and there are significant coastal assets under private ownership and management. As discussed in this chapter, management and planning for climate impacts on such assets and infrastructure requires a high degree of coordination.

The National Oceanic and Atmospheric Administration (NOAA) is a federal agency with origins dating back to 1807. NOAA's mission focuses on scientific work to understand and predict changes in climate, weather, oceans, and coasts; dissemination of scientific information; and conservation and management of coastal and marine ecosystems and resources. The NOAA Coastal Services Center is dedicated to working with state and local coastal programs to determine data needs and deliver not only the data, but also the tools and training needed to turn these data into useful information.⁴²⁰

The Federal Emergency Management Agency (FEMA) also plays an important role in flood disaster planning and preparation and response and recovery. Both NOAA and FEMA are important

partners for the State of California with respect to ocean and coastal ecosystem and resource management.⁴²¹

As discussed in this chapter, local and regional governments play an important role with respect to California's ocean and coastal ecosystems and resources.⁴²²