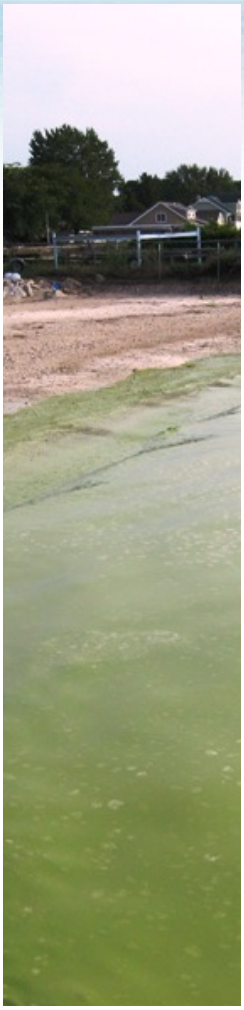
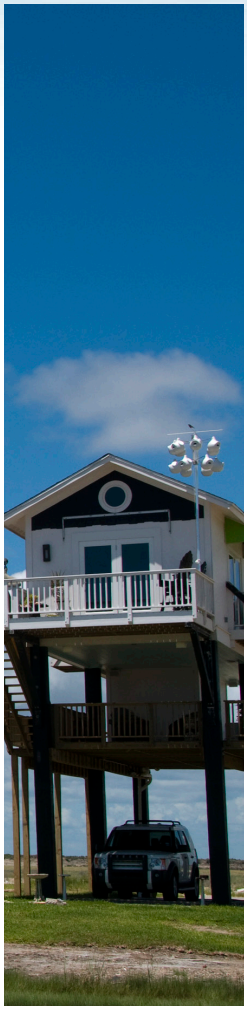
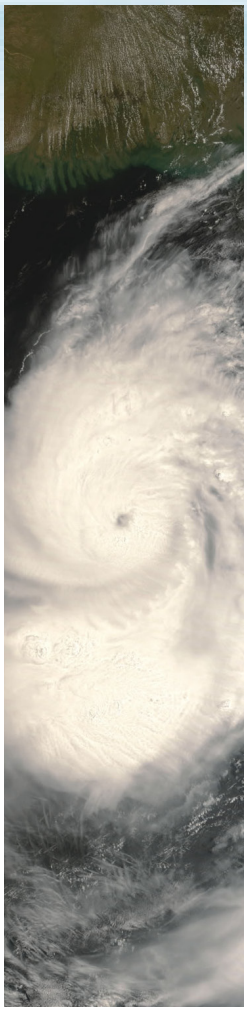
Adapting to Climate Change: A Planning Guide for State Coastal Managers







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"Climate change is real. It is here, and it is happening now, in our backyards and around the globe."

Jane Lubchenco, Ph.D.

Under Secretary of Commerce for Oceans and Atmosphere
Administrator, National Oceanic and Atmospheric Administration

Individuals and decision makers across widely diverse sectors—from energy to transportation to natural resource management—are increasingly asking NOAA for information about climate change in order to make the best choices for their families, communities, and businesses. This guide, *Adapting to Climate Change: A Planning Guide for State Coastal Managers*, offers a framework for state coastal managers to follow as they develop and implement climate change adaptation plans in their own states. State coastal managers, and their counterparts in local governments, are at the forefront of adapting to climate change. Issues that coastal managers face every day—such as coastal erosion, stormwater management, habitat protection, and aging Great Lake infrastructure—are being exacerbated by climate change. This guide is one of the many products and services that NOAA is offering to help the nation prepare for and address the impacts of climate change.

This guide benefited greatly from the input of individuals from several organizations within and outside NOAA, including NOAA's Office of Ocean and Coastal Resource Management, Coastal Services Center, National Sea Grant College Program, Climate Program Office, and National Marine Fisheries Service Office of Habitat Conservation; members of the Coastal States Organization; and others.

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CHAPTER 1 INTRODUCTION

Overview

The climate is changing, affecting global temperatures, extreme weather patterns, precipitation, and the oceans. The effects of climate change are already being observed. These impacts are expected to increase in scale and scope over time. Scientists report that at least half of the increases in temperature observed since 1951 are likely attributable to human activity, primarily emission of heat-trapping or "greenhouse" gases (CCSP 2008c). Because of the influence of greenhouse gas emissions on climate change, humans may be able to reduce the rate and severity of climate change by reducing the rate at which carbon and other heat-trapping gases are added to the atmosphere. Some states are already addressing how they can mitigate climate change, primarily by reducing greenhouse gas emissions. However, how successful these efforts will be is unknown, and some level of climate change is inevitable based on past emissions (Solomon et al. 2009). So, while federal, state, and local governments continue to attend to climate change mitigation, they must also develop strategies for adapting to the impacts of climate change they will not be able to avoid.

The following definitions are from the Intergovernmental Panel on Climate Change Fourth Assessment Report and will be used in this guide (IPCC 2007a). While this guide focuses on adaptation, it is important to understand the role of mitigation in addressing climate change and, ultimately, what it means for adaptation.

Adaptation—Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.[1]

Mitigation—An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

The purpose of this guide is to help U.S. state and territorial (state) coastal managers develop and implement adaptation plans to reduce the impacts and consequences of climate change and climate variability (climate change) in their purview.[2] It was written in response to a request from state coastal managers for guidance from the National Oceanic and Atmospheric Administration (NOAA) on adaptation planning in the coastal zone. It is intended as an aid, not as a prescriptive directive, and a state may choose to use individual steps or chapters or the entire guide, depending on where they are in their planning process.

A climate change adaptation plan identifies and assesses the impacts that are likely to affect the planning area, develops goals and actions to best minimize these impacts, and establishes a process to implement those actions. While an adaptation plan for the coast or the larger state may stand alone, planning to adapt to climate change should be incorporated to varying degrees in all statewide planning efforts (as well as regional and local planning efforts). However you choose to move forward, the ultimate goal is coastal states and communities that are organized to take action, have the tools to take action, and are taking action to plan for and adapt to the impacts of climate change.

As illustrated by its mission goals to "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management" and "understand climate variability and change to enhance society's ability to plan and respond," NOAA is committed to helping coastal communities prepare for and respond to climate change (NOAA 2008). This includes protecting and managing coastal resources to meet social, environmental, and economic needs.

NOAA's Office of Ocean and Coastal Resource Management (OCRM), part of the National Ocean Service, provides national leadership, strategic direction, and guidance to state coastal management programs. OCRM has a particular interest in climate change because of its role in administering the Coastal Zone Management Act of 1972 as amended. The act, which finds that "because global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence," declares it national policy to "preserve, protect, develop, and, where possible, restore and enhance the resources of the Nation's coastal zone for this and succeeding generations" (16 U.S.C. 1451, et seq.). Specifically, it calls for states to protect natural resources and manage coastal development to minimize the loss of life and property caused by improper development in hazardous areas as well as those areas likely to be affected by sea level rise and other impacts of climate change.

[1] While some coastal communities may experience benefits from a changing climate change, adapting to and capitalizing on these benefits is outside the scope of this document.

[2] This guide is only one of a number of guides to adaptation planning. It is not intended to be definitive, and NOAA encourages states to explore and use other guides and frameworks as they see fit to best meet their individual needs.

Coastal inundation resulting from sea level rise or storm surge, as illustrated here, is one of the likely impacts of climate change on U.S. coasts.

Coastal managers have been asking NOAA and other federal agencies to provide increased and improved information about how climate change will affect their human and natural communities (e.g., regional impacts, site-specific data) and what can be done to prevent or adapt to the negative impacts. In 2008, the Coastal States Organization surveyed states to help inform members of Congress, federal agencies, and others about the anticipated costs and needs of the coastal states in regard to the impacts of climate change (Climate Change Work Group 2008). The survey found that several states have begun to take action on climate change adaptation (as many of the examples in this guide illustrate) and that lack of data, or uncoordinated data collection, was a limiting factor. Nevertheless, despite the data limitations and the uncertainty of climate change, managers should be planning for climate change now.

The intent of this document is to help guide coastal managers at the state level in their initial and ongoing climate change adaptation planning efforts. Planning is not a one-time event, and as the science and tools to understand and address climate change evolve, so should the associated plans and strategies.

Methodology

Information in this guide is based on needs assessments and a wide variety of resources specific to climate change, sustainability, resilience, general hazard mitigation, and natural resource management. This information is synthesized so it is specific to state coastal managers, their responsibilities, and the impacts and consequences of climate change on our nation's coasts. Key resources include:

- *Global Climate Change Impacts in the U.S.* (2009) (and associated reports, 2006-2009)—U.S. Global Change Research Program (formerly the U.S. Climate Change Science Program)
- *Intergovernmental Panel on Climate Change Fourth Assessment Report* (2007)
- The Federal Emergency Management Agency's Mitigation Planning "How-To" Guides (2001-2008)
- *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (2007)—ICLEI–Local Governments for Sustainability
- *Synthesis of Adaptation Options for Coastal Areas* (2008)—U.S. Environmental Protection Agency, Climate Ready Estuaries Program
- *Coastal No Adverse Impact Handbook* (2007)—Association of State Floodplain

"The high degree of uncertainty inherent in assessments of climate change impacts can make it difficult for a manager to translate results from those assessments into practical management action. However, uncertainty is not the same thing as ignorance or lack of information—it simply means that there is more than one outcome possible as a result of climate change" (CCSP 2008b).

Managers and the NOAA Coastal Services Center

- *Adapting to Coastal Climate Change: A Guidebook for Development Planners* (2009)—U.S. Agency for International Development

Structure

This document is structured to help guide managers through the planning process from establishing the planning team to implementing the plan. This chapter, Chapter 1, introduced the guide, its purpose, intended audience, methodology, and structure. The remainder of the guide is organized as follows:

- **Chapter 2 Climate Change and the Coast** provides a brief and general overview of the value of our coasts and how they may be affected by climate change to establish the importance of adaptation planning.
- **Chapter 3 Planning Process** describes the steps to take to create a plan and bring it to life.
- **Chapter 4 Vulnerability Assessment** explains the elements involved in a vulnerability assessment for the purposes of guiding adaptation efforts.
- **Chapter 5 Adaptation Strategy** discusses how to establish goals and identify actions that may be able to reduce the negative impacts associated with climate change and introduces a framework to help users choose and prioritize actions that will aid them in achieving their goals.
- **Chapter 6 Plan Implementation and Maintenance** suggests ways to implement a plan; track, evaluate, and communicate its progress; and update it to reflect completed actions, changing circumstances, and new science, data, tools, and techniques.
- **Appendix A Potential Federal Funding Sources** provides information about some of the existing programs, which may not target climate change specifically, that may provide funding for climate change adaption planning or project implementation.
- **Appendix B Federal Laws and Executive Orders** lists some of the federal laws and executive orders that support climate change adaptation.
- **Appendix C Regional Climate Summaries** provides brief summaries of how climate change may affect the different regions of the United States.

Global Climate Change Impacts in the United States *is the most comprehensive and authoritative report on the current and future impacts of climate change on the United States.*

Key Resources are noted at the end of each chapter. Additional resources can be found on the NOAA Coastal Services Center Coastal Climate Adaptation web site at http://collaborate.csc.noaa.gov/climateadaptation/ and on NOAA's Climate Portal at www.climate.gov/.

CHAPTER 2
CLIMATE CHANGE AND THE COAST

This purpose of this chapter is to set the context for adaptation planning by providing an overview of the value of our nation's coastal resources and how they may be affected by climate change. As a coastal manager, you already appreciate the importance and value (market as well as nonmarket) of your coasts. Understanding these values and how they may be affected by climate change will play a significant role in adaptation planning, providing a basis for informed decision making and helping to tell the story and gain stakeholder support. While this chapter looks at our coasts and climate change from a national perspective, it can be adapted to tell your state-specific story.

The Value of Our Coasts

Our coasts are critically important to our nation, supporting a large percentage of its population as well as its economy. In 2007, According to the National Ocean Economics Program (NOEP), the coastal zone was home to an estimated 127 million people, supported 57 million jobs, and contributed $6.7 trillion to the U.S. economy, accounting for 42 percent of the U.S. population and 49 percent of its national economic output (NOEP 2009a).

In its 2009 *State of the U.S. Ocean and Coastal Economies report*, the NOEP provided a snapshot of the

"ocean economy." The ocean economy consists of economic activities that are tied to the ocean or Great Lakes, or that are partially related to the ocean or Great Lakes, and are located in a shore-adjacent zip code. In 2004 (the most recent year for which the information is available), the ocean economy contributed $138 billion to the U.S. economy:

- Tourism and recreation: $70 billion
- Marine transportation: $28 billion
- Offshore minerals: $20 billion
- Ship and boat building: $11 billion
- Living resources: $7 billion
- Marine construction: $3 billion

Measuring the ocean economy is complicated, and data are limited. In order to make data compatible and comparable across all six sectors, some sector data were excluded in the NOEP study. Sector-specific reports from other sources, which use different definitions, methodologies, and parameters, can provide greater detail. For example, NOAA's National Marine Fisheries Service reported that the commercial fishing industry generated over $103 billion in sales and $44 billion in income in 2006. That same year, recreational fishing contributed $82 million in sales (largely in durable equipment) to the U.S. economy and generated $38 billion in value-added impacts (NOAA n.d. Fisheries).

The coasts also provide a number of services that do not have traditional market values but in total may be even more valuable than those that do. The value of coastal wetlands, for example, has been estimated to be between $3 and 13 million per km^2 (Knogge et al. 2004). And, additional research suggests that the storm protection services they provide are worth $23.2 billion annually (Costanza et al. 2008). The total nonmarket value for U.S. coastal and ocean resources is "at minimum tens of billions of dollars per year and likely much more" (NOEP 2009b).

According to the Millennium Ecosystem Assessment, "coastal ecosystems—coastal lands, areas where fresh water and salt water mix, and nearshore marine areas—are among the most productive yet highly threatened systems in the world. These ecosystems produce disproportionately more services relating to human well-being than most other systems" (Hassan et al. 2005). Some of the nonmarket services provided by coastal ecosystems (e.g., estuaries, marshes, coral reefs, mangroves, lagoons, salt ponds, seagrass) include flood and storm protection, erosion control, water quality maintenance, biological productivity, fish and wildlife habitat, recreational opportunities, and aesthetic values.

Impacts and Consequences of Climate Change on the Coast

Our nation's coasts are particularly susceptible to climate change. They are already subject to an array of social and environmental stressors that have resulted in habitat loss and conversion, habitat degradation, and overexploitation. Key stressors include coastal development, storms and other natural processes (e.g., erosion and subsidence), deforestation, pollution, invasive species, unsustainable and destructive fishing practices, recreational activities, energy development, etc. Climate change, defined by the Intergovernmental Panel on Climate Change (IPCC) as "any change in climate over time, whether due to natural variability or as result of human activity," will exacerbate these stressors (IPCC 2007a). Implications are expected to be far reaching for coastal communities, economies, and ecosystems (Karl et al. 2009).

Since 1900, the global average surface temperature of the Earth has risen by about 1.5°F (Karl et al. 2009). And, the 2000s decade (2000-09) was the warmest on record, with 9 of its 10 years (2001-09) ranking among the top 10 warmest years on record (NOAA 2010a). Significantly, it was the global warming that occurred over the last 50 years that accounts for the majority of the increase, which is largely attributable to human activities (i.e., greenhouse gas emissions). In the United States, the average temperature has risen more than 2°F over the last 50 years (Karl et al. 2009).

The cumulative and secondary impacts from development in the coastal zone can threaten coastal resources and exacerbate impacts of climate change.

The IPCC has projected a likely rise in the average global surface temperature of an additional 2 to 11.5°F by 2100 (relative to the 1980-99 time period) based on an assumption of no changes in climate policy. In the United States, the average temperature is projected to increase by approximately 7 to 11°F under a higher emissions scenario and by approximately 4 to 6.5°F under a lower emissions scenario (Karl et al. 2009).

In addition to increases in air temperature, there is evidence that other associated changes are taking place. Some of these climate change "phenomena," which are discussed throughout this guide, include rising sea levels, declining Great Lake levels, increasing storm intensity/frequency (tropical and cold-season storms), changing precipitation patterns, increasing water temperature, and ocean acidification. The effects of these changes are being observed across all sectors in the United States and around the world (Karl et al. 2009).

Our understanding of the effects of climate change on the United States is still evolving. According to the U.S. Global Change Research Program, future changes in some phenomena are more difficult to project than others (e.g., changes in precipitation are more difficult to project than changes in temperature) (Karl et al. 2009). A lot remains uncertain and depends on the success of our efforts to mitigate climate change. Nevertheless, despite the uncertainties, current climate change projections are considered reliable enough to warrant and support adaptation planning (Karl et al. 2009).

The Summary of Climate Change Phenomena: Observed and Projected Changes table summarizes how climate change may affect—and in some cases is already affecting—coastal communities. It presents a general overview of the issues with national-level observations and projections and offers a starting point for discussions. Specifically, the table calls out the key climate change phenomena and their associated impacts and consequences that may fall, albeit possibly in a very limited way, within the purview of state coastal management programs and that are addressed further in this guide. (The public health discussion is largely limited to consequences of extreme weather events/conditions. Agriculture, forestry, and emergency preparedness and response are not included.) The table also includes observed and projected changes, which are for the United States and taken from the *Global Climate Change Impacts in the United States* (Karl et al. 2009) report unless specified otherwise. Brief descriptions of the potential impacts and consequences of the phenomena follow the table. It should be noted that while these descriptions are written in the future tense, some of the impacts and consequences are already being felt.

It is vitally important to recognize that these phenomena and their resultant impacts and consequences will not occur in isolation. They will interact with the stressors discussed above as well as other social and economic stressors. The possibility of cumulative and secondary impacts should be considered, as this combination of phenomena and stressors will likely result in more severe impacts than those caused by individual factors. And, for some systems, these impacts may be irreversible.

The general nature of the guide does not allow for a more thorough examination of how these phenomena may vary by region, although strong regional variations in most of these phenomena are expected. For more information about some of these regional variations, see Appendix C.

Summary of Climate Change Phenomena: Observed and Projected Changes

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Increasing Air Temperature *Note: With the exception of ocean acidification, all phenomena listed here are driven by increasing air temperature.*	• Heat waves • Drought • Wildfire • Invasive species • Shift in species range • Changes in timing of ecological events • Loss of sea ice • Reduction in snowpack	• Illnesses, injuries, and loss of life • Loss/degradation/alteration/ migration of coastal ecosystems and the goods and services they provide • Decline in quantity and quality of freshwater • Destruction and damage to coastal property and infrastructure • Economic losses	• The average temperature has risen more than 2°F over the past 50 years, generally resulting in longer warm seasons and shorter, less intense cold seasons • The number of days with high temperatures above 90°F is projected to increase throughout the country	• By 2100, the average temperature is projected to increase by approximately 7 to 11°F under a higher emissions scenario and by approximately 4 to 6.5°F under a lower emissions scenario
Rising Sea Levels	• Coastal inundation • Erosion • Storm surge flooding • Rising water tables • Saltwater intrusion • Nonpoint source pollution • Introduction of toxics	• Illnesses, injuries, and loss of life • Destruction and damage to coastal property and infrastructure • Loss/degradation/alteration/ migration of coastal ecosystems and the goods and services they provide • Loss of beach access • Decline in quantity and quality of freshwater • Loss of cultural resources • Population displacement/ migration • Economic losses	• During the last 50 years, sea level has risen up to 8 inches or more along some areas of the U.S. coast and has fallen in others • Global average sea level rose 1.7 mm (~.067 in)/year during the 20th century, 1.8 mm (~.071 in)/year between 1961 and 2003, and 3.1 mm (~.122 in)/year between 1993 and 2003 (it is unknown if the increase in the latter reflects natural variability or a long-term trend) (IPCC 2007b)	• Recent estimates substantially exceed IPCC estimates, suggesting global sea level rise between 3 and 4 feet by 2100 • Global average sea level is projected to rise from 8 to 24 inches by the end of the century (this excludes contributions to sea level rise due to changes in ice sheet dynamics)

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Declining Great Lake Levels	• Water loss • Bluff erosion • Hypoxia • Harmful algal blooms • Invasive species	• Decline in quantity and quality of freshwater • Water dependent coastal infrastructure impairment • Navigational challenges • Loss/degradation/alteration of coastal ecosystems and the goods and services they provide • Destruction and damage to coastal property and infrastructure • Reduced access to waterfront facilities • Public trust conflicts • Economic losses	• Since 1961, with the exception of Lake Superior, Great Lakes water levels have dropped almost .25 feet, on average • Since the early 1970s, there has been a decrease in extent of Great Lakes ice coverage, which leads to more evaporation	• Under lower emissions scenarios, Great Lakes water levels will fall no more than 1 foot by 2100, but under high emissions scenarios, they will fall between 1 and 2 feet
Increasing Storm Intensity/Frequency*	• Flooding • High wind • High waves • Erosion • Salinity shifts • Nonpoint source pollution • Introduction of toxics	• Injuries and loss of life • Destruction and damage to coastal property and infrastructure • Loss/degradation/alteration of coastal and marine ecosystems and the goods and services they provide • Decline in quality of freshwater • Economic losses	• The power and frequency of Atlantic hurricanes has increased in recent decades, but there has been little increase in the number of hurricanes that make landfall • Since the 1980s, the number of tropical storms in the eastern Pacific has decreased, but the strongest storms have become stronger • Cold-season storm tracks have shifted northward and the strongest storms have become stronger	• The intensity of Atlantic hurricanes is likely to increase, but more slowly than observed in recent decades • The strongest hurricanes are likely to get stronger in both the eastern Pacific and the Atlantic oceans • Cold-season storms will continue to track northward; *strong* cold season storms are likely to become stronger and more frequent

* This includes both tropical and cold-season storms (extratropical).

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Changing Precipitation Patterns	Increasing Precipitation			
	• Flooding • Erosion • Nonpoint source pollution • Introduction of toxics • Salinity shifts	• Illnesses, injuries, and loss of life • Destruction and damage to coastal property and infrastructure • Loss/degradation/alteration of coastal ecosystems and the goods and services they provide • Decline in quality of freshwater • Economic losses	• Total average precipitation increased by about 7% during the 20th century (5% in the last 50 years) • The amount of rain in the heaviest 1% of downpours increased about 20% in the last century • Regional patterns indicate that precipitation increased the most in the wettest areas	• The widespread trend toward more heavy downpours is expected to continue; precipitation will be less frequent but more intense • Regional patterns will continue
	Decreasing Precipitation			
	• Drought • Wildfire • Nonpoint source pollution • Salinity shifts	• Illnesses, injuries, and loss of life • Loss/degradation/alteration/ migration of coastal ecosystems and the goods and services they provide • Decline in quantity and quality of freshwater • Destruction and damage to coastal property and infrastructure • Economic losses	• Droughts have become more frequent and intense during the past 40 to 50 years	• Droughts are likely to become more frequent and severe in some regions

Climate Change Phenomenon	Associated Potential Impacts	Associated Potential Consequences	Observed Changes	Projected Changes* (to mid to late 21st century)
Increasing Water Temperature	• Coral bleaching • Hypoxia • Pathogens and disease • Harmful algal blooms • Invasive species • Shift in species range • Changes in timing of ecological events	• Loss/degradation/ alteration/migration of coastal and marine ecosystems and the goods and services they provide • Decreased water quality • Economic losses	• Since the 1970s, coastal water temperatures have risen by about 2°F in several regions	• Increases in water temperature will accompany increases in air temperature
Ocean Acidification	• Dissolution of calcium carbonate in marine shell-forming organisms	• Loss/degradation/ alteration/migration of coastal and marine ecosystems and the goods and services they provide • Economic losses	• Globally, the pH of seawater has decreased significantly (0.1 units) since 1750, making it more acidic (IPCC 2007c)	• Globally, the pH of seawater will drop much more dramatically (0.14-0.35 units) by 2100 if carbon dioxide concentrations continue to increase (IPCC 2007c)

Increasing Air Temperature

With the exception of ocean acidification, all of the phenomena discussed in this chapter can be attributed to increasing air temperature. Increasing temperatures will also mean more droughts, wildfires, and heat waves, which are expected to threaten human and other populations and strain infrastructure and its capacity to provide the services we have grown accustomed to. Within ecosystems, native species may leave or die-off if they cannot handle the higher temperatures. Invasive species may replace them or take advantage of their weakness and force them out. And, changes in the timing of ecological events (i.e., lifecycle stages) as a result of warmer air may cause disruptions in the food web, further stressing ecosystems and local economies that depend on them.

Increasing temperatures will also cause more precipitation to fall as rain than snow and shift the timing of the melting of snowpack to earlier in the year. In areas where snowpack runoff is a critical source of water, reduced snowpack and earlier snow melt (which means reduced stream flows later in the year) will pose significant challenges.

In the Arctic, warming will reduce sea ice and cause permafrost to thaw. As sea ice melts, the coast will be more prone to damage and destruction. Thawing permafrost will damage buildings, roads, airstrips, pipelines, and other infrastructure. It will also have impacts on drainage, ground water, river runoffs, and ecosystems and will release carbon sequestered in the frozen soil (NOAA n.d. Arctic).

Rising Sea Levels

Global sea level rise is largely attributable to the thermal expansion of the oceans and the melting of glaciers and polar ice sheets resulting from a warming atmosphere (Karl et al. 2009). Relative sea level, which is the sea level measured against land elevation at a given particular location, is influenced by these as well as localized processes such as plate tectonics (e.g., earthquakes), postglacial rebound, and land subsidence. Atmospheric and oceanic

Storm surge on a Louisiana highway shows the potential effects of rising sea levels.

circulation, which will be altered by climate change, will also influence relative sea levels. As a result of the variability of these processes, relative sea level rise, and its impacts and consequences, will vary by location.

In general, rising sea levels will inundate coastal wetlands, barrier islands, and other low-lying lands and intensify erosion and flooding as new areas are exposed to storm surges, waves, currents, and tides. Inundation, erosion, and flooding will threaten human health, coastal property, and infrastructure as well as coastal ecosystems, especially those that cannot migrate inland or are sediment-starved. Any changes to these ecosystems will, in turn, affect the biological, ecological, and physical services they provide. Human and ecosystem populations will also suffer from a loss in quantity and quality of freshwater as saltwater inundates estuaries, marshes, rivers, and aquifers; water tables rise; and inundated lands and infrastructure introduce more nonpoint source pollutants and toxic substances into the rising seas.

Ultimately, rising sea levels mean land and ecosystem loss. Some degree of economic loss is inevitable. In 1991, the Federal Emergency Management Agency (FEMA) estimated that a one-foot rise in sea level by 2100 would increase annual flood damage to insured property by 36-58 percent and a three-foot rise would increase annual damage by 102-200 percent. Recent estimates indicate that a sea level rise of nearly 20

inches by 2100 would cause $23-170 billion in damage to U.S. coastal property (Ruth et al. 2007). In addition, as land and ecosystems are inundated, associated cultural resources may also be lost, especially where populations, both human and otherwise, are forced to relocate.

Declining Great Lake Levels

In the Great Lakes, water levels may drop as a result of a warming climate. Average lake levels depend on a balance between precipitation and runoff and evaporation and outflow. While precipitation is expected to increase in the winter and spring, with more precipitation falling as rain and less as snow, evaporation is due to increase because of higher temperatures and reduced lake ice and is expected to outpace precipitation (Karl et al. 2009).

Declining lake levels will impact water supplies and utilities, hydroelectric and nuclear power plants, commercial navigation, property owners, marine recreation and tourism, marinas, beaches, and more. Navigation will be impeded, water quantity and quality will be diminished, and lakefront property and water dependent infrastructure will be farther away from the water's edge, reducing accessibility and raising issues of public trust. In general, erosion will be less of a problem, but bluff failure may result from decreased hydrostatic pressure.

Water level decreases will also have broad impacts on lake ecosystems. Coastal wetlands fronted by barrier beaches will be cut off from the lakes, and as water levels drop, wetlands may dry up. In addition, lower water levels may result in an increase in the concentration of nutrients and pollutants and a decrease in dissolved oxygen concentrations, which in conjunction with associated warmer air and water temperatures may exacerbate harmful algal blooms and hypoxia. Changing ecological conditions may facilitate invasion by new species or encourage expansion of previously established invaders.

As Great Lakes water levels decline, ports and marinas will be increasingly ill-equipped to meet the needs of shipping and fishing vessels.

Storm Intensity and Frequency

As coastal storms become more intense, and these stronger storms become more frequent in the case of cold-season storms (e.g., nor'easters), damage to the built and natural environments from flooding, erosion, and high winds will become more commonplace. Consequences of these storms may include injuries and loss of life as well as damage to and destruction of coastal property and infrastructure.

In recent decades, coastal storms have accounted for the majority of U.S. annual disaster losses (Heinz Center 1999; NOAA 2010a). Thus, in coastal areas, where real estate values may be very high, the potential economic impacts of natural disasters, which will be exacerbated by climate change, could be significant. The 2004 Atlantic hurricane season caused damage and incurred associated costs estimated at more than $50 billion. One year later, Hurricane Katrina alone cost approximately $134 billion, becoming the costliest U.S. storm on record (NOAA 2010a).

In addition to the physical damage caused by flooding, erosion, and high winds, shifts in salinity (excess freshwater as well as saltwater) and the introduction of pollutants and toxic substances from stormwater runoff will likely stress habitats. Some will bounce back, but others, under the weight of cumulative impacts (e.g., multiple storms, rising sea levels, preexisting stressors, etc.), will be degraded or lost, which will lead to diminished or loss of productivity, temporarily or permanently. And, damage to and loss of natural protective features such as coral reefs, barrier islands, beaches, dunes, and wetlands will leave coastal communities more vulnerable to future storms.

Changing Precipitation Patterns

The overall effect of changing precipitation patterns, which will have strong regional variations, is that there will be too much or too little water, either seasonally or throughout the year (Karl et al. 2009). Some regions may experience the impacts and consequences of both extremes.

In either case, water quality will be negatively impacted. Increased runoff associated with heavy rains will further pollute coastal waters with nitrogen and phosphorous, sediments, and other, sometimes toxic, contaminants and negatively impact dissolved oxygen levels. Conversely, diminished water supplies will be threatened by increased concentrations of pollutants. Shifts in the salinity gradient as a result of too much freshwater, or not enough, will also stress coastal ecosystems.

Heavy downpours will likely cause flooding and erosion that could damage or destroy property and infrastructure and harm ecosystems along the coasts and throughout watersheds. Existing water/flood management systems and structures (e.g., drainage systems, combined sewer overflow systems, dams) were likely not planned and designed with climate change in mind and will likely be taxed by, and possibly unable to handle, increased quantities of water.

While these heavy downpours are likely to be more frequent, longer periods of time between rainfalls are also expected (i.e., precipitation will become less frequent but more intense) (Karl et al. 2009). This lack of regular precipitation, combined with higher air temperatures, may lead to drought. Similarly, increased runoff could reduce infiltration, limiting the amount of water available for groundwater recharge and also resulting in drought. Drought conditions would limit water availability for all sectors and stress human and ecosystem health and could also result in increased incidence of wildfire and losses to both the built and natural environments.

Increasing Water Temperature

Increasing air temperatures are leading to warmer conditions in both marine and fresh water systems

Harmful algal blooms, which can have toxic or harmful effects on people, fish, shellfish, marine mammals, and birds, will be exacerbated as water temperatures rise.

(Karl et al. 2009). In addition to their role in sea level rise, increases in water temperature, and associated changes to coastal currents that moderate ocean temperatures and increased stratification, will impact the quality of coastal and marine waters and their living resources, affecting species distribution and biological productivity and connectivity.

Warming seas will likely be accompanied by more incidences of coral bleaching, hypoxia, pathogens and disease, harmful algal blooms, and invasive species. Ecosystems, habitats, and species will be weakened or lost (although some may just relocate). Consequences may be severe where fisheries, ecosystems, and coastal communities depend on a vulnerable resource for sustenance, livelihoods, tourism, etc.

Ocean Acidification

In addition to global warming, the buildup of carbon dioxide in the atmosphere has also been linked to changes in the chemistry of the oceans, changes that are "essentially irreversible over a time scale of centuries" (Karl et al. 2009). Ocean acidification is the result of an increase in carbon dioxide absorption by ocean water and the corresponding decrease in pH. As seawater becomes less alkaline (more acidic), less calcium carbonate is available for corals, shellfish, and other sea life to build their shells and skeletons. Threats to these ecosystems and species will be wide-ranging across the marine food web and associated coastal communities.

Key Resources

- Climate Change—Science, EPA. http://epa.gov/climatechange/science/
- Climate Change 2007: The Physical Science Basis, IPCC. www.ipcc.ch/
- Climate Change 2007: Synthesis Report, IPCC. www.ipcc.ch/
- Climate Change: Fitting the Pieces Together (online training), University Corporation for Atmospheric Research, Cooperative Program for Operational Meteorology, Education and Training. www.meted.ucar.edu/broadcastmet/climate/
- Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, National Assessment Synthesis Team, U.S. Global Change Research Program (2000, includes regional and sectoral assessments). www.globalchange.gov/publications/reports/scientific-assessments/first-national-assessment
- Climate Change Indicators in the United States, EPA Climate Change Division. www.epa.gov/climatechange/indicators.html
- Climate Literacy—The Essential Principles of Climate Science: A Guide for Communities and Individuals, U.S. Climate Change Science Program. www.globalchange.gov/resources/educators/climate-literacy
- Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Fisheries Economics and Sociocultural Status and Trends Series, NOAA National Marine Fisheries Service. www.st.nmfs.noaa.gov/st5/publication/
- Global Climate Change Impacts in the United States, U.S. Global Change Research Program. www.globalchange.gov/publications/reports/scientific-assessments/us-impacts
- National Ocean Economics Program Web Site (includes state summaries). www.oceaneconomics.org/
- NOAA Climate Service. www.climate.gov/
- NOAA Great Lakes Environmental Research Laboratory. www.glerl.noaa.gov/
- PMEL Ocean Acidification Home Page, NOAA Pacific Marine Environmental Laboratory. www.pmel.noaa.gov/co2/OA/
- Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- State of the U.S. Ocean and Coastal Economies—2009, National Ocean Economics Program. www.oceaneconomics.org/nationalreport/
- Thresholds of Climate Change in Ecosystems, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- U.S. Global Change Research Program Web Site. www.globalchange.gov/

CHAPTER 3
PLANNING PROCESS

The first two chapters of this guide explain why coastal managers need to begin planning for the effects of climate change in the coastal zone. This chapter discusses the framework for the planning process, focusing primarily on where to begin.

The framework presented here follows the steps of a traditional planning process. However, adaptation planning is neither purely linear nor cyclical in nature. While some tasks will need to be completed before others, it is important to build flexibility into the

Planning: The act or process of **making** or **carrying out** plans; specifically: the establishment of goals, policies, and procedures for a social or economic unit (Merriam-Webster).

Planning works to improve the welfare of people and their communities by creating more convenient, equitable, healthful, efficient, and attractive places for **present and future** generations (American Planning Association).

Planning is a partnership- and consensus-building exercise that requires a variety of skills and expertise.

process that will allow for accommodation of new data, perceptions, realizations, and vulnerabilities. The primary tasks associated with climate change adaptation planning as suggested in this guide are as follows:

- **Establish the Planning Process**
  - Step 1.1: Scope out Level of Effort and Responsibility
  - Step 1.2: Assess Resource Needs and Availability
  - Step 1.3: Assemble Planning Team and Establish Responsibilities
  - Step 1.4: Educate, Engage, and Involve Stakeholders
- **Assess Vulnerability**
  - Step 2.1: Identify Climate Change Phenomena
  - Step 2.2: Identify Climate Change Impacts and Consequences
  - Step 2.3: Assess Physical Characteristics and Exposure
  - Step 2.4: Consider Adaptive Capacities
  - Step 2.5: Develop Scenarios and Simulate Change
  - Step 2.6: Summarize Vulnerability and Identify Focus Areas
- **Create an Adaptation Strategy**
  - Step 3.1: Set Goals
  - Step 3.2: Identify Actions
  - Step 3.3: Evaluate, Select, and Prioritize Actions
  - Step 3.4: Write Action Plans
- **Design a Plan Implementation and Maintenance Process**
  - Step 4.1: Adopt the Plan
  - Step 4.2: Implement the Plan
  - Step 4.3: Integrate Plan Findings into Other State Planning Efforts and Programs
  - Step 4.4: Track, Evaluate, and Communicate Plan Progress
  - Step 4.5: Update the Plan

The rest of this chapter elaborates on establishing the planning process. The other steps are addressed in the chapters that follow.

Step 1.1: Scope Out Level of Effort and Responsibility

Before initiating planning activities, you will need to decide on the scope of your planning efforts. While this guide is written for coastal managers at the state level and focuses largely on activities for which they have responsibilities, your state may want to address adaptation at a larger scale. In that case, you may be the lead, or you may be one of many planning team members.

The process described in this guide can be scaled up to incorporate impacts, consequences, and sectors not discussed here (e.g., those not under the jurisdiction of the coastal management program) or can be scaled down to focus on a single impact, consequence, or region. Conducted on its own, a coastal adaptation plan could easily be integrated into larger planning efforts, which may or may not yet have begun.

Consider whether a stand-alone adaptation plan is really necessary. What other ongoing planning

Hazard mitigation is defined as "sustained action taken to reduce or eliminate long-term risk to people and their property from hazards." (FEMA n.d.). A hazard mitigation plan is a long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage. The Disaster Mitigation Act of 2000, an amendment to the Robert T. Stafford Disaster Relief and Emergency Assistance Act, requires states and local governments to develop hazard mitigation plans as a condition for receiving certain types of nonemergency disaster assistance, including funding for hazard mitigation projects. www.fema.gov/plan/mitplanning/

efforts is your state engaged in? Some states are including climate change adaptation planning along with climate change mitigation planning or in their hazard mitigation plans, which may give short shrift to ecological systems and needs. Others are including it in wildlife action plans, which, in turn, will likely exclude impacts on the built environment. Other plans that may relate to climate change adaptation include coastal management, watershed management, emergency operations, transportation, economic development, and growth plans. These plans are also excellent resources for the adaptation plan's vulnerability assessment and adaptation strategy.

Know what your state is thinking about climate change adaptation planning, both short and long term, and where your program best fits into the process. Also, look into how adaptation planning is being handled at the local level in your state and consider how to incorporate existing efforts into your plan and/or how your plan can be used to guide and support local planning.

A new state law or executive order authorizing the climate change adaptation planning process would help ensure it has adequate resources, support, and legitimacy. This may require educating elected officials,

Learning from others…Connecticut Integrates Adaptation into Hazards Mitigation
Connecticut's Department of Environmental Protection included climate change in the 2007-2010 update to the state's "Natural Hazards Mitigation Plan." The issue of climate change is addressed throughout, and a special section is dedicated to the potential impacts from climate change and sea level rise. One of the plan's three goals is to "Increase research and planning activities for natural hazards mitigation on a state and local level particularly with regard to climate change and associated adaptation strategies." Related activities include enhanced climate change research and adaptation planning. www.ct.gov/dep/cwp/view.asp?a=2720&q=325652&depNav_GID=1654

Learning from others…Washington Executive Order and Law Call for Action on Climate Change
In Washington State, the governor signed an executive order (95-05) on climate change that includes a charge to state agencies to protect the state's vulnerable coastal areas. Specifically, it tasks the director of the Department of Ecology, in collaboration with the Washington State Association of Counties and the Association of Washington Cities, with evaluating the potential impacts of sea level rise on the state's shoreline and developing recommendations for addressing them. A complementary state law (SB 5560) directs the departments of ecology; agriculture; community, trade, and economic development; fish and wildlife; natural resources; and transportation (in consultation with other stakeholders as specified) to develop an integrated climate change response strategy. It calls for the Department of Ecology to compile a strategy, based on a range of scenarios, summarizing climate change impacts to Washington, assessing Washington's vulnerability to those impacts, prioritizing solutions, and identifying funding and technical resources to support implementation. The law also encourages state agencies to consider the strategy when planning and designing new policies and programs. www.ecy.wa.gov/climatechange/laws.htm

which should be done early in the planning process. See the discussion beginning on page 23 about educating, engaging, and involving stakeholders.

Step 1.2: Assess Resource Needs and Availability

After reading through this guide, you will have a good understanding of what it will take to develop and implement an adaptation plan. Once you know what the scope of your plan will be, you can begin to assess resource availability. Planning efforts will require three primary types of resources:

- **Human resources**—This category includes anyone who will help with plan development and implementation. This is a planning team effort, as is described in the next step, and responsibilities should be distributed across participants and other stakeholders. By engaging multiple agencies, sectors, and levels of government, the plan will become less of a burden on any one entity and will benefit from access to more information and points of view, as well as financial and technical resources and greater acceptance and buy-in to the idea of climate change adaptation and the climate change adaptation plan.
- **Technical resources**—Climate change adaptation planning and implementation will require a lot of technical data and know-how. Much of the expertise can be secured when building the planning team. You will need people who understand and track the science as well as people who can take the science and state-specific data and help decipher what it may mean for your coastal areas. This will likely require information technology ranging from basic geographic information systems (GIS) to sophisticated modeling programs. Understand the limitations of your state's computing capacity before acquiring the latter. If you do not have access to the technical expertise or the necessary computing capacity, you may want to consider contracting with a university, consulting firm, or other technical partner. Finally, you will likely need to involve social scientists and technical experts (e.g., engineers, biologists, geologists) when you identify and implement adaptation actions.
- **Financial resources**—You will need financial resources to support both human and technical resources as well as general planning activities (e.g., public meeting notices, meeting space, office supplies, etc.). A number of federal agencies provide grants for planning and implementation activities, most of which, at this point in time, indirectly support climate change adaptation. A list of possible federal funding sources can be found in Appendix A. Other sources of funding may include private foundations and nonprofit organizations.

Step 1.3: Assemble Planning Team and Establish Responsibilities

There are numerous agencies and organizations with vested interest in climate change adaptation, and others who may have technical and human resources to support it. Coordination and collaboration with these entities is vital to the success of the adaptation plan. You may prefer to conduct your vulnerability assessment before you build the planning team, but having the team in place first means more resources, and likely better information, are available for the assessment.

Note: The Coastal Zone Enhancement Program conducted under Section 309 of the Coastal Zone

Planning is a time and resource consuming endeavor. Think about where you may be able to get graduate students to help, particularly with collecting data for the vulnerability assessment. Or, consider hiring a NOAA Coastal Services Center Fellow. The Coastal Management Fellowship program matches postgraduate students with state coastal management programs for two years to work on projects proposed by the state, which may include climate change adaptation. www.csc.noaa.gov/fellowships/

Management Act provides a mechanism to convene a climate change adaptation planning team backed by federal funding to conduct operations.

Who you invite to participate on the planning team, and who you choose to involve in more of a supporting role, will depend on state-specific needs and circumstances. Nevertheless, involvement of a diverse set of stakeholders will be critical to the process. More information about how to involve stakeholders, including the general public, who may not be directly involved as part of the planning team, is presented in the next section. Most of the state and federal partners on the planning team will likely already be aware of the need to adapt to climate change impacts. If not, be sure to educate them as you would other stakeholders as discussed in the next step.

Planning is a partnership- and consensus-building exercise that requires a variety of skills and expertise. It will allow coordination and integration of activities across agencies, organizations, and jurisdictions, capitalizing on human, technical, and financial resources and avoiding unnecessary redundancies. It should be an inclusive process that allows diverse concerns to be addressed, considered, and incorporated. And, it will also require creativity and compromise.

Your climate change adaptation planning team will be responsible for overseeing, coordinating, and advocating climate change adaptation from planning through implementation and beyond. Ideally, members of the planning team will be engaged in climate change issues or be willing to become so, be able to provide needed input to the process, and have the support of their employers.

It may be necessary to have a formal invitation process, which could include asking agency and department heads (or other figures of authority) to designate appropriate representatives to serve on the planning team. This can help ensure the representative has some level of authority to act on behalf of the organization. Such a request could be sent as a letter explaining the need for the plan, the planning process, and the role of planning team members, which could include:

- Participating in planning meetings
- Providing input and information for the vulnerability assessment
- Participating in goal setting
- Identifying adaptation actions for the plan
- Reviewing and commenting on plan drafts
- Assisting with outreach activities
- Monitoring implementation of activities specific to their organizations
- Contributing to plan review and updating activities
- Working to mainstream climate change adaptation into other agency activities

Your climate change adaptation planning team will cross levels of government and sectors. Inclusion of a wide variety of partners will result in a coast better prepared for the impacts of climate change. As you structure the planning team, some of the questions for consideration include:

- What entities engage in activities that might impact or stress coastal systems and activities managed by the coastal management program?
- What other agencies and organizations have investments or management responsibilities in the coastal zone?

Coordination and collaboration with agencies and organizations with vested interest in climate change adaptation, and others who may have technical and human resources to support it, is vital to successful adaptation planning.

Learning from others…Maryland Climate Action Plan Benefits from Diversity of Interests and Expertise
In August 2008, the Maryland Commission on Climate Change released the state's Climate Action Plan. Formed in 2007 by executive order, the commission, made up of 16 state agency heads and six members of the general assembly, was charged with developing a plan addressing both climate change mitigation and adaptation. The commission was supported by three working groups—Scientific and Technical, Greenhouse Gas and Carbon Mitigation, and Adaptation and Response—which were supported by technical work groups. Chaired by the secretary of the Department of Natural Resources, the Adaptation and Response Working Group was supported by four technical work groups: Existing Built Environment and Infrastructure; Human Health, Safety and Welfare; Future Built Environment and Infrastructure; and Resources and Resource-Based Industries. Together, the commission and the groups that supported it represented diverse stakeholder interests and lent broad perspective and expertise to the project. www.mde.state.md.us/Air/climatechange/

- ☐ Who is already, or planning to be, engaged in planning for climate change adaptation, directly or indirectly?
- ☐ Who is involved in climate change mitigation?
- ☐ What kind of experience and expertise is needed on the planning team?
- ☐ Who might be able to provide additional human or technical resources?

Following is a list of entities from which potential climate change adaptation planning team members may be recruited. Based on the number of people you plan to include on the team, as well as the issues and sectors you choose to address, you may decide to create workgroups to handle individual tasks and issues. Some of the entities listed below may serve the planning team better in a supporting role (e.g., providing resources, expertise, and experience) rather than in a decision-making role as a team member.

State Agencies/Departments

Environment and Agriculture
- ☐ Agriculture
- ☐ Coastal Management
- ☐ Environmental Protection
- ☐ Fish and Wildlife
- ☐ Forestry
- ☐ Geological Survey
- ☐ Marine Resources
- ☐ Natural Resources
- ☐ Parks and Recreation
- ☐ State Climatologist
- ☐ State Lands and Public Trust Area Trustee

Planning and Public Safety
- ☐ Building Code
- ☐ Emergency Management
- ☐ Fire
- ☐ Flood Control
- ☐ Hazard Mitigation
- ☐ Homeland Security
- ☐ Local Affairs
- ☐ National Guard
- ☐ Planning
- ☐ Public Health

Housing and Infrastructure
- ☐ Energy
- ☐ Engineering
- ☐ Housing
- ☐ Public Works
- ☐ Stormwater Management
- ☐ Transportation
- ☐ Utilities
- ☐ Water Resources

Economic Development
- ☐ Commerce
- ☐ Economic Development
- ☐ Insurance

Other
- ☐ Education
- ☐ Historic Preservation
- ☐ Tourism

Federal Agencies/Departments

- ☐ U.S. Department of Commerce
  - ○ Economic Development Administration
  - ○ National Oceanic and Atmospheric Administration
    - • National Environmental Satellite, Data, and Information Service
    - • National Marine Fisheries Service
    - • National Ocean Service
    - • National Weather Service
    - • Office of Oceanic and Atmospheric Research
- ☐ U.S. Department of Agriculture
  - ○ Animal and Plant Health Inspection Service
  - ○ National Institute of Food and Agriculture
  - ○ National Resources Conservation Service
  - ○ U.S. Forest Service
- ☐ U.S. Department of Defense
  - ○ U.S. Army
    - • U.S. Army Corps of Engineers
  - ○ U.S. Air Force
  - ○ U.S. Marine Corps
  - ○ U.S. Navy
- ☐ U.S. Department of Energy
  - ○ Office of Electricity Delivery and Energy Reliability
- ☐ U.S. Department of Homeland Security
  - ○ Federal Emergency Management Agency
  - ○ U.S. Coast Guard
- ☐ U.S. Department of the Interior
  - ○ Bureau of Indian Affairs
  - ○ Bureau of Water Reclamation
  - ○ National Park Service
  - ○ U.S. Bureau of Land Management
  - ○ U.S. Fish and Wildlife Service
  - ○ U.S. Geological Survey
- ☐ U.S. Department of Housing and Urban Development
  - ○ Community Planning and Development
  - ○ Housing
  - ○ Public and Indian Housing
- ☐ U.S. Department of Transportation
  - ○ Federal Highway Administration
  - ○ Pipeline and Hazardous Materials Safety Administration
- ☐ U.S. Environmental Protection Agency
  - ○ Office of Air and Radiation
  - ○ Office of Policy, Economics, and Innovation
  - ○ Office of Water

Other

- ☐ Elected officials
- ☐ Universities/research institutions
- ☐ Regional governments/organizations/programs
- ☐ Local governments, coastal management programs in particular
- ☐ Regional planning organizations
- ☐ Native American tribal organizations
- ☐ Nonprofit organizations and associations
- ☐ Civic groups
- ☐ Neighboring states
- ☐ Infrastructure managers
- ☐ Industries
- ☐ Contractors/engineers
- ☐ Developers
- ☐ General public

The planning team, as well as the entire planning process, should be flexible. As the planning progresses, additional team members may be needed as new issues and questions arise.

Once planning team members are identified, consider holding a kick-off meeting(s) to:

- ☐ Designate a planning team leader/leadership team
- ☐ Identify a climate science advisor
- ☐ Create a common understanding of climate change
- ☐ Communicate process goals and parameters (e.g., scope and planning timeframe)
- ☐ Create workgroups and designate leaders
- ☐ Establish roles and responsibilities and set expectations
- ☐ Set a schedule

Learning from others…Issue Identification Workshop Launched Planning Process in Delaware
To kickoff the planning process for Delaware's "Statewide Sea Level Rise Adaptation Plan," the Delaware Coastal Program hosted an issue identification workshop that attracted approximately 100 stakeholders, including representatives from all levels of government, nonprofit organizations, academia, and business interests. The goals of the workshop were to raise awareness about how sea level rise may impact Delaware and to initiate a dialog about these impacts among stakeholders. Workshop participants identified and described sea level rise issues for the purpose of establishing the plan's priority issues and determining data gaps and strategies for management and adaptation to sea level rise. Results from the workshop also served as the basis for the formation of a coordination committee, technical working groups, and research and monitoring projects. www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx

Step 1.4: Educate, Engage, and Involve Stakeholders

Central to a successful planning effort is a well-crafted plan to educate, engage, and involve stakeholders. Stakeholders include individuals who can effect change, have relevant knowledge or skills, represent the interests of particular groups, and/or will be affected by climate change. They will include the members of the planning team, elected officials (state and local), coastal landowners, the general public, educators, the media, and everyone else identified in the previous step.

These efforts will be ongoing and may be quite challenging. For a more thorough discussion of how to integrate stakeholder participation, a number of useful Key Resources are suggested at the end of this chapter. Additionally, you may find it beneficial to seek out planning partners with expertise in communication and participatory planning.

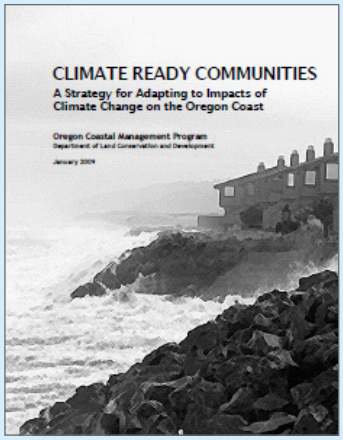
You are encouraged to identify stakeholders and bring them into the process early to get them interested in the idea of climate change adaptation and secure their support. Efforts to adapt to climate change will be more effective the better stakeholders are educated, prepared, and committed to the cause. Think about what vehicles are already being used by planning team members and their organizations to reach out to stakeholders. For more information about outreach and education, see Chapter 5.

Each step in the planning process provides opportunities for stakeholder participation, and there are many methods and techniques that can be used to facilitate this critical part of the planning effort; examples include, but are not limited to, charrettes,

According to the NOAA Coastal Services Center's *Introduction to Stakeholder Participation*, including stakeholders in the planning process can help (NOAA 2007a):

- Produce better outcomes or decisions
- Garner public support for agencies and their decisions
- Bring to light important local knowledge about natural resources
- Increase public understanding of natural resource issues or management decisions
- Reduce or resolve conflicts between stakeholders
- Ensure implementation of new programs or policies
- Increase compliance with new laws and regulations
- Help agencies understand flaws in existing management strategies
- Create new relationships among stakeholders

www.csc.noaa.gov/stakeholder/



Learning from others…Oregon Assists Local Adaptation through Strategy Guidance

"Climate Ready Communities: A Strategy for Adapting to Impacts of Climate Change on the Oregon Coast" from the Oregon Coastal Management Program was created to help coastal decision makers, legislators, and the public prepare for climate change. Specifically, the document makes a case for adaptation, looks at the likely effects of climate change on Oregon coasts, and promotes a strategy that consists of coordinated planning and action by coastal cities and counties, state agencies, businesses, individuals, and nongovernmental organizations, framing the basic steps needed to prepare adaptation plans and to implement them over time. www.oregon.gov/LCD/OCMP/

focus groups, open houses, workshops, and public meetings. There is no "one size fits all" solution for stakeholder participation. You will need to review and choose those methods and techniques that are most likely to result in effective and efficient stakeholder participation in your state (NOAA 2007a).

As the plan takes shape, ask for stakeholder input on the vulnerability assessment (stakeholders may have knowledge about past events and exposure and have opinions about which community assets should be protected), brief them on the vulnerability assessment findings and invite comment, involve them in goal setting and action selection, get their feedback on the final plan, and engage them in implementation and monitoring activities, as appropriate.

Stakeholders play an important role in adaptation planning and should be identified and brought into the process early.

Learning from others…Maryland Uses Role Playing to Engage Stakeholders on Climate Change

When Maryland launched its Coast-Smart Communities Initiative, it did so with an interactive summit jointly created by the Maryland Department of Natural Resources (DNR), the Consensus Building Institute, and the Massachusetts Institute of Technology–U.S. Geological Survey Science Impact Collaborative. Over 170 participants, including state and local elected officials, city planners, emergency managers, and other community stakeholders, gathered to work through a simulated consensus-building exercise. Climate change adaptation measures were debated using a scorecard based on real-world actions that Maryland's coastal communities can take to protect their people, infrastructure, and investments from future risk. The DNR encourages communities in Maryland and across the country to use the simulation to raise awareness about the challenges local governments face from a changing climate and to demonstrate the value of a facilitated negotiation. Materials are available free online. http://maryland.coastsmart.org/

Key Resources

Publications and Web Sites

- Adapting to Coastal Climate Change: A Guidebook for Development Planners, U.S. Agency for International Development. www.crc.uri.edu/index.php?actid=366
- Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decisionmaking, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Building Public Support for Floodplain Management, Association of State Floodplain Managers. www.floods.org/ace-files/documentlibrary/Publications/BPS_Guidebook_2_1_10.pdf
- Climate Literacy—The Essential Principles of Climate Science: A Guide for Communities and Individuals, U.S. Climate Change Science Program. www.globalchange.gov/resources/educators/climate-literacy
- Engaging Stakeholders in the Adaptation Process (from Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures), United Nations Development Programme. www.undp.org/gef/documents/publications/apf-technical-paper02.pdf
- Getting Started: Building Support for [Hazard] Mitigation Planning, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Introduction to Stakeholder Participation, NOAA Coastal Services Center. www.csc.noaa.gov/stakeholder/
- Multi-Hazard Mitigation Planning, FEMA. www.fema.gov/plan/mitplanning/
- Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook/
- Seven Cardinal Rules of Communication, U.S. Environmental Protection Agency. www.epa.gov/CARE/library/7_cardinal_rules.pdf
- Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans & Other Management Plans, Association of Fish and Wildlife Agencies. www.fishwildlife.org/pdfs/ClimateChangeGuidance%20Document_Final_December2009.pdf

Training

- Coastal Training Program, National Estuarine Research Reserve System. www.nerrs.noaa.gov/Training.aspx
- Education and Outreach Training, U.S. Fish and Wildlife Service National Conservation Training Center. http://nctc.fws.gov/
- Introduction to Hazard Mitigation (online), FEMA. http://training.fema.gov/EMIWeb/IS/
- Negotiating for Coastal Resources, NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/negotiating_coastal.html
- Public Issues and Conflict Management, NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/public_issues_conflict.html

CHAPTER 4 VULNERABILITY ASSESSMENT

The vulnerability assessment will lay the foundation for the adaptation strategy. It will help the planning team understand what could happen as climate changes and will help focus attention on the areas, or the specific assets (people, places/buildings/infrastructure, and natural resources) that are most vulnerable as well as the phenomena and associated impacts that could cause the greatest losses. There are numerous definitions for the term "vulnerability," and it is often used interchangeably with, or as a part of, "risk." For the purpose of simplicity, this guide captures the intent of both risk and vulnerability assessments into a vulnerability assessment and defines vulnerability as the potential for loss of or harm/damage to exposed assets largely due to complex interactions among natural processes, land use decisions, and community resilience.[1]

The process described in this chapter for conducting a vulnerability assessment is structured as follows:

Research and Information Collection

- Step 2.1: Identify Climate Change Phenomena
- Step 2.2: Identify Climate Change Impacts and Consequences
- Step 2.3: Assess Physical Characteristics and Exposure
- Step 2.4: Consider Adaptive Capacities

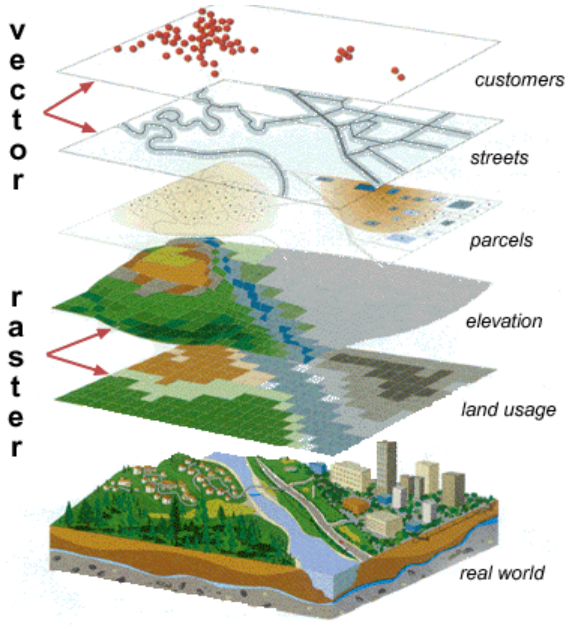
[1] According to the IPCC, "vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007a).

Simulation and Analysis

- ☐ Step 2.5: Develop Scenarios and Simulate Change
- ☐ Step 2.6: Summarize Vulnerability and Identify Focus Areas

Steps 2.1 through 2.4 largely involve collecting existing information to set the context. In Steps 2.5 and 2.6, the planning team will use the information collected to fine tune projections, simulate climate change in the planning area, and integrate exposure data (and adaptive capacity as appropriate) into the simulations in order to summarize vulnerability.

Critical to this process will be data about the phenomena, potential impacts, existing stressors, your state's physical geography, and exposed assets (exposure). As the planning team moves through the steps, and to the extent possible, members should collect relevant maps and datasets in a geographic information system (GIS).[2] GIS will play an important role in this assessment, allowing you to store, manage, analyze, and display spatial data. GIS will allow the planning team to compare the extent of impacts and consequences across scenarios and better understand where vulnerability is greatest, which will support decision making.



GIS uses layers of overlapping spatial information to aid in analysis and decision making.

While the vulnerability assessment task may be assigned to a working group (or groups), contributions to the assessment by planning team members and other key stakeholders (see Chapter 3 for suggestions) who might be able to provide resources and valuable information to better inform the assessment will be fundamental to the process. Key Resources for data, information, and tools to help conduct a vulnerability assessment are included at the end of this chapter.

Note: This is a baseline assessment and should be based on best available data. State and local hazard mitigation plans and natural resource plans are good resources for information about existing stressors that are likely to be exacerbated by climate change as well as exposure information. Other plans may also have useful information. **You should not put off adaptation planning efforts because you do not have all the information you need.** This could increase vulnerability and result in high social, natural, and economic costs. Adaptation planning is an adaptive process, and the planning team will need to revisit and adjust the vulnerability assessment, as well as the goals and actions that are based on its assumptions, as new data and capacities are acquired. Take note of where critical data are missing. As a result of this assessment, the planning team may want to include data acquisition and capacity building as actions in the adaptation strategy.

As a public document, the adaptation plan is an educational tool. For this reason, and for ease of updating, the plan should fully document the vulnerability assessment process. In particular, it should explain how the assessment was conducted and its limitations, describe (and illustrate, where possible) the changes that may take place, and capture the data sources.

[2] Your state may already have some of this information centralized in a geospatial clearinghouse.

Learning from others…California Studies Evaluate Potential Impacts of Climate Change
In 2005, through Executive Order S-03-05, the governor of California required biennial science reports on potential climate change impacts in the state. The report released in 2009 synthesizes the findings of more than 30 technical papers and includes information on the impacts and consequences of climate change on California's public health, infrastructure, and natural resources; identifies economic impacts of climate change on California; provides an overview of climate change research in California; and describes state efforts to adapt to current and future effects of climate change. Based on the outputs from six global climate models run for the recent IPCC Fourth Assessment using the A2 and B1 emissions scenarios, the report and its background papers served as the scientific foundation upon which the state developed its climate adaptation strategy. www.climatechange.ca.gov/publications/cat/

Step 2.1: Identify Climate Change Phenomena

The climate change phenomena expected to impact your state, including those that impacted your state in the past, will form the base of the vulnerability assessment. The table of phenomena, impacts, and consequences in Chapter 2 provides a national overview of the climate change phenomena expected to be of greatest importance in coastal regions.

These phenomena are:

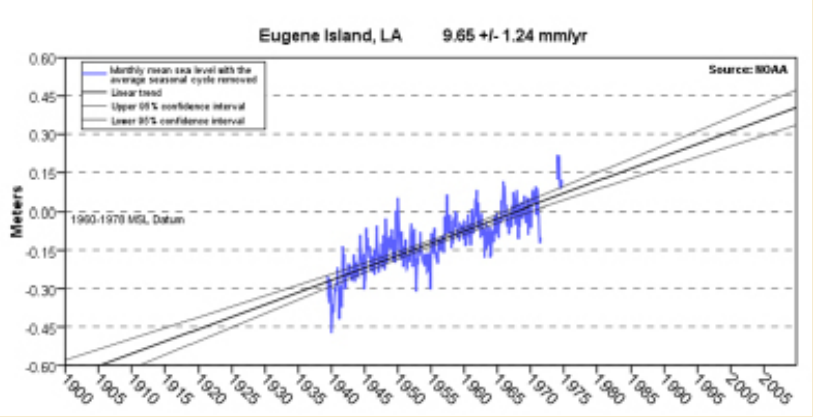
- Rising Sea Levels
- Declining Great Lake Levels
- Increasing Storm Intensity/Frequency
- Changing Precipitation Patterns
- Increasing Air Temperature
- Increasing Water Temperature
- Ocean Acidification

Because of the strong regional variations in most of these phenomena, and based on the scope of the plan, the planning team will need to decide which phenomena to include in its vulnerability assessment. There are a number of resources available to help with this decision and to provide input into other steps of this assessment. The U.S. Global Climate Research Program's *Global Climate Change Impacts in the United States*, which contains information about potential impacts by region and is the authoritative source on climate change science and impacts in the United States, provides a good starting point. Other good resources for existing projections include research institutions (especially Sea Grant institutions), regional climate centers, state climatologists, and NOAA Regional Integrated Sciences and Assessments programs.

From this research, the planning team should be able to collect preliminary information about the climate change phenomena that may affect the state's coast in the future. Note observed and projected changes. This information will prove useful in later steps, where you will have the opportunity to further refine projections.

Learning from others…North Carolina Synthesizes Science on Sea Level Rise
The North Carolina Coastal Resources Commission's Science Panel on Coastal Hazards produced a report synthesizing the best available science on sea level rise in the state. Released at an expert and stakeholder forum, the intent of the report is to provide North Carolina's planners and policy makers with a scientific assessment of the amount of rise likely to occur in this century, which was determined to be one meter (39 inches), for policy development and planning purposes. www.nccoastalmanagement.net/

Sea Levels Online from NOAA's Center for Operational Oceanographic Products and Services illustrates regional trends in sea level. The trends are based on data collected from tide stations in NOAA's National Water Level Observation Network (NWLON). The NWLON also tracks water level trends in the Great Lakes. The graphic below illustrates the sea level trends for Eugene Island, Louisiana, one of the most severe examples of sea level rise captured by the network.



The mean sea level rise trend is 9.65 mm (~.380 in)/year with a 95 percent confidence interval of +/- 1.24 mm (~.049 in)/year based on monthly mean sea level data from 1939 to 1974, which is equivalent to a change of 3.17 feet in 100 years. http://tidesandcurrents.noaa.gov/

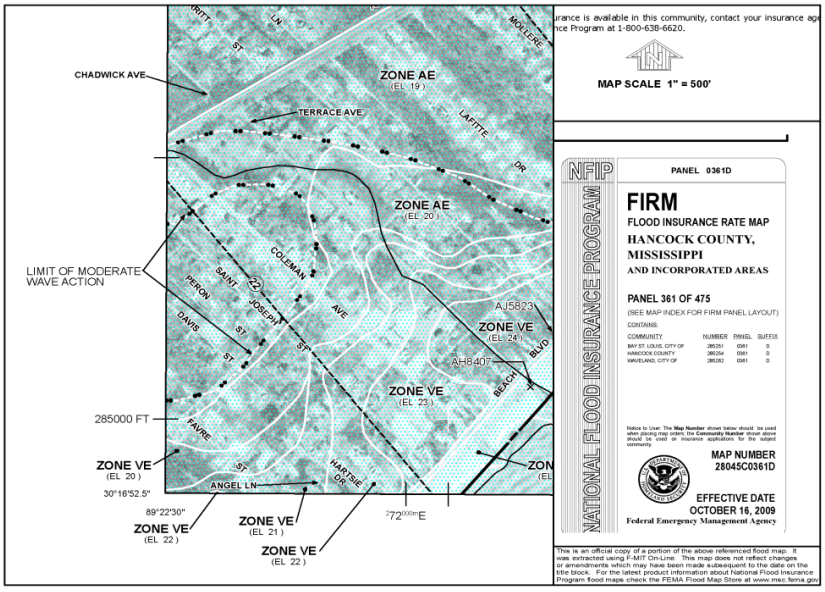
Step 2.2: Identify Climate Change Impacts and Consequences

Climate change impacts and consequences are the changes to the physical, biological, and social systems that occur as a result of climate change phenomena. There are a number of ways to categorize and address these potential impacts and consequences. While this guide categorizes them by phenomenon, you may choose to approach them differently (e.g., by impact, sector, or type of environment—natural vs. built).

Based on the phenomena identified in Step 2.1, the planning team will identify the associated impacts and consequences. The resources consulted in Step 2.1 and the information in Chapter 2 and Appendix C can provide an idea of these impacts. Many, if not all, of these impacts will have been experienced in the past and are likely to be exacerbated by climate change. The planning team may choose to address all of these impacts, and others, or may choose to limit them based on the scope of the plan.

By establishing a baseline that shows how climate change-associated hazards and other stressors have affected the planning area in the past, the team will be better able to envision how they might affect it in the future and will also be well-positioned to monitor

Digital Flood Insurance Rate Maps (DFIRM) are risk-based maps from FEMA that depict areas likely to be flooded by storms with a 1 percent chance and a 0.2 percent chance of occurring in a single year (known as a 100-year and 500-year flood, respectively). Flood hazard information is determined from engineering studies, which include hydrologic and hydraulic models, flood profiles, data tables, digital elevation models, and structure-specific data (e.g., digital elevation certificates and digital photographs of bridges and culverts) overlain on a base map. DFIRMs do not typically consider future conditions. However, communities can elect to include a 100-year floodplain based on future-conditions land use and hydrology on their DFIRM based on their own studies and ordinances and in accordance with FEMA's *Final Guidelines for Using Future-Conditions Hydrology.* http://msc.fema.gov/; www.fema.gov/plan/prevent/fhm/ft_futur.shtm



FIRMettes are full-scale sections of Digital Flood Insurance Rate Maps that can be generated for free online.

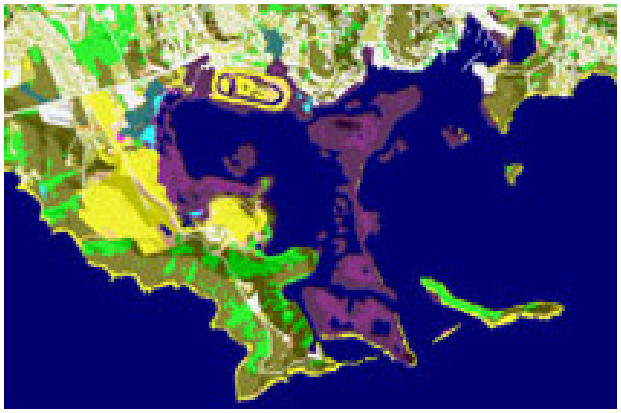
and respond to changes as they occur. The baseline should be based on trends and observed changes to the climate phenomena compiled in Step 2.1 and a review of historical and present day impacts (e.g., storms, floods, droughts, invasive species, harmful algal blooms, hypoxia, ocean acidification, etc.) and their consequences, as well as related cumulative and secondary impacts. Relevant data and maps (e.g., Digital Flood Insurance Rate Maps, shoreline change maps) may already be available from state (and local) agencies involved in planning for managing such events (e.g., in hazard mitigation and natural resource plans). Impact characteristics the planning team may want to collect include existing stressors, timing/seasonality, magnitude, and persistence/reversibility.

Step 2.3: Assess Physical Characteristics and Exposure

In this step, the planning team will assess what it is about the planning area that might affect your state's vulnerability to climate change. This could include elevation, the health of wetlands, or the number of buildings repetitively damaged by storm surge flooding. Information about your coastal zone's physical geography and exposure (including social and economic characteristics), and associated datasets, has likely already been collected for similar planning efforts, such as hazard mitigation and natural resource planning, at the state and local level. These plans should provide a good starting point for this step, and the data should be accessible through the authoring agencies or a central state clearinghouse for geospatial data.

Physical Characteristics

Awareness of your coast's physical characteristics is vital to understanding how it may be affected by the impacts of climate change. Generally, physical characteristics include features and processes of the natural environment (which may be altered by



Land cover maps illustrate how much of an area is covered by wetlands, forests, agriculture, impervious surfaces, and other features.

To use data successfully, coastal organizations need more than just data. They need tools, information, and training to turn these data into useful information. NOAA's Digital Coast offers a diverse selection of data (e.g., elevation, land cover, shoreline, benthic, orthoimagery, socioeconomics, etc.) and companion resources. The Coastal Inundation Toolkit shows users how spatial information can be used to help address their inundation issues and includes basic information about inundation, simple visualization tools, easy access to county-level data, and a guidebook and training for creating local inundation maps. Web site content continues to grow with contributions and guidance from Digital Coast partners and users. www.csc.noaa.gov/digitalcoast/

changes in the climate and human activities and should be kept current and monitored over time), such as:

- ☐ Topography
- ☐ Bathymetry
- ☐ Coastal geomorphology
- ☐ Hydrography
- ☐ Hydrology
- ☐ Geology
- ☐ Soil characteristics
- ☐ Soil saturation
- ☐ Land cover
- ☐ Land use

Exposure

Exposure is an inventory of the "assets"—people, property, systems, and functions—that could be lost, injured, or damaged due to an impact of climate change. In this section, the planning team will consider:

- ☐ What is in the area that the impacts could affect (the coastal zone)?
- ☐ What are the specific assets your state and its stakeholders want to protect?
- ☐ How are these assets projected to change in the future?

Assets the planning team may want to inventory and map, based on best available data, include the following:

- ☐ **Population** (numbers, densities, percentage of state population, social vulnerability (see page 33))
  Potential sources: State demographer, U.S. Census, HAZUS-MH, local governments
- ☐ **Buildings** (exclusive of infrastructure, see below) (numbers and densities, purpose, type of construction, elevation, values; specific vulnerabilities, e.g., mobile homes, repetitive losses, structures in hazard zones)
  Potential sources: State department of finance, HAZUS-MH, FEMA (repetitive losses), local governments
- ☐ **Infrastructure** (numbers, types, values; specific vulnerabilities, e.g., structurally deficient bridges, levees, shore protection structures; see definition on next page)[3]

If you need to purchase data, such as lidar, consider using the contracting vehicle the NOAA Coastal Services Center has established with geospatial industry leaders. State and local agencies use the existing contracts to collect coastal data and obtain other GIS services. Fund transfers are coordinated through an established memorandum of understanding process. This provides an easy way to get data, and since the center does not charge overhead, 100 percent of state and local dollars applied to the contracts goes to the service requested. csc@csc.noaa.gov

[3] Infrastructure should also be assessed for how it might exacerbate the impacts of climate change (e.g., impermeable roads, shore protection structures that interrupt natural processes, etc.). Additionally, infrastructure associated with hazardous materials and pollutants needs to be protected not just for the services it provides but also for the negative impacts it could have on the environment if it were damaged and contaminants were released.

There are a number of definitions for "critical infrastructure." For the purposes of homeland security and emergency management, your state may have its own. For the purposes of this guide, "infrastructure" means the basic facilities, services, networks, and systems needed for the functioning of a community that if lost or damaged could cause significant disruption (physically, functionally, and economically). This includes:

- Water supplies
- Wastewater systems
- Transportation systems (e.g., roads, highways, bridges, tunnels, railways, airports, ports, harbors, canals, ferries, evacuation routes)
- Electrical systems
- Communications networks
- Medical facilities
- Police and fire stations
- Emergency operations centers
- Government buildings
- Schools
- Shore protection and flood control structures
- Oil and gas production, storage, and transportation
- Hazardous material facilities (including those that handle nuclear materials)
- Military bases
- Prisons

Potential sources: State agencies, HAZUS-MH, U.S. Department of Transportation, U.S. Department of Energy, National Atlas, local governments

- ☐ **Natural Resources** (numbers, types, values (quantitative or qualitative, if available); e.g., wetlands, beaches, barrier islands, coral reefs, marine protected areas, refuges, reserves, protected species, essential fish habitat, migration corridors, etc.)
  Potential sources: State natural resource agencies, National Wetlands Inventory, National Marine Fisheries Service regional offices and science centers, National Marine Protected Areas Center, National Wetlands Research Center, regional Endangered Species Program offices, local governments, nonprofit organizations, academia
- ☐ **Historical Resources** (numbers, names, values (quantitative or qualitative, if available))
  Potential sources: State historic preservation office/ register, National Register of Historic Places, local governments
- ☐ **Cultural Resources** (numbers, names/ types, values (quantitative or qualitative, if available); e.g., museums, parks, public access facilities, recreational resources, tourist attractions, etc.)
  Potential resources: State departments of culture, parks and recreation, natural resources, tourism; tourism bureaus; National Park Service; local governments
- ☐ **Economic Resources** (names, types, values (quantitative or qualitative), number employed; e.g., major employers, industries, etc.)
  Potential resources: State departments of finance and labor, chambers of commerce, U.S. Census, National Ocean Economics Program, local governments

It is important, where possible, to estimate the value (market and nonmarket) of exposed assets. This will prove useful when determining where to focus adaptation efforts as well as in making the case to

FEMA's GIS-based loss-estimation software, Hazards U.S. Multihazard (HAZUS-MH) is a software program for analyzing potential losses from floods, hurricane winds, and earthquakes. In HAZUS-MH, current scientific and engineering knowledge is coupled with the latest GIS technology to produce estimates of hazard-related damage before, or after, a disaster occurs. The software package contains national datasets, including select boundary maps (states, counties, census tracts), aggregated building information (square footage, building count by occupancy), essential and high potential loss facilities, transportation systems, lifeline utility systems, hazardous materials, and demographic data, which are useful in inventorying exposure. www.fema.gov/plan/prevent/hazus/

decision makers and the public regarding the need for adaptation planning. For the built environment, the most accurate value will include replacement cost, contents value, function value (value of services), and displacement cost (cost associated with temporary relocation). FEMA's HAZUS-MH can help the planning team estimate these values for different types of buildings (i.e., occupancy classes).[4]

It is also important to consider how these assets are projected to change in the future and what that might mean in the context of climate change. For example, what are the projections for growth and development, and where is it expected to occur? Are plans for economic development based on resources that might be threatened by climate change? Are there plans to conduct activities that may stress natural resources that may be further stressed by changes in the climate?

Socially Vulnerable Populations

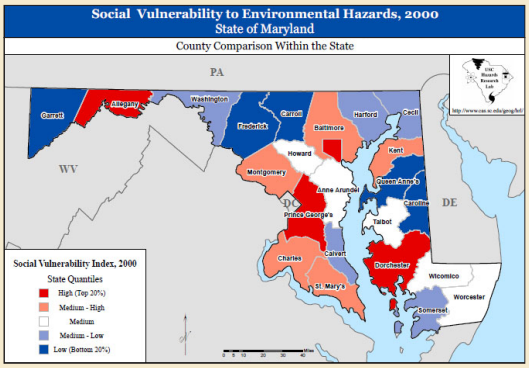
Not everyone will be equally able to respond to climate change. Some groups of people are inherently more vulnerable than others. It is important to understand how social and economic characteristics may affect vulnerability. Socially vulnerable populations will likely need more assistance preparing for, responding to, and recovering from the impacts of climate change.

Characteristics that influence social vulnerability include personal wealth, age, health, density of the built environment, single-sector economic dependence, housing stock and tenancy, race, ethnicity, occupation, and infrastructure dependence. The planning team should identify

"State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level along the U.S. Atlantic Coast" examines where shore protection is likely to be constructed to protect development from rising seas while at the same time limiting the inland migration of wetlands. It classifies coastal lands vulnerable to sea level rise according to the likelihood of shore protection based on existing coastal policies, zoning, and land use and incorporates discussions with local planners to approximate where efforts are likely to be made to hold back the sea. Supplementary material, including state-specific discussions, maps, and GIS data are available online. Studies such as this can help set the stage for creating an adaptation strategy to address sea level rise and other inundation threats. http://risingsea.net/ERL/

[4] If using building values provided by HAZUS-MH, note that these values do not account for total land loss. These values will need to be determined separately for losses attributable to erosion and sea level rise.

The Social Vulnerability Index from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina measures the social vulnerability of U.S. counties to environmental hazards. The index synthesizes 42 socioeconomic and built environment variables that research literature suggests contribute to social vulnerability. http://webra.cas.sc.edu/hvri/products/sovi.aspx



where there may be high concentrations of these socially vulnerable populations so it understands the level of support they may need as the climate changes. Also, consider native populations, whose unique social, economic, and cultural characteristics may make them particularly vulnerable.

Vulnerable Ecosystems and Habitats

The extent to which a natural system (e.g., ecosystem or habitat) will be affected by climate change will depend on the degree of change, the sensitivity of the system, and the system's ability to respond. As with human populations, not every system will be equally positioned to respond. As data are collected about natural resources, the planning team may want to consider attributes of these systems that provide a sense of how vulnerable they may be to climate change and, thus, which systems may need the most assistance preparing for and responding to climate change.

To gauge the potential vulnerability of your coastal and marine ecosystems and habitats, consider the following:

- **Health**—Healthy systems may be less vulnerable to the added stress of climate change.
- **Management plan**—Resources that are well-managed lead to improved biodiversity, shore protection, and food security; a more sustainable income; continuity of fish nursery and breeding; continuity of feeding grounds; and more attractive areas for visitors.
- **Monitoring program**—Programs that monitor systems for health, stress, and change allow potential problems in those systems to be identified and addressed early.
- **Space to migrate**—Systems with adequate and appropriate space to migrate may be less vulnerable and better able to adapt to sea level rise and other climate change phenomena.
- **Connectivity**—Systems that are connected to other systems with similar community structures can migrate if threatened.
- **Management integration**—Coordination of management efforts across jurisdictions and owners allows systems to be managed for common goals and objectives and can promote connectivity.
- **Threatened, endangered, and other protected species**—Systems with high numbers of protected species may be more sensitive and vulnerable to climate change.
- **Stressors**—Systems already threatened by stressors such as coastal development, invasive species, pollution, etc. may be more vulnerable to climate change.
- **Impact thresholds**—Systems at or near their impact threshold (after which their vulnerability increases) will be more vulnerable to climate change.

Healthy systems may be less vulnerable to the added stress of climate change.

Any assessment of the vulnerability of ecosystems to climate change should include evaluation of the potential impacts on the goods and services they provide and the cascading effects that could result if the systems were damaged or destroyed. By understanding the vulnerability and value of coastal systems, the planning team will be prepared to make decisions about where to focus protection and adaptation efforts once there is a clearer picture of how they may be affected by climate change.

Step 2.4: Consider Adaptive Capacities

The vulnerability of coastal areas to climate change will depend not only on the physical stressors to the environment, but also on the ability of the affected areas to adapt to those changes. Thus, another key factor in assessing vulnerability is adaptive capacity.

According to the IPCC, adaptive capacity is "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007a). In general, coastal areas or systems with higher adaptive capacities will be better able to react and accommodate to the changes associated with climate change.

Capacity can be described in terms of the ability of your state's governments and their populations to prepare for, respond to, and recover from the impacts of climate change. Due to regional variability, capacity may vary significantly along your coast. In addition to support from elected officials and other leaders, which will be critical to successful adaptation, examples of existing tools and resources that can support the ability of governments to address climate change include, but are not limited to:

- **Regulatory and planning capabilities** (e.g., building codes, development restrictions, real estate disclosure requirements, coastal management regulations, and hazard mitigation, natural resource, land conservation, climate change mitigation, sustainability, sediment management, special area management, shoreline management, capital improvement, transportation improvement, and postdisaster recovery plans)[5]

An example of a tool to assess the vulnerability of a given species of plant or animal to climate change is NatureServe's Climate Change Vulnerability Index. The index allows scientists, natural resource managers, planners, and conservation practitioners to perform rapid assessments of the relative vulnerability of species to the effects of predicted climate change. The scoring system considers a species' predicted exposure to climate change within a defined geographic area and its sensitivity to climate change. Each species is scored on a detailed set of factors, such as dispersal ability, natural and manmade barriers to dispersal, sensitivity to changes in temperature and precipitation, physical habitat requirements, and genetic variation. Total scores reflect whether a given species will likely suffer a contraction in range, reduction in population, or both in coming decades and are rated as extremely vulnerable, highly vulnerable, moderately vulnerable, not vulnerable—presumed stable, not vulnerable—increase likely, and insufficient evidence. The index and guidance are available for free download. www.natureserve.org/prodServices/climatechange/ClimateChange.jsp

[5] Federal laws and executive orders that may also contribute to states' adaptive capacity are included in Appendix B.

Learning from others…GOMA Aims to Inventory Hazards Resilience Capabilities Gulfwide
The Gulf of Mexico Alliance's (GOMA) Governor's Action Plan II includes the preparation of an inventory of existing capabilities and tools to address coastal hazards in the Gulf region, identify important gaps, and, where needed, develop new methods to enhance regional and local resilience. Action steps include compiling and maintaining an inventory of existing resilience-related data, projects, tools, and policies from across the Gulf region; developing a Resilience Index self-assessment tool for coastal communities; creating and packaging planning and hazard mitigation tools for use in management at the local and state levels; and researching existing policies guiding coastal development and making recommendations to enhance resilience. http://gulfofmexicoalliance.org/pdfs/ap2_final2.pdf

- **Administrative and technical capabilities** (e.g., dedicated staff, climate change experts/champions, planners, engineers, and GIS and mapping and modeling resources (staff and equipment))
- **Fiscal capabilities** (e.g., taxes, bonds, grants, impact fees, withholding spending in hazard zones, and insurance)
- **Infrastructure** (e.g., flood and erosion control structures, evacuation routes, and redundant water, wastewater, and power systems)

To improve capacity, think about how the effects of climate change can be better integrated into these existing tools and resources. In addition, consider how some of them may work at cross purposes, hindering climate change adaptation, and how conflicts could be resolved.

Your state's adaptive capacity will also depend on the adaptive capacity of its natural systems. As has been demonstrated in the past, given time, natural systems can adjust to changes in climate by relocating or changing the timing of life cycle events. However, anticipated changes may happen more quickly than in the past, and nonclimate stressors will present obstacles to adaptation. Humans will need to be prepared to address the needs of natural systems, which will include altering their activities. Natural systems with the greatest capacity to adapt to change will be those that are healthy, are able to migrate (based on space and elevation), and/or are connected to other systems, which allows for species migration.

Determining your state's overall adaptive capacity is largely a subjective exercise, but it can help the planning team identify strengths and weaknesses as well as existing mechanisms that can be leveraged to increase capacity. Once the planning team has an understanding of where capacity needs to be built or enhanced, this information can be combined with the other vulnerability information compiled in this process to identify where adaptation efforts should be focused. Actions to build adaptive capacity can then be included in the adaptation strategy, which is discussed in Chapter 5.

Step 2.5: Develop Scenarios and Simulate Change

So far, the planning team has identified the phenomena likely to affect the coast, examined the associated impacts, and assessed what it is about the coast that may affect its vulnerability to climate change (physical characteristics, exposure, and capacity). In this step, based on the information collected in Steps 2.1 through 2.4, the planning team will develop scenarios that illustrate potential projected impacts and consequences of climate change.

Scenario planning is a tool for developing a science-based decision-making framework in an environment of uncertainty. The goal is to develop a range of plausible climate change outcomes (impacts and consequences) based on multiple points of time and on multiple emissions levels that can provide the basis for further analysis and decision making. For example, the planning team could establish and define low, moderate, and high emissions levels (which would correspond to low, moderate, and high degrees of

The future is not a static continuation of the past; scenarios recognize that several potential futures are feasible from any particular point in time. Scenario studies commonly target issues which are sensitive to stakeholders and they provide the means by which decision makers can anticipate coming change and prepare for it in a responsive and timely manner. Through exploration and evaluation of feasible future conditions, scenario studies enable assessment of system vulnerabilities and possibilities for adaptation measures (Mahmouda et al. 2009).

climate change) and project each of them out to 20, 50, and 100 years from now (see Washington example on the next page).[6] This would result in nine scenarios as indicated in the table below (additional scenarios may be developed to account for regional differences within your state).

Each completed scenario should include quantitative projections of the climate change phenomena and descriptions of the potential associated impacts and consequences (qualitative if not quantitative) relevant to the plan (e.g., if the planning team is focusing adaptation planning on specific management issues, it may choose to only include a subset of the impacts in the scenarios). Consider seasonality and extremes, not just annual averages. More robust scenarios will include consideration of cumulative impacts (e.g., a wetland threatened by sea level rise will also be more vulnerable to storms) and adaptation actions already planned for.

For the purposes of this plan, it may be easiest to evaluate event-related consequences based on a single event (e.g., a 100-year flood), keeping in mind that these events may occur more than once, with the potential to cause repetitive damage and losses. The baseline established in Step 2.2 can help the planning team envision what the consequences might be at low-level emissions.

Note: The baseline was largely based on current and historical trends. Changes are likely even if emissions are decreased, so the low-level emissions scenario at 20 years may show incremental changes from the baseline. In addition, the review of your state's physical characteristics and assets was also based on current conditions. Where possible, the scenarios should reflect expected changes over time (e.g., changes in population, development, land cover, etc.). Similarly, when projecting out into the future, adjust dollar values to account for inflation.

Climate Modeling

Scenarios based on global climate models will likely be the most reliable. Global climate models use mathematical equations to simulate how, on a global scale, the earth's physical processes will react to changes. It must be emphasized that while models are extremely valuable tools for simulating and understanding climate change, shortcomings

Examples of Scenarios for Assessing Vulnerability

	Low-Level Emissions	Moderate-Level Emissions	High-Level Emissions
20 years	Scenario 1	Scenario 4	Scenario 7
50 years	Scenario 2	Scenario 5	Scenario 8
100 years	Scenario 3	Scenario 6	Scenario 9

[6] While there is much more uncertainty associated with the longer time horizon, it is important to acknowledge that many of your current decision processes (land use, transportation, infrastructure, conservation) have a longer design life and should consider projected conditions much further out than 20 years. Much of the literature and research, including that conducted by the IPCC, provide projections through 2100.

Learning from others…Washington Projects Sea Level Rise for Use in Scenario Planning

Sea Level Rise in the Coastal Waters of Washington State, a report from the University of Washington Climate Impacts Group and the Washington Department of Ecology, features scenarios for sea level rise based on the IPCC's projections for global sea level rise. The following table from the report shows very low, medium, and very high estimates of Washington sea level change for 2050 and 2100, accounting for local variability in vertical land movement (VLM) and atmospheric dynamics, for the northwest Olympic Peninsula, the central and southern Washington coast, and Puget Sound. Negative VLMs represent vertical uplift and negative totals represent sea level drop. The very low and very high estimates are considered low probability scenarios. www.cses.washington.edu/db/pdf/moteetalslr579.pdf

SLR Estimate	Components	2050			2100		
		NW Olympic Poninsula	Central & Southern Coast	Puget Sound	NW Olympic Poninsula	Central & Southern Coast	Puget Sound
Very Low	Global SLR	9 cm			18 cm		
	Atm. Dynamics	-1 cm			2 cm		
	VLM	-20 cm	-5 cm	0 cm	- 40 cm	- 10 cm	0 cm
	Total	- 12 cm(- 5″)	3 cm (1″)	8 cm (3″)	- 24 cm (-9″)	6 cm (2″)	16 cm (6″)
Medium	Global SLR	15 cm			34 cm		
	Atm.Dynamics	0 cm			0 cm		
	VLM	-15 cm	-2.5 cm	0 cm	- 30 cm	- 5 cm	0 cm
	Total	0 cm(- 5″)	12.5 cm(5″)	15 cm(6″)	4 cm(2″)	29 cm(11″)	34 cm(13″)
Very High	Global SLR	38 cm			93 cm		
	Atm. Dynamic	7 cm			15 cm		
	VLM	- 10 cm	0 cm	10 cm	- 20 cm	0 cm	20 cm
	Total	35 cm(14″)	45 cm(18″)	55 cm(22″)	88 cm(35″)	108 cm(43″)	128cm(50″)

remain. "Their main shortcomings are limited observations, incomplete understanding of climate processes and their interrelationships, imperfect model representations of the processes, and relatively large grid boxes that don't represent smaller terrain features" (Meted 2009). It is important to recognize these deficiencies, understand the uncertainties, and consider results from multiple models, as well as how results track with observations, to account for the range of uncertainty and variability among them.

To model climate change in your state, consider 1) using the results of the scenarios generated for 2100 for the IPCC's Fourth Assessment Report[7] and adjusting global projections to account for local conditions (e.g., add local subsidence projections to global sea level rise projections) and to estimate shorter-term projections or 2) downscaling global climate data.

Since global climate models have relatively coarse spatial resolution, downscaling is required to achieve the finer spatial resolution needed to understand regional impacts. Downscaling should result in better projections of how the phenomena may change in your state and thus better inputs for other models and maps to illustrate the potential impacts and consequences on your coast.

[7] The IPCC based its six scenarios on four "storylines" that represent different assumptions about demographic, social, economic, technological, and environmental change (in the absence of new climate policies).

Scenarios are also useful in project planning to determine the level of protection an individual project needs to provide. The U.S. Army Corps of Engineers is now incorporating direct and indirect physical effects of projected future sea level change in managing, planning, engineering, designing, constructing, operating, and maintaining Corps coastal projects and systems of projects. They use a multiple scenario approach that considers low, intermediate, and high rates of change.

These activities are guided by *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations In Civil Works Programs*, which also recommends determining how sensitive alternative plans and designs are to these rates of future sea level change, how this sensitivity affects calculated risks, and what measures should be implemented to minimize adverse consequences while maximizing beneficial effects. It instructs project designers to consider planning for adaptive management, designing to facilitate future modifications, and designing for a more aggressive future sea level change scenario. http://140.194.76.129/publications/eng-circulars/

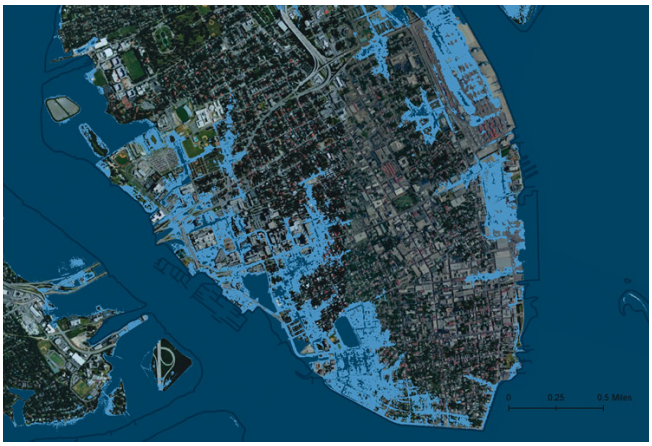
If the planning team has access to the capacity, downscaling could be incorporated into the vulnerability assessment. **However, experts are still cautious about making regional predictions and stress the need to accept the limitations of downscaled climate models and understand potential sources of errors, which include the potential to compound errors in global models.** Consider results from a number of models, and if they diverge from each other or from observed trends, be careful about how they are used in decision making (Schiermeier 2010). It will be up to the planning team to decide how much uncertainty the state is willing to accept, and this may differ by phenomenon/impact/consequence.

Note: Modeling activities require extensive resources. They can be costly and complicated, and they require a robust information technology infrastructure (high-performance, fast, dedicated computer systems). Make sure your state has the technical capacity to run these applications before acquiring them. Research institutions may have the necessary capacity and may be able to assist in these efforts. Alternatively, the planning team could propose developing the capacity as an action in the adaptation strategy (see Chapter 5).

Mapping and Visualization

The use of mapping (both simple and interactive) and other visualization techniques to illustrate the potential impacts of climate change will greatly ease and increase the effectiveness of the planning process. While modeling is the set of rules and procedures for representing a phenomenon or predicting an outcome, mapping is the process of graphically depicting that outcome, or other spatial information.

By using GIS, the data collected throughout this assessment and the outputs from the scenarios or other modeling efforts, the planning team will be able to map projected future conditions, decide where to focus adaptation efforts, and, later, evaluate the results of these efforts. These visuals, which will clearly illustrate what is vulnerable, should also be useful in outreach



Inundation mapping can be used to visualize where flooding may occur as climate changes.

Coastal inundation maps are based on model outputs and can be used to simulate inundation from a variety of processes. There are a number of models available, which may also be coupled with other models (e.g., wave models); each has its own applications and limitations, both of which should be well-understood. Modeling experts can help select and run models and educate the planning team about the limitations. The following are some of the most commonly used inundation models, however other models are also available or under development that may be more appropriate based on your state's circumstances and needs.

- The **Advanced Circulation Model for Oceanic, Coastal, and Estuarine Waters** (ADCIRC) is a hydrodynamic model, which means it projects the motion of water. It can be used to model (in two or three dimensions) tide and wind driven circulation, to project storm surge and flooding, and for other applications. The model can also be used to predict wave height and run-up, particularly when seamless bathymetric and topographic data are available.
- The **Sea, Lake, and Overland Surges from Hurricanes** model (SLOSH) is a scenario-based model developed by the NOAA National Hurricane Center. It is used to estimate storm surge heights and winds resulting from historical, predicted, or potential hurricanes by taking into account storm pressure, size, forward speed, track, and winds. The model also considers characteristics specific to a locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, and other physical features.
- The **Sea Level Affecting Marshes Model** (SLAMM) simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. It can account for inundation, erosion, accretion, overwash, and even wetland migration to adjacent upland areas (saturation).
- The **Sea-Level Rise Rectification Program** (SLRRP) is a software program designed to generate a suite of future sea level projections from various Global Circulation Models (GCM) and emissions scenario options. The model allows users to select a region-based tide station, GCM model, and emissions scenario to generate a graph and output file of future sea level change. SLRRP also shows the inundation process and period for which sea level will overtop a given landscape feature or elevation under a future changing climate.

efforts to help secure political and public support for the need to adapt to climate change.

Step 2.6: Summarize Vulnerability and Identify Focus Areas

At this point, the planning team should have a good understanding of how climate change may affect the coast. The final step of the assessment process is summarizing vulnerability based on your findings. This step is critical, as this summary will be used to identify where to focus adaptation efforts and to set goals and select the actions your state will take to meet them (see Chapter 5).

This step provides a good opportunity for the planning team to re-engage the stakeholders identified in Step 1.4 (see Chapter 3). Present them with the results of the scenarios and involve them in deciding

Learning from others…Maryland Visualizes Sea Level Rise to Support Planning

The Maryland Coastal Program and local partners acquired high resolution topographic lidar data for the majority of the state's coastal counties. These data have been used to develop models that demonstrate both the impact of gradual sea level rise inundation over time, as well as impacts associated with increased storm surge from episodic flood events. Sea level rise modeling has been completed for some of the state's most vulnerable areas. The models are already proving useful to state and county planners and emergency responders as they plan for a coastal region faced with a high likelihood of damaging coastal storms and rising sea level. The project partners are exploring ways to integrate the models into future research efforts and land use decision making. Sea level inundation maps are integrated into Maryland's online interactive shoreline mapping program. www.dnr.state.md.us/ccp/coastalatlas/shorelines.asp

which consequences are of greatest concern and where the state should invest its climate adaptation resources.

This summary should reflect the outcomes the planning team thinks are most realistic and best reflect the extent of acceptable impacts in the planning area. If the planning team develops scenarios based on three levels of emissions, it is not likely it will plan for all three (although it should still plan for multiple points in time). It is also not likely it will focus all adaptation activities based on the possible outcomes projected by one level of emissions. It may be determined that the potential losses to one sector projected at the highest level of emissions are too great to risk, but that other potential losses at that level are acceptable. In other words, when the stakes are low, the planning team may want to plan based on the outcomes of a low-emissions scenario, but when the stakes are high (e.g., significant losses, irreversible consequences), it may want to consider planning for a higher-emissions scenario. The potential consequences of low probability, high consequence impacts should be recognized so that they can be adequately addressed.

The summary should highlight areas, systems, sectors, or assets that the planning team has determined to be most vulnerable to the impacts of climate change (i.e., potential damage/losses that would have most the significant impact). Criteria that may help prioritize where to focus adaptation efforts include:

- Importance or value of a system, asset, or sector
- Magnitude of impacts
- Timing of impacts
- Persistence and reversibility of impacts
- Certainty of projected impacts
- Threats from existing stressors

It may help to ask questions such as the following:

- What locations along the coast are most vulnerable to climate change impacts?
- What environments (natural, built) are most vulnerable to climate change impacts?
- What assets are most important to your state's coastal values, identity, culture, and economy?
- Which impacts of climate change are likely to inflict the greatest losses (economically, socially, environmentally, etc.)?

It may also be useful to include the associated phenomena and impacts, as there may be actions that can be taken to alleviate the consequences that may cross sectors and/or protect multiple assets. In addition, for each potential loss, indicate which scenarios the decisions were based on and why. This will be useful in future plan updates.

Key Resources

General

- Adapting to Coastal Climate Change: A Guidebook for Development Planners, U.S. Agency for International Development. www.crc.uri.edu/index.php?actid=366
- ArcGIS Online Resource Center, ESRI. http://resources.esri.com/arcgisonlineservices/index.cfm
- Climate Ready Estuaries Coastal Toolkit, EPA Climate Ready Estuaries. www.epa.gov/cre/toolkit.html
- NOAA Climate Service. www.climate.gov/
- Digital Coast, NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/
- eCoastal, U.S. Army Corps of Engineers. http://ecoastal.usace.army.mil/
- Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, United Nations Environment Programme. http://dare.ubvu.vu.nl/bitstream/1871/10440/1/f1.pdf
- HAZUS-MH, FEMA. www.fema.gov/plan/prevent/hazus/
- Introduction to Hazard Mitigation (online training), FEMA. http://training.fema.gov/EMIWeb/IS/
- National State Geographic Information Council. www.nsgic.org/
- Planning for Climate Change, NOAA Estuarine Reserves Division. http://nerrs.noaa.gov/CTPIndex.aspx?ID=455
- Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook/
- Regional Integrated Science and Assessment Program, NOAA Climate Program Office. www.climate.noaa.gov/cpo_pa/risa/
- Road Map for Adapting to Coastal Risk (training), NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/training/coastalrisk.html
- Understanding Your Risks: Identifying Hazards and Estimating Losses, FEMA. www.fema.gov/plan/mitplanning/resources.shtm

Identify Climate Change Phenomena

- Climate Change 2007: The Physical Science Basis, IPCC. www.ipcc.ch/
- Climate Change 2007: Synthesis Report, IPCC. www.ipcc.ch/
- Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, National Assessment Synthesis Team, U.S. Global Change Research Program (2000, includes regional and sectoral assessments). www.globalchange.gov/publications/reports/scientific-assessments/first-national-assessment
- Global Climate Change Impacts in the United States, U.S. Global Change Research Program. www.globalchange.gov/publications/reports/scientific-assessments/us-impacts
- Great Lakes Water Levels, U.S. Army Corps of Engineers Detroit District. www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/
- Synthesis and Assessment Products, Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Tides and Currents, NOAA Center for Operational Oceanographic Products and Services. http://tidesandcurrents.noaa.gov/

Identify Climate Change Impacts and Consequences

- Climate Monitoring, NOAA National Climatic Data Center. http://lwf.ncdc.noaa.gov/climate-monitoring/
- The Economic Impacts of Climate Change and the Costs of Inaction, Center for Integrative Environmental Research, University of Maryland. www.cier.umd.edu/climateadaptation/
- FEMA Mapping Information Platform, FEMA. https://hazards.fema.gov/
- FEMA Map Service Center, FEMA. http://msc.fema.gov/
- Multi-Hazard Identification and Risk Assessment, FEMA. www.fema.gov/library/viewRecord.do?id=2214
- National Assessment of Coastal Vulnerability to Sea-Level Rise, U.S. Geological Survey. http://woodshole.er.usgs.gov/project-pages/cvi/
- The NatureServe Climate Change Vulnerability Index, NatureServe. www.natureserve.org/prodServices/climatechange/ClimateChange.jsp
- NCDC Storm Events, NOAA National Climatic Data Center. www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms
- NOAA Regional Climate Centers, NOAA National Climatic Data Center. www.ncdc.noaa.gov/oa/climate/regionalclimatecenters.html
- PERI Presidential Disaster Declaration Web Site, Public Entity Risk Institute. www.peripresdecusa.org/
- Spatial Hazard Events and Losses Database for the United States, Hazards and Vulnerability Research Institute, Department of Geography, University of South Carolina. http://webra.cas.sc.edu/hvri/products/sheldus.aspx
- United States Historical Climatology Network, NOAA National Climatic Data Center. http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html

Assess Physical Characteristics and Exposure

- Bathymetry and Global Relief. NOAA National Geophysical Data Center. www.ngdc.noaa.gov/mgg/bathymetry/relief.html
- Coastal Change Analysis Program Land Cover, NOAA Coastal Services Center. www.csc.noaa.gov/landcover/
- Data Basin Climate Center, Conservation Biology Institute. www.databasin.org/climate-center
- Demographic Baseline Report of U.S. Territories and Counties Adjacent to Coral Reef Habitats, NOAA NOS Special Projects Office. www.coris.noaa.gov/activities/coral_demographics/
- Endangered Species Program, U.S. Fish and Wildlife Service. www.fws.gov/endangered/
- Geospatial One Stop. www.geodata.gov/
- Likelihood of Shore Protection Data Set. http://risingsea.net/ERL/data.html
- Mapping Socio-Economic Variables Using 2000 Census Data, NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/inundation/_pdf/census_methodology.pdf
- MPA Inventory, NOAA National Marine Protected Areas Center. http://mpa.gov/dataanalysis/mpainventory/
- National Atlas. www.nationalatlas.gov/
- National Land Cover Database, Multi-Resolution Land Characteristics Consortium. www.mrlc.gov/nlcd.php

- The National Map Seamless Server, U.S. Geological Survey. http://seamless.usgs.gov/
- National Ocean Economics Program. http://noep.mbari.org/
- National Register of Historic Places, National Park Service. www.nps.gov/history/nr/
- National Wetlands Inventory, U.S. Fish and Wildlife Service. www.fws.gov/wetlands/
- National Wetlands Research Center, U.S. Geological Survey. www.nwrc.usgs.gov/
- NOAA Shoreline Website, NOAA Coastal Services Center. http://shoreline.noaa.gov/
- NOAA's State of the Coast, NOAA. http://stateofthecoast.noaa.gov/
- Resilience Assessment of Coral Reefs, International Union for Conservation of Nature Climate Change and Coral Reefs Marine Working Group. http://data.iucn.org/dbtw-wpd/edocs/2009-020.pdf
- Social Vulnerability Index, Hazards and Vulnerability Research Institute, Department of Geography, University of South Carolina. http://webra.cas.sc.edu/hvri/products/sovi.aspx
- Spatial Trends in Coastal Socioeconomics, NOAA Coastal and Ocean Resource Economics Program. http://marineeconomics.noaa.gov/socioeconomics/
- Species Protected under the Endangered Species Act, NOAA Office of Protected Resources. www.nmfs.noaa.gov/pr/species/esa/
- U.S. Census Bureau, www.census.gov/

Develop Scenarios and Simulate Change

- Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decisionmaking, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- CanVis, NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/tools/canvis/
- Climate Modeling, Geophysical Fluid Dynamics Laboratory. www.gfdl.gov/climate-modeling/
- Climate Models: An Assessment of Strengths and Limitations, Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Coastal Inundation Mapping (training), NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/training/inundationmap.html
- Coastal Inundation Mapping Toolkit, NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/inundation/
- Final Guidelines for Using Future-Conditions Hydrology, FEMA. www.fema.gov/plan/prevent/fhm/ft_futur.shtm
- GIS Climate Change Scenarios, National Center for Atmospheric Research. www.gisclimatechange.org/
- HAZUS Training, FEMA. http://training.fema.gov/EMICourses/
- IPCC Data Distribution Centre, IPCC. www.ipcc-data.org/
- NCAR Models & Modeling, National Center for Atmospheric Research. www.ncar.ucar.edu/tools/models/
- Special Report on Emissions Scenarios, IPCC. www.ipcc.ch/publications_and_data/publications_and_data_reports.htm
- U.S. National Assessment of the Potential Consequences of Climate Variability and Change Scenarios & Data, U.S. Global Change Research Program. www.usgcrp.gov/usgcrp/nacc/background/scenarios/
- Vertical Datum Transformation, NOAA National Ocean Service. http://vdatum.noaa.gov/

CHAPTER 5 ADAPTATION STRATEGY

Upon completion of the vulnerability assessment, the planning team should know where it wants to direct preliminary adaptation efforts. The adaptation strategy consists of establishing goals and identifying and prioritizing actions that can help meet them. These goals and actions may change over time based on new scientific findings, improved vulnerability assessments, observed climate change impacts and consequences, and implementation successes and failures. As is discussed further in Chapter 6, goals and actions will need to be revisited and revised over time.

The basic steps involved in creating an adaptation strategy are as follows:[1]

- Step 3.1: Set Goals
- Step 3.2: Identify Actions
- Step 3.3: Evaluate, Select, and Prioritize Actions
- Step 3.4: Write Action Plans

The following definitions are based on those provided in FEMA's hazard mitigation planning guidance (FEMA 2002):

- **Goals** are general guidelines that explain what the planning team wants to accomplish. They are usually long-term (but may also be short-term), broad statements.
- **Actions** explain how measures (laws, regulations, projects, programs, plans, etc.) will be implemented to help achieve the goals.

It is recommended that all stakeholders be invited to participate in setting goals and choosing actions. This

[1] Some strategic planning processes are more involved and recommend visions, objectives, and alternative definitions. The process offered here is just a basic example of a how an adaptation strategy may be crafted.

keeps them engaged, allows for incorporation of their input, and increases the likelihood that they will be supportive of the plan and the actions chosen for implementation.

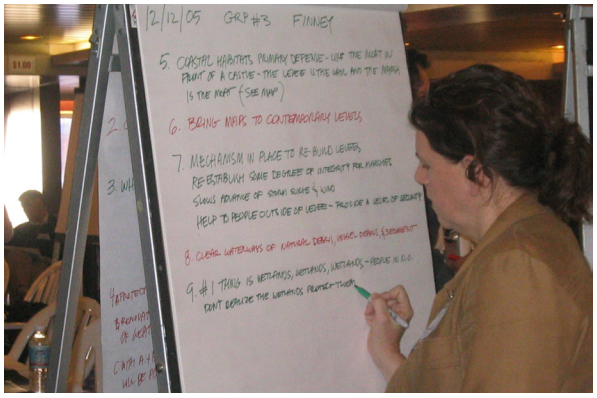
Step 3.1: Set Goals

There is no one set of goals that can be applied to all coastal zones. They will vary based on a number of factors, such as the type and magnitude of projected climate change impacts and the vulnerable assets as identified in the vulnerability assessment. Other important factors include the availability of financial, technical, and human resources and the state's acceptable level of impacts. Goals should be clearly written, attainable, and measurable (qualitatively or quantitatively).

After reviewing the vulnerability assessment findings, a good starting point for goal setting is to review goals established in other state plans/programs (e.g., those for coastal management, hazard mitigation[2], emergency operations, environmental preservation, economic development, resource management, transportation, etc.). Adaptation plans from other governments, state and local, are also useful resources. Some of these plans can be accessed online at http://collaborate.csc.noaa.gov/climateadaptation/.

Examples of potential goals include:

- Reduce the vulnerability of the built environment to sea level rise
- Monitor and maintain functioning and healthy coastal ecosystems
- Reduce the costs associated with disaster response and recovery
- Protect critical infrastructure from the impacts of climate change
- Minimize economic losses attributable to the impacts of climate change
- Adapt to climate change in a manner that minimizes harm to the natural environment and loss of public access



Plan goals should be clearly written, attainable, and measurable.

- Increase public awareness about climate change and how it may affect the coast
- Reduce the impact of climatic and nonclimatic stressors on natural systems
- Increase and improve technical capacity to project impacts of climate change
- Provide leadership and support to local governments for climate change adaptation planning
- Enhance the state's ability to detect climate change impacts
- Improve coordination and collaboration among relevant agencies and organizations

Step 3.2: Identify Actions

Since many of the impacts and consequences of climate change are not new, simply exacerbated or accelerated, actions to reduce them already exist and are being implemented outside the context of climate change. This chapter illustrates how familiar actions can also be used to support climate change adaptation.

However, some of these actions are likely insufficient for addressing the scale of the potential changes. It will take a combination of existing, reconfigured, and new actions to meet the challenges of climate change. Importantly, the potential impacts of climate change on the coast should be considered in all related planning, law and policy making, and investment activities.

[2] Note: Federal funding for hazard mitigation (which in many cases includes climate change adaptation actions) from FEMA is tied to goals set in federally approved hazard mitigation plans. To be eligible for these funds, where appropriate, state hazard mitigation and climate change adaptation goals should be aligned.

While reviewing state plans for possible goals, also look at the actions and consider the following questions in regard to actions along the coast as well as elsewhere in the watershed:

- Are there any actions that directly address climate change impacts along the coast?
- Are there any actions that indirectly address climate change impacts along the coast?
- Are there any actions that could or should be modified to help meet the goals of the adaptation plan?
- Are there any actions that are in direct conflict with the goals of the adaptation plan?

To ensure the plan is inclusive of all actions that may affect your coast and to avoid duplication, you may want to consider incorporating ongoing and already planned activities in your plan. Additionally, there may be actions that could be modified to meet multiple purposes with shared resources. If there are actions that might hinder efforts to meet adaptation goals, try to work with the entity responsible for that action to reach a mutually beneficial solution. As mentioned before, coordination and collaboration among other state agencies and stakeholders is critical, both to capitalize on each other's efforts and to avoid conflicts that could prove difficult and expensive to overcome in the future.

Think broadly and do not be afraid to think big. Do not worry about resource or technology constraints, these issues will be raised during the evaluation process, which will help the planning team narrow down the list and prioritize the agreed upon actions. Hold on to the list of actions that do not make the initial cut. In the future, some of these actions may be more appropriate and/or feasible. Finally, be creative.

Action identification is a creative and collaborative process that should involve all stakeholders.

Actions can be built to encompass one or more measures (see examples in the table on page 51) and should be crafted so they can be clearly understood (e.g., does the action involve planning, promoting, encouraging, mandating, constructing, etc.). While not all of the measures included here can be implemented at the state level, they are examples of activities states can support and promote to local governments. A lot of climate change adaptation will take place at the local level, and financial and technical assistance from higher levels of government, as well as mandates, in some instances, will be vital to secure the necessary level of local commitment.

Not all actions included in this guide will be suitable for every situation. One action may be appropriate in one location but not in another. Suitability will depend on circumstances specific to each state and its

Learning from others…BCDC Seeks Sea Level Rise Solutions through Design Competition

The San Francisco Bay Conservation and Development Commission (BCDC) held an international design competition to identify innovative climate change adaptation strategies for coastal communities. Planning and design professionals, consultants, developers, students, and the public were invited to submit entries, which were required to solve a meaningful sea level rise problem, while being environmentally smart, simply designed, and transferable to other estuaries beyond San Francisco Bay. Six winners, from among 131 entries representing 18 countries, were awarded stipends to further refine their ideas. www.risingtidescompetition.com/risingtides/

Learning from others…Rhode Island Policy Accommodates for Sea Level Rise
In January 2008, the Rhode Island Coastal Resources Management Council (CRMC) adopted a new coastal policy to explain the science of sea level rise in the state and help manage the state's coastal resources and property and protect life and property from sea level rise. For planning and management purposes, the policy calls for an accommodation of a "base rate of expected three- to five-foot rise in sea level by 2100 in the siting, design, and implementation of public and private coastal activities." The CRMC is in the process of developing guidance that will promote the application of this policy. www.crmc.ri.gov/regulations.html

coastal zone and may require additional research, study, legal review, and legislative or regulatory change.

Planning, Law Making, and Regulating

A number of measures can be used to alleviate many of the impacts and consequences of climate change and will be critical to successful climate change adaptation efforts. Importantly, these measures include planning, law making, and regulating. Adaptation will require new, and modifications to existing, plans, laws, and regulations. Going forward, all planning and rulemaking activities should consider climate change and future conditions so outcomes support, and do not deter, adaptation efforts.

Measures listed in the table on page 51 and discussed further at the end of the chapter are more likely to be acceptable and effective if they result from a traditional planning process such as the one presented in this guide. These measures can be incorporated into the adaptation planning process or that of an existing plan (e.g., comprehensive, hazard mitigation, watershed management, capital improvement, etc.). Alternatively, the planning team may decide a measure requires its own plan (e.g., because of scope or complexity).

One type of plan encouraged by the Coastal Zone Management Act is the Special Area Management Plan (SAMP). SAMPs are broadly defined in the act as "plans which provide for increased specificity in protecting significant natural resources, reasonable coastal dependent economic growth, improved protection of life and property in hazardous areas, including those areas likely to be affected by land subsidence, sea level rise, or fluctuating water levels of the Great Lakes, and improved predictability in governmental decision making" (CZMA 1972). SAMPs and other plans with similar intents are especially appropriate in areas where authorities overlap and coordination and cooperation is required to effectively address the multitude of needs that have arisen along the coasts.

Many local governments, and some states, have comprehensive plans to guide development. Some states require local governments to have such plans; others provide incentives that encourage them. In

Learning from others…Oregon Protects Estuaries with Estuary Management Plans
Oregon's Statewide Planning Goal 16, Estuarine Resources, establishes detailed requirements for the planning and management of the state's estuaries. The overall objective is to "recognize and protect the unique environmental, economic and social values of each estuary and associated wetlands and to protect, maintain, and, where appropriate, develop and restore the long-term environmental, economic, and social values, diversity and benefits of Oregon's estuaries." To accomplish this, Goal 16 sets broad requirements for individual estuary plans, which are prepared by affected cities and counties with input from the public and other interested units of government, and for review of individual projects. www.oregon.gov/LCD/OCMP/Est_Intro.shtml

either case, states typically specify the elements that should be included in local comprehensive plans. For the purposes of adaptation, a new adaptation element could be specified, adaptation measures could be incorporated into existing elements (e.g., land use, transportation, environment, natural hazards, etc.), as appropriate, or local adaptation plans could be incorporated by reference. In addition, to address climate change, the timeframe of comprehensive plans may need to extend further into the future. Incorporating adaptation into local comprehensive plans in some way lends them the strength of internal consistency, which is required by some states, to ensure local actions are taken based upon and consistent with the legally adopted comprehensive plan.

Research on local comprehensive plans as vehicles for reducing insured losses in natural disasters suggests that comprehensive plans that include hazard mitigation can reduce such losses: losses are lower in states that require comprehensive plans and even more so in those that require comprehensive plans to address hazards. However, research also suggests that in the absence of a state mandate to prepare a comprehensive plan and address hazards, the planning efforts of many local governments are inadequate (Burby 2005).

While mandates may result in plans, they may not have the desired effect if they do not consider existing barriers to effective planning and/or if the plans are not effectively implemented.[3] When issuing or revising a state mandate, consider the role of the state in the oversight process and how it can enforce and monitor plan implementation as well as development and content (while maintaining flexibility for local decision making).

Since plans are typically not legally binding, governments may pass laws and ordinances and issue implementing regulations to best achieve the desired outcomes identified through the planning process, especially when it comes to land use. The *Second National Assessment on Natural and Related Technological Hazards* states "No single approach to bringing sustainable hazard mitigation into existence shows more promise at this time than increased use of sound and equitable land-use management" (Mileti 1999). The same is likely to hold true for climate change adaptation as well.

Examples of actions that benefit from force of law, some of which are discussed in more detail later in this chapter, include:

- Refining permitting programs to account for climate change
- Zoning development away from sensitive and hazard-prone areas
- Creating setbacks or rolling easements
- Restricting the use of shore protection structures
- Minimizing extent of impervious surfaces
- Establishing buffers around natural features
- Instituting or strengthening building codes in flood- and erosion-prone areas

Learning from others…Washington Requires Local Shoreline Master Programs

Under the State of Washington's Shoreline Management Act, local governments must develop shoreline master programs to balance land use and preservation along shorelines. Essentially, these programs are comprehensive plans and zoning ordinances with distinct environmental orientations that are applicable to shoreline areas and customized to local circumstances. Required environmental designations dictate how much and what types of development and land use are allowed, including what type of shoreline stabilization structures (if any) are permissible. The Department of Ecology provides technical and financial assistance for plan updates. www.ecy.wa.gov/programs/sea/shorelines/

[3] A number of journal articles have been published that examine the effectiveness of state planning mandates. A recent article that references other relevant research is "The Proof of the Planning is in the Platting: An Evaluation of Florida's Hurricane Exposure Mitigation Planning Mandate" published in the *Journal of the American Planning Association* (74, no. 3 (2008): 349-70).

Learning from others…Florida Coastal Communities Plan for Post-Disaster Redevelopment
The State of Florida requires all coastal counties and communities to produce post-disaster redevelopment plans. The plans are expected to cover policies, operational strategies, and roles and responsibilities for implementation to guide decisions for long-term recovery and redevelopment. They should also integrate hazard mitigation and community improvement in line with the goals of the local comprehensive plan. The Florida Coastal Management Program and Department of Community Affairs are completing a pilot planning initiative to create a best practices guide for development of local post-disaster redevelopment plans, which is scheduled to be released in 2010. www.dca.state.fl.us/fdcp/DCP/PDRP/

Regardless of your state's role in regulating or planning for local land use, the state can still make efforts to guide development to help achieve adaptation goals by providing local governments with incentives and recommendations supported by education, model ordinances, and other technical assistance. These incentives should be tied to actual plan implementation and planning outcomes assessed through an evaluation process.

Other Adaptation Measures

The Climate Change Adaptation Measures table introduces measures that can be taken to reduce the impacts and consequences of climate change on the coast. It is not a comprehensive list and is largely limited to measures that coastal managers may have a significant role in. Adaptation measures are organized into categories that describe their primary purpose. In many cases, they serve multiple purposes and could fit into multiple categories (e.g., acquisition could fit under Growth and Development Management, Coastal and Marine Ecosystem Management, and Shoreline Management in addition to Loss Reduction). Some of them also support climate change mitigation (e.g., through carbon sequestration).

It may be useful to reorganize, add, or delete measures in this table when discussing options within the planning team and with stakeholders or when presenting options to local governments. The table also cross references the measures with the phenomena (as introduced in Chapter 2) they may be used to address and the environment (natural and built) they protect, which illustrates that a measure designed to protect one type of environment may also provide protection for the other. The individual measures are discussed, by category, in further detail at the end of the chapter prior to the Key Resources.

Recognizing the benefits of mainstreaming climate change with development, *Adapting to Coastal Climate Change: A Guidebook for Development Planners*, published by the U.S. Agency for International Development, contains an annex that organizes adaptation measures by development goals (as they pertain to climate change adaptation). The goals are:

- Functioning and healthy coastal ecosystems
- The built environment is less exposed and less vulnerable to damages from natural hazards
- Livelihood opportunities are maintained or strengthened in the face of climate change impacts
- Impacts of climate change to human health and safety are minimized
- Governance, policy, and planning capacities for planned adaptation are strengthened

Practitioner briefs describe each measure's relevance, purpose, and application to climate change; information and data requirements; design considerations; and suggestions for improving likelihood of success and provide a list of resources. www.crc.uri.edu/index.php?actid=366

Climate Change Adaptation Measures

Measure	Phenomenon								Environment	
	Increased Air Temperature	Rising Sea Levels	Declining Lake Levels	Increased Storm Intensity/Frequency	IIncreased Precipitation	Decreased Precipitation	Increased Water Temperature*	Ocean Acidification*	Natural Environment	Built Environment
Impact Identification and Assessment										
Research and Data Collection	x	x	x	x	x	x	x	x	x	x
Monitoring	x	x	x	x	x	x	x	x	x	x
Modeling and Mapping	x	x	x	x	x	x	x	x	x	x
Awareness and Assistance										
Outreach and Education	x	x	x	x	x	x	x	x	x	x
Real Estate Disclosure		x	x	x	x				x	x
Financial and Technical Assistance	x	x	x	x	x	x	x	x	x	x
Growth and Development Management										
Zoning		x		x	x	x			x	x
Redevelopment Restrictions		x		x	x				x	x
Conservation Easements		x	x	x	x				x	x
Compact Community Design		x		x	x				x	x
Loss Reduction										
Acquisition, Demolition, and Relocation		x		x	x				x	x
Setbacks		x		x	x				x	x
Building Codes	x	x		x	x	x			x	x
Retrofitting	x	x	x	x	x	x			x	x
Infrastructure Protection	x	x	x	x	x	x			x	x
Shore Protection Structures		x		x	x				x	x
Shoreline Management										
Regulation and Removal of Shore Protection Structures		x		x	x				x	x
Rolling Easements		x		x	x				x	x
Living Shorelines		x		x	x				x	x
Beach Nourishment		x		x	x				x	x
Dune Management		x		x	x				x	x
Sediment Management		x	x	x	x				x	x
Coastal and Marine Ecosystem Management										
Ecological Buffer Zones	x	x	x	x	x				x	x
Open Space Preservation and Conservation	x	x	x	x	x	x			x	x
Ecosystem Protection and Maintenance	x	x	x	x	x	x	x	x	x	x
Ecosystem Restoration, Creation, and Enhancement	x	x	x	x	x	x	x	x	x	x
Aquatic Invasive Species Management	x						x		x	
Water Resource Management and Protection										
Stormwater Management		x	x	x	x			x	x	x
Green Infrastructure		x	x	x	x	x		x	x	x
Water Supply Management		x	x	x	x	x			x	x

* The impacts of increased water temperature and ocean acidification are best managed by reducing the impacts of existing stressors and supporting healthy ecosystems.

Step 3.3: Evaluate, Select, and Prioritize Actions

Unfortunately, there will be more things the planning team wants to do than it will be able to, for a variety of reasons. In this task, the planning team will decide which of the actions identified in the previous step are actually suitable for the state's unique set of circumstances and then prioritize them for implementation. Decisions will need to be made; difficult tradeoffs may be required. Much of this discussion is based on FEMA's *Developing the Mitigation Plan: Identifying Actions and Implementing Strategies* (2003).

One way to evaluate the proposed actions is to use a method that considers the **S**ocial, **T**echnical, **A**dministrative, **P**olitical, **L**egal, **E**conomic, and **E**nvironmental (STAPLEE) opportunities and constraints of each action. The information the planning team generates from this evaluation process will help them weigh the pros and cons of each action to determine which are best for the state. There are no right or wrong answers. The criteria are defined as follows:

- **Social**—The action should be socially acceptable.
  - Will the proposed action disproportionately affect (positively or negatively) one segment of the population?
  - Is the action compatible with present and future community values?
- **Technical**—The action should be technically feasible, help to reduce losses in the long term, and have minimal cumulative and secondary impacts.
  - How effective is the action in avoiding or reducing future losses?
  - Will it create more problems than it solves?
  - Does it solve the problem or only address a symptom?
- **Administrative**—The action should be implementable by the state. Can the state meet the staffing and funding needs of the action or will it need outside assistance?
  - Does the state have the capacity (staff, technical expertise, and funding) to implement and maintain the action, or can it be realistically obtained elsewhere?
- **Political**—The action should be politically acceptable.
  - Is there political support to implement and maintain this action?
  - Is there a champion willing to help see the action to completion?
  - Is there enough public support to ensure the success of the action?
- **Legal**—The state must have the legal authority to implement/enforce the action.
  - Does the state have the authority to implement/enforce the action?
  - Are the proper laws and regulations in place to implement/enforce the action?
  - Are there any potential legal consequences?
  - Will the state be liable for the action or lack of action?
  - Is the action likely to be challenged by stakeholders who may be negatively affected?
- **Economic**—The action should be cost-effective and be likely to pass a benefit-cost analysis.
  - Are there currently sources of funds that can be used to implement the action?

Actions will need to be evaluated based on criteria established by the planning team and, once selected, prioritized for implementation.

Coastal No Adverse Impact is based on the concept of No Adverse Impact from the Association of State Floodplain Managers, which advocates that the actions of any community or property owner should not adversely impact others. It aims to help communities in the coastal zone manage development and growth to avoid activities that might increase flooding or erosion on or off site, degrade the environment, or increase the need for public services such as emergency response and stormwater management. Coastal No Adverse Impact promotes community-based decision making and responsible land use that exceeds minimum requirements established by the federal government. www.floods.org/index.asp?menuid=340&firstlevelmenuid=187&siteid=1

- What benefits (market and nonmarket) will the action provide?
- Does the cost seem reasonable for the size of the problem and likely benefits?
- What burden will be placed on the tax base or local economy to implement this action?
- Does the action contribute to or detract from other community economic goals, such as capital improvements or economic development?
- What are the economic consequences of not implementing the action?

□ **Environmental**—The action should meet statutory considerations and public desire for sustainable and environmentally healthy communities.

- How will the action affect the environment (land, water, protected species)?
- Will the action comply with state and federal environmental laws and regulations?
- Is the action consistent with state environmental goals?

Once the planning team has decided on the acceptable actions given review of the criteria above (or a different set of criteria), it should prioritize the actions for implementation. As part of this exercise, it may want to consider answers to the questions above as well as:

□ How well the action meets the adaptation goals

The following terms (as defined by the United Nations' 2009 *Guidance on Water and Adaptation to Climate Change*) are found throughout the climate change adaptation literature and may be useful in prioritizing actions given the uncertainties of climate change:

- **Win-win options**—Cost-effective adaptation measures that minimize climate risks or exploit potential opportunities but also have other social, environmental, or economic benefits. In this context, win-win options are often associated with those measures or activities that address climate impacts but which also contribute to climate change mitigation or meet other social and environmental objectives.
- **No-regrets options**—Cost-effective adaptation measures that are worthwhile (i.e., they bring net socioeconomic benefits) whatever the extent of future climate change. These types of measures include those which are justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are also consistent with addressing risks associated with projected climate changes.
- **Low-regrets (or limited-regrets) options**—Adaptation measures where the associated costs are relatively low and where the benefits, although mainly met under projected future climate change, may be relatively large.
- **Flexible adaptation options**—Measures which are designed with the capacity to be modified at a future date as climate changes.

Learning from others…Maine BCA Favors Retreat over Protection
In a sea level rise study conducted for the Maine State Planning Office and the U.S. Environmental Protection Agency (EPA) in 1995, benefit-cost analysis (BCA) was used to evaluate four potential options for adapting to sea level rise at a specific study site. The researchers concluded, in that particular case, that it would be more cost-effective to use rolling easements to retreat from the shoreline as sea level rises than to impose setbacks for new development or to protect development and maintain the shoreline. www.epa.gov/climatechange/effects/coastal/SLRAnticipatory.html

- ☐ How urgent the need is for implementation of the action
- ☐ How easy the action is to implement
- ☐ If the action meets multiple objectives (maximizes benefits)
- ☐ If the action also helps mitigate climate change
- ☐ How reliable the projections the action is based on are
- ☐ How flexible the action can be under a range of climate change scenarios

Step 3.4: Write Action Plans

Once the planning team has agreed upon the actions to move forward with, it is highly recommended that brief action plans are written for EACH individual action. Among other things, these plans will establish accountability and ease tracking and evaluating as further described in Chapter 6. Information that could be captured in these action plans includes:

- Title
- Responsible Party(s)
- Priority
- Benefit-Cost Analysis
- Schedule/Milestones
- Evaluation Plan
- Description
- Other Players
- Cost
- Potential Funding Source(s)
- Maintenance Needs
- Goals Addressed

Adaptation Measure Descriptions

The text that follows provides brief descriptions of the adaptation measures listed in the Climate Change Adaptation Measures table on page 51. As previously stated, the measures are roughly organized into categories that describe their primary purpose, yet not necessarily their only purpose, as some could fit into multiple categories. It is outside the scope of this document to provide all the information needed to implement each measure. Key Resources are provided at the end of the chapter.

Impact Identification and Assessment

- ☐ **Research and Data Collection**
- ☐ **Monitoring**
- ☐ **Modeling and Mapping**

It is likely that when the planning team embarked on the vulnerability assessment it did not have as much information as it would have liked. And, even if it did, circumstances will change, science and technology will evolve, and more information will become available. Adaptation is an ongoing process that will continue to rely on new and better information about climate change as well as your state's communities' needs, strengths, and weaknesses. Informed decision making supported by an ongoing vulnerability assessment program that incorporates research and data collection, monitoring, and modeling and mapping should result in coastal communities that are better prepared to adapt to a changing climate.

Research and Data Collection

There is still a lot to be learned about climate change, its impacts and consequences, and how we can reduce our vulnerability to them. The better the planning team understands what climate change means for coastal communities, the better

Learning from others…South Carolina Assesses Management of Shoreline Change
In 2007, the South Carolina Department of Health and Environmental Control established an external advisory committee made up of 23 experts from academia, government, and the private sector to examine science and policy issues related to beachfront and estuarine shoreline management in South Carolina. Specifically, the intent was to help the state address future social, economic, and natural resource impacts of shoreline changes that may result from continued (or accelerated) rise in sea level, development encroachment into the beach/dune system, shoreline alterations, and coastal storms. The committee's report, *Adapting to Shoreline Change*, reflects on over 20 years of shoreline management in South Carolina and makes suggestions for the coming decades. The goals and policy and management recommendations presented in the committee's final report are intended to provide a new foundation for continued shoreline planning, policy development, and program implementation at the federal, state, and local levels.
www.scdhec.gov/environment/ocrm/

positioned they will be to address it. A research agenda could include:

- Monitoring academic and public news media to keep informed about changes in climate change science and adaptation tools, technologies, and success stories
- Collecting physical and socioeconomic data to better understand vulnerabilities
- Documenting events and impacts associated with climate variability and change
- Projecting climate and nonclimate changes (e.g., population growth, loss/gain of open space, etc.)
- Coordinating research agendas and partnering with other state and local governments as well as academic institutions, federal agencies, and nongovernmental organizations

While research activities can stand alone, they will also support other assessment measures (e.g., modeling and mapping) as well as the selection and design of other adaptation actions. Research will likely need to be undertaken to examine the feasibility and cost-effectiveness (benefit-cost analyses) of potential actions.

Monitoring

Monitoring plays a vital role in climate change adaptation. It can alert you to changes in the climate and associated impacts and consequences and

Learning from others…Delaware Shares Lessons Learned in Lidar Acquisition
In 2005, a coalition composed of the Delaware Department of Natural Resources and Environmental Control, U.S. Department of Agriculture, and Delaware Geological Survey contracted with the U.S. Geological Survey and the National Aeronautics and Space Administration to collect lidar for Sussex County. In 2007, the lidar for the remaining two counties, Kent and New Castle, was collected by a commercial contractor. As a result, Delaware is one of the few states with statewide lidar coverage. However, the acquisition and use of the data have posed great challenges, which the state has made great strides in overcoming. To other states seeking to obtain statewide lidar coverage, Delaware offers the following lessons learned:

- Agree on data standards
- Know the end users' technical capacity
- Use a common format for the entire state
- Ensure all data and products are contract deliverables
- Capture metadata and incorporate quality assurance and control

www.csc.noaa.gov/digitalcoast/inundation/_pdf/de_lessons.pdf

Elevation change can be monitored with surface elevation tables placed on benchmarks installed in wetlands.

track ecological and socioeconomic responses. If properly planned and implemented, a comprehensive monitoring program that incorporates multiple tools and considers a variety of systems and processes can provide input to the vulnerability assessment and adaptation strategy. Such a program can document changes and their effects, enabling timely preventive or corrective action and illustrating the effectiveness of adaptation actions. Monitoring can also be an effective way to engage community members and raise climate change awareness.

Learning from Others…Connecticut and New York Team Up to Monitor Long Island Sound
Sentinel Monitoring for Climate Change in Long Island Sound began in 2008 as a partnership between Connecticut's Department of Environmental Protection and the University of Connecticut. With the addition of the Long Island Sound Study (a bi-state partnership of federal and state agencies, user groups, concerned organizations, and individuals dedicated to restoring and protecting the sound), New York has also joined the monitoring effort. The goal of the program is to design and develop a dynamic climate change monitoring program for the ecosystems of the sound and its coastal ecoregions. The long-term monitoring program will identify resources in the sound that are most vulnerable to climate change and most critical to protect and will ultimately enable the partners to develop appropriate adaptation strategies to protect the sound's biodiversity and significant natural resources. jennifer.pagach@ct.gov

Learning from others…Oregon Monitors Beach and Shoreline Change
The Oregon Beach and Shoreline Mapping Analysis Program maintained by the Oregon Department of Geology and Mineral Industries is a monitoring program designed to document the response of Oregon's beaches to both short-term climate variability (e.g., El Niños, extreme storms) and longer-term effects associated with climate change (e.g., increasing wave heights, changes to storm tracks, and sea level rise). The broad purpose of the program is to provide high-quality scientific information about changes along the Oregon coast to coastal managers, city and county planners, the geotechnical community, and other stakeholders to support responsible land use and development, both today and into the future. www.oregongeology.com/sub/news&events/archives/press-release-2009-02-25.pdf

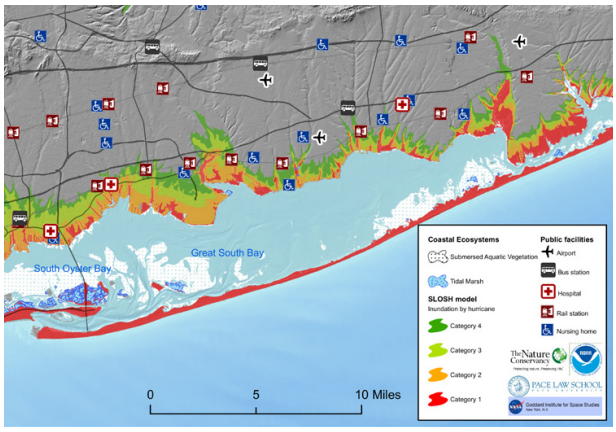
NOAA's National Estuarine Research Reserve Systems' System-Wide Monitoring Program (SWMP) tracks short-term variability and long-term changes in estuarine waters to understand how human activities and natural events can affect ecosystems. SWMP focuses on three related environmental measures: abiotic monitoring, including atmospheric conditions, nutrients and contaminants, and physical water quality factors (e.g., salinity, dissolved oxygen, and tidal range); biological monitoring, including biodiversity, habitat, and population characteristics; and watershed and land cover/land use classification, including changes over time in coastal and estuarine habitat and land use. Coastal managers can use these data to make informed decisions on local and regional issues, which include climate change adaptation. www.nerrs.noaa.gov/RCDefault.aspx?ID=18

A number of tools already exist for monitoring climate variability and ecological health that could be incorporated into a climate change monitoring program. Some of these tools are listed as Key Resources at the end of this chapter.

Modeling and Mapping

Modeling and mapping, which were discussed in Chapter 4, provide valuable input to climate change adaptation planning and implementation. Specifically, models and maps provide information about how climate change might affect a planning area, lending support to vulnerability assessments and communications tools. They may also be used to illustrate the potential outcomes of adaptation actions.

Models simulate reality to better understand how changes in climate may impact natural and built environments. Maps illustrate model outputs but may also be basic graphic representations of certain characteristics (e.g., social, physical, environmental) in a geographic area. Model-based maps may be risk-based, event-based, or scenario-based. Risk-based maps illustrate an event that has a specific probability of occurring over a specific time frame (e.g., Digital Flood Insurance Rate Maps). Event-based maps depict events that have already occurred and their impacts. Scenario-based maps illustrate the outcomes of a projected event (or events). All can provide useful information for climate change adaptation planning and project implementation.



Visually integrating ecosystem, infrastructure, and inundation data helps planners make more informed decisions.

These measures, modeling in particular, can be extremely resource intensive and complex and may require engaging experts, such as academics, nongovernmental organizations, consultants, or federal partners. Alternatively, pre-existing models and maps can be used in their original form, or they could be downscaled or improved upon through

As part of its activities related to the National Flood Insurance Program, FEMA has begun the transition from Flood Map Modernization to Risk Mapping, Assessment, and Planning (Risk MAP). The vision for Risk MAP is to work collaboratively with state, local, and tribal entities to deliver quality information that increases public awareness and leads to actions that reduce threats to life and property. FEMA is updating Digital Flood Insurance Rate Maps to address gaps in required engineering and mapping, based on current conditions, for high flood risk areas impacted by coastal flooding, levees, and other flood hazards. www.fema.gov/plan/prevent/fhm/rm_main.shtm

Learning from others…BCDC Updates Sea Level Rise Maps

In 2006, the San Francisco Bay Conservation and Development Commission (BCDC) released a series of maps depicting the lands most vulnerable to sea level rise. To improve the accuracy and precision of the maps, in 2009, using funds from the California Energy Commission's Public Interest Energy Research Program, BCDC released new maps based on sea level rise data from the U.S. Geological Survey. The maps show areas vulnerable to 16 inches of sea level rise at mid-century and 55 inches at the end of the century (scenarios that are generally consistent with other state sea level rise estimates). www.bcdc.ca.gov/planning/climate_change/index_map.shtml

the addition of data (e.g., Digital Flood Insurance Rate Maps could be enhanced by adding future conditions hydrology, erosion zones, or areas that may be inundated by sea level rise). In any case, models and maps will need to be updated to reflect observed changes, new projections, improved data, and changes in exposure.

Awareness and Assistance

- **Outreach and Education**
- **Real Estate Disclosure**
- **Financial and Technical Assistance**

Effective climate change adaptation relies on an informed stakeholder base, from elected officials to the general public. In addition, since a number of the measures discussed in this guide are best implemented at the local level, providing financial and technical assistance to local governments, as well as individual home and business owners, will be critical to overall success. Increasing awareness and providing assistance enhances adaptive capacity and can better prepare your state's coast to withstand the impacts and consequences of climate change.

Outreach and Education

Outreach and education are distinct but related activities, and both are vitally important for effective climate change adaptation. In this guide, outreach is the provision of information to all stakeholders (anyone who will be affected by climate change in your state), and education involves the formal education system (typically kindergarten through grade 12).

Purposes of outreach can include engaging stakeholders in the planning effort, gaining support for planning and action implementation, informing the public about climate change and their role in adaptation, communicating the benefits of natural resources and ways to protect them, and changing attitudes and behaviors. Outreach is not a one-time activity. It should begin with the launching of the adaptation planning effort and continue throughout the process (as introduced in Chapter 3) and as new information becomes available, milestones are met, successes become evident, and whenever an appropriate opportunity presents itself (e.g., when the plan is released or when adaptation actions are implemented that require support, adherence, or assistance).

Using visuals to explain how coastal areas may be impacted by climate change can build support for adaptation.

There are numerous challenges to communicating about climate change. The uncertainty of the science and the presence of more immediate issues are perhaps the biggest. While a few resources for helping conduct outreach and craft and deliver adaptation messages are noted at the end of the chapter, the planning team should consider enlisting communications specialists to help in this endeavor.

An outreach strategy can help guide climate change adaptation communications and, similar to the strategy for an adaptation plan, should identify goals and actions to ensure stakeholders are being reached in an effective manner. An outreach strategy involves identifying the target population, conducting a population profile (so the best way to communicate with them is understood), crafting the message, and then deciding how to disseminate it. There will likely be multiple stakeholder groups/target populations (e.g., planning team members and other participating stakeholders, the general public, state and local elected officials and other decision makers, developers, resource managers, etc.) who may require tailored messages and different delivery formats.

Learning from others…Hawaii Guide Informs Buyers about Purchasing Coastal Real Estate
Recognizing the increasing rates of rapid residential growth and development along the waterfront of the main Hawaiian Islands, the University of Hawaii Sea Grant College Program, with support from the State of Hawaii Department of Land and Natural Resources and the Coastal Zone Management Program, published the *Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawai'i—A Practical Guide of Common Questions*. The publication provides basic information on coastal hazards that waterfront property investors and developers should consider when purchasing coastal land. The guide also addresses common concerns and questions and provides options and resources to protect coastal real estate and safeguard the lives of residents. www.soest.hawaii.edu/SEAGRANT/communication/publications.php

As the strategy is drafted, the planning team should consider what is already being done to reach the target populations. Can climate change adaptation be incorporated into existing government programs for climate change mitigation, coastal management, emergency management, public health, water conservation, stormwater management, etc.? What communications vehicles are planning team members already using? Are there lessons learned that the planning team can benefit from? As appropriate, coordinate outreach efforts with federal activities, including National Flood Safety Awareness Week, Hurricane Preparedness Week, American Wetlands Month, and others. Be prepared to take advantage of windows of opportunity, which may come in the form of extreme weather events (in your state or elsewhere); the arrival of climate conditions that may affect your state (e.g., annual storm seasons, El Niño, La Niña); national media attention, etc.

"Effective communication has to achieve a match between message content, framing, and the concerns and values with which audiences resonate" (Bostrom and Lashof 2007). When communicating with the public, consider geographic, socioeconomic, and cultural differences. Who is most vulnerable? What languages do they speak? What are their interests?

Surveys can help inform the planning team about how stakeholders feel about climate change and adaptation and what they value most and may help it better understand how to engage them on the subject. For instance, if some stakeholders have doubts about climate change, or the term itself is too politically charged, taking an approach that focuses on the impacts and consequences, many of which they may have already experienced or are familiar with, may be more effective.[4] A demonstration of the trends can illustrate the need to take action.

Initial outreach efforts to engage and involve stakeholders (see Chapter 3) may simply include an introduction to climate change and the planning process and information about how to get involved. In crafting

A number of resources are available to help develop and conduct effective outreach. One of these resources is the NOAA Sea Grant program. Sea Grant's network of extension agents links university resources and expertise with local communities and user groups, taking complex information and showing people how to use it to solve problems. This includes developing new information through original applied research, gathering existing information to meet user needs, and transmitting information through pamphlets, courses, workshops, lectures, and meetings. www.seagrant.noaa.gov/

[4] While this may help adaptation's cause, it should be noted that such an approach does not support climate change mitigation. And, since mitigation is essential to addressing climate change, this kind of approach should be used with caution.

"If individuals are to be involved in mitigating and adapting to climate and other global changes, the problems need to be meaningful and relevant; people need help to understand both causes and solutions; communicators must—despite uncertainty—create a sense of appropriate urgency (but not irrational fear); and they must enable and empower people to act in sustainable ways and support relevant public policy" (Vogel 2007).

Learning from others…Maine and Oregon Sea Grant Programs Advance Outreach through Social Science
Since 2007, Maine and Oregon Sea Grant Programs have been working together to understand how best to educate the public about climate change and motivate them to act. Specifically, the project used focus groups and surveys of coastal landowners and decision makers to better understand their concerns, knowledge, motivations, and decision-making processes and aims to, ultimately, develop a test model of public outreach about climate change that is transferable to coastal managers in other states. Videos were produced for both states based on the results. In Maine, a five-year outreach plan includes projects to address identified information gaps, including a hazard mitigation guide, an interactive web site, and a series of workshops for coastal property owners and municipal officials.
www.seagrant.umaine.edu/extension/coastal-community-resilience; http://seagrant.oregonstate.edu/research/ClimateChange/index.html

the message, the planning team should consider what it wants the target population to take away from the message and/or how it would like them to respond (i.e., what it would like them to do).

Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments offers the following suggestions, which should be localized and made relevant for your target population(s), for developing a general climate change adaptation message (Snover et al. 2007):

- Describe changes that have already been observed
- Describe changes that are expected
- Describe the potential impacts and consequences
- Convey the need for action but balance the challenges with optimism
- Develop a course of action
- Acknowledge that questions remain

Also, think about illustrating the message, either with images, maps, or success stories. Convey the importance of recognizing that the needs of humans and nature are complementary. Emphasize how, in some instances, adaptation will provide benefits with or without climate change. And, explain the potential costs of inaction or delayed action. As the plan evolves, so will the level and type of information that can be provided and that stakeholders will require.

A variety of traditional and nontraditional ways exist to communicate the message. These include, but are

Learning from others…Fact Sheets Support Adaptation Planning in Connecticut
The Connecticut Department of Environmental Protection has developed a series of initial climate adaptation fact sheets, "Facing Our Future," detailing current observations and providing cursory recommendations for alternative approaches to foster adaptation at the local and regional level. These fact sheets address overlapping technical areas or categories: biodiversity and habitat, fisheries, forestry, infrastructure, natural coastal shoreline environment,outdoor recreation, water resources, and wildlife. www.ct.gov/dep/cwp/view.asp?a=2684&q=436600&depNav_GID=1619

Learning from others…Texas Brings Climate Change to the Classroom
The University of Texas Austin's Bureau of Economic Geology and the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University Corpus Christi have developed a 3-D virtual model of the Gulf of Mexico and Texas coastal environments for use in the classroom and for the general public to explore how relative sea level change may impact the coastal zone. The project, sponsored in part by the Texas State Energy Conservation Office and the Texas Coastal Coordination Council, also includes a lesson plan titled "Sea Level Changes and the Texas Coastal Environment," a PowerPoint presentation for teachers to use to introduce the lesson in their classrooms, and a short video explaining how to use the virtual model. http://coastal.beg.utexas.edu/thscmp/vbi.htm

not limited to, print, broadcast, online, and social media; events and meetings; internal governmental communications; billboards; and direct mail, such as newsletters, brochures, utility bills, flyers, and surveys (which can be used to inform as well as gather information). Museums, libraries, nature centers and preserves, and other informal education providers can also serve as effective venues for dissemination of information about climate change.

In addition to the education provided via the outreach program, the planning team may want to work with the state's department of education to create programs to educate teachers about climate change and to develop curricula for the classroom. The primary goals of these efforts should be to equip students with basic information about climate change and to empower them to take action and to build awareness among their family and friends. Your state research institutions can also provide input to these efforts.

Real Estate Disclosure

According to FEMA, most prospective buyers do not factor in hazards when they are considering purchasing property (CRS 2007). The disclosure of an individual property's vulnerability to coastal hazards enables potential buyers to make informed decisions reflecting the level of impacts they are willing and able to accept. States can require disclosures that include information about known flood, erosion, and subsidence hazards and may even suggest that a given property may become more vulnerable as the climate changes (e.g., rising sea levels, increasing storm intensity). States can also provide information about hazard mitigation to help new homeowners willing to accept the potential impacts and consequences. Information about rolling easements, setbacks, buffers, wetlands, redevelopment restrictions, shore protection structures (prohibition, restrictions, maintenance requirements), beach nourishment, and other coastal zone and environmental laws, regulations, and policies that may affect the property could also be disclosed.

Learning from others…South Carolina Real Estate Disclosure Protects Interests of Buyers
South Carolina's Coastal Tidelands and Wetlands Act requires contracts of sale or transfers of real property to contain disclosure statements if a beachfront property is located seaward of the setback or jurisdictional line. The statement must indicate that the property is or could be affected by the lines and must include the local erosion rate most recently made available by the South Carolina Office of Ocean and Coastal Resource Management (SC OCRM) for that zone. SC OCRM has developed an educational brochure for real estate workshops, and the state's Real Estate Commission has developed an addendum for contracts of sale that addresses the disclosure requirement and also includes information about the width of the flood zone (V-Zone). In addition, per the Residential Property Condition Disclosure Act, South Carolina's Residential Property Condition Disclosure Statement includes information about flood hazards.
www.scstatehouse.gov/code/statmast.htm; www.scdhec.gov/environment/ocrm/pubs/docs/qa_realestate.pdf; www.llr.state.sc.us/POL/REC/index.asp?file=pub.htm

Learning from others…Louisiana Funds Resiliency Projects in Coastal Parishes
With $10 million from the U.S. Department of Housing and Urban Developments' Community Development Block Grant program, the Louisiana Recovery Authority is helping communities affected by Hurricanes Gustav and Ike create plans to increase resiliency. The competitive Comprehensive Resiliency Program will fund nonconstruction projects, such as the development of forward-thinking plans related to land use, economic development, resiliency, and water management; development of local zoning ordinances that will help prevent or dramatically minimize business, housing, and infrastructure damage from future storm events; and augmentation of local code enforcement staffs. http://lra.louisiana.gov/index.cfm?md=newsroom&tmp=detail&articleID=608

Information could be provided in property listings, in contracts to purchase, or at settlement and should be recorded in deeds and other appropriate legal documents; mapped hazard areas could be shown on lot surveys. Brochures that provide more detailed information about the hazards and associated regulations would also benefit potential buyers and may be part of a larger outreach strategy as described above. Best practices for hazard disclosure include providing notification as early in the process as possible, crafting clear and direct notices, educating professionals involved in the disclosure process, and establishing strong and clear enforcement provisions (Godschalk et al. 2000).

Financial and Technical Assistance

Since a lot of climate change adaptation will be taking place at the local level, it is in your state's best interest to build the capacity of local governments to respond through both financial and technical assistance. Financial support could be provided as competitive or formula grants or could be targeted to specific projects and pilots, which may also be accompanied by technical assistance. By supporting pilot projects, the state will be able to test out adaptation measures in a limited number of communities before applying them statewide. Financial assistance could also be provided through incentives, where special funds are only available where prerequisites established by the state have been met. An example of a related incentive program is the National Flood Insurance Program's Community Rating System, which offers discounts on flood insurance in participating communities.

Technical assistance could also take a number of forms. It could include the provision of training, data,

The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Participating communities receive flood insurance discounts that reflect reduced vulnerability to flooding. Other benefits of participation include enhanced public safety, reduction in damage to built and natural environments, avoidance of economic disruption/losses, reduction of suffering, and access to technical assistance. In addition, some activities can help a community qualify for federal assistance programs (e.g., hazard mitigation planning). There are 18 floodplain management activities credited by the CRS, organized under four series:

- Public Information
- Mapping and Regulations
- Flood Damage Reduction
- Flood Preparedness

Each CRS activity has criteria that must be met in order for communities to receive credit. Encourage local governments to review these criteria when designing and implementing adaptation measures to ensure they do so in a way that will earn them maximum credit. Additionally, consider how the activities of state agencies can support local governments in their efforts to improve their ratings, including through uniform minimum credits, which communities can earn for activities implemented by regional or state agencies. www.fema.gov/business/nfip/crs.shtm

Learning from others…Connecticut Helps Town with Climate Change Adaptation
With funding from the EPA's Climate Ready Estuaries Program, the Connecticut Department of Environmental Protection's Office of Long Island Sound Programs partnered with ICLEI–Local Governments for Sustainability through the Long Island Sound Study to host a series of coastal climate change adaptation workshops for the Town of Groton. The three-part series was designed to engage representatives from federal, state, and local governments in climate change adaptation efforts and provide them with the understanding and tools needed to effectively adapt to climate change. The results of the workshops, including an adaptation report with recommendations for future actions, will be presented to town officials and other agency leaders in fall 2010. www.icleiusa.org/action-center/planning/climate-adaptation-planning-resources/groton-connecticut-coastal-climate-adaptation-workshop-presentations; www.ctclimatechange.com/

maps, models, GIS support, planning guidebooks, model ordinances, and outreach materials. Once again, survey the planning team to see what programs already exist. Could adaptation be incorporated into them or could their focus be shifted?

Training advances outreach efforts and, as with outreach, will likely have multiple target populations and messages. Each program should address the individual needs of the target population, which could be elected officials; state and local planners, natural resource managers, or building code officials; developers; marine contractors; the general public; etc. For example, a training program to educate elected officials about their role in climate change adaptation would look very different from a program designed to teach marine contractors about living shorelines.

Many local governments already provide map information services, where they respond to inquiries regarding the location of a property in relation to special flood hazard areas as well as its base flood elevation. However, due to both financial and technical constraints, this information may be limited to information on a Digital Flood Insurance Rate Map. Should the state expand mapping activities to better capture the location of natural resources and identify areas susceptible to other coastal hazards, this information could be passed along (e.g., as GIS overlays) to local governments to better inform their map information service as well as their planning efforts. In addition, this information could be used as input to a coast-wide web mapping application that would allow local governments and other stakeholders to view the location of hazard-prone and natural areas.

In addition to providing data, maps, and models, which will help lay the foundation for an adaptation plan, the state can further support the planning activities of local governments by providing planning guidance, such as a local version of this document customized for your state. Consistent information provided all along your coast in the form of vulnerability assessment tools and planning requirements and standards can help compare needs across communities and better assess how to allocate limited resources.

Learning from others…Ohio Coastal Atlas Supports Coastal Decision Making and More
The Ohio Coastal Atlas Project is a suite of resources developed by the Ohio Department of Natural Resources Office of Coastal Management. The atlas provides coastal decision makers, professionals, educators, interest groups, and the public with information about Lake Erie and its watershed. The atlas project consists of a 240-page printed edition, a DVD, and two online components—an interactive Lake Erie map viewer and static map library. Topics range from Lake Erie bathymetry, elevation contour lines, coastal barrier resources, wetlands, land cover, U.S. Army Corps of Engineers project locations, flood hazards, sand resources, nearshore substrates, and more. www.ohiodnr.com/AtlasGIS/tabid/19562/Default.aspx

NOAA's National Estuarine Research Reserve System's Coastal Training Program offers a number of trainings relevant to meeting the challenges of climate change. Programs focus on issues such as living shorelines, Coastal No Adverse Impact, effective science communication, wetland restoration, and more.

In 2009, the "Planning for Climate Change" workshop, geared primarily toward shoreline planners, was developed for Coastal Training Programs at National Estuarine Research Reserves (and other programs/agencies) to customize and use as part of their climate change educational efforts. It was piloted twice in Washington State and, while it lays a foundation in current climate research, it primarily addresses the fundamentals of how to prepare and adapt to the anticipated impacts of climate change. The workshop has already been modified for the San Francisco area, and a number of other reserves plan to offer similarly customized workshops in 2010. Workshop materials, evaluation results, lessons learned, PowerPoint presentations, and streaming video of the training sessions are available online. Project partners include the Padilla Bay National Estuarine Research Reserve, Washington State Department of Ecology, Washington Sea Grant, the University of Washington's Climate Impacts Group, and the King County Executive Office.
http://nerrs.noaa.gov/Training.aspx

Growth and Development Management

- Zoning
- Redevelopment Restrictions
- Conservation Easements
- Compact Community Design

As development and redevelopment along our coasts continues, there are a number of ways growth can be managed to guide it away from hazard-prone areas and valuable or sensitive natural resources. While growth is often desirable and necessary, it must be managed in a way that addresses the needs of the population and also offers protection to natural resources and supports the services they provide.

A robust planning program is essential to effectively manage growth and development, and "evidence suggests that land use planning techniques are the most effective approaches for promoting sustainable mitigation from hazards and avoiding infrastructure losses" (Burby et al. 2000). While most growth will be managed locally, there is still a role for the state to play, including restricting growth where it affects state lands and offering assistance and disincentives (e.g., not providing funding for infrastructure or other services that will encourage growth in inappropriate areas) to local governments.

The greatest opportunity to protect land is before it is developed. It is much easier and cheaper to direct new

In consultation with the Smart Growth Network, NOAA, EPA, the International City/County Management Association, and Rhode Island Sea Grant drafted coastal and waterfront smart growth elements to address the unique growth-related issues of waterfront communities. The elements augment the existing smart growth principles to reflect the specific challenges and opportunities characterizing the coast and waterfront. *Smart Growth for Coastal and Waterfront Communities* is a guidance document for planners, government officials, developers, nonprofit groups, and coastal and waterfront residents that describes the coastal and waterfront smart growth elements to help communities plan for growth while protecting their natural and economic resources, maritime heritage, and traditional sense of place. The guide includes an overview of growth-related challenges and opportunities faced by coastal and waterfront communities, a description of tools and techniques for applying smart growth elements, and case studies illustrating smart growth in action. A number of the suggestions can be applied to climate change adaptation.
http://coastalsmartgrowth.noaa.gov/

The Coastal Barrier Resources Act (CBRA) was passed in 1982 to "minimize the loss of human life, wasteful expenditure of federal revenues, and the damage to fish, wildlife, and other natural resources associated with the coastal barriers." It does so through a free-market approach that restricts federal expenditures that might encourage or support development, including flood insurance, within the Coastal Barrier Resources System, which consists of undeveloped coastal barriers along the Atlantic, Gulf, and Great Lakes coasts. The law does not prohibit development; it simply assigns the burdens associated with the potential hazards directly to those who choose to accept them and away from the American taxpayers. According to the U.S. Fish and Wildlife Service, which administers the program, CBRA has saved over $1 billion and will save millions more in the future. www.fws.gov/habitatconservation/coastal_barrier.html

construction away from sensitive and hazard-prone areas than it is to restore disturbed and degraded land and to retrofit or move existing structures. A number of the measures discussed in this guide can be used to restrict unwise development. Vulnerability is best reduced by limiting exposure. However, even if land is allowed to be developed, measures that can help reduce the impacts of climate change (e.g., easements and building design) are more feasible before development than after.

Growth and development management also includes loss reduction and shoreline management measures. These measures are discussed in more detail later in this chapter.

Zoning

Intended to create a healthy, safe, and orderly community while balancing a diversity of interests, ideally as envisioned by a comprehensive plan, zoning is one of the most commonly used methods of regulating land use. A number of the measures discussed in this guide can be implemented through zoning.

Zoning can be used to regulate parcel use, density of development, building dimensions, setbacks, impervious surfaces, type of construction (e.g., easily movable), shore protection structures, landscaping, etc. It can also be used to regulate where development can and cannot take place, making it an invaluable tool in efforts to protect natural resources and environmentally sensitive areas and guide development away from hazard-prone areas. Permissible uses and standards vary by zoning district. Types of districts include general use districts; overlay districts, where provisions in addition to those on the underlying districts apply; and special use districts, in which all uses require permits.

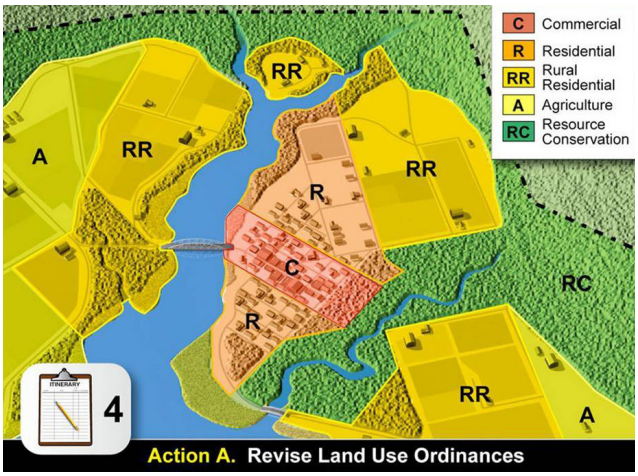
Floodplain zoning is an example of a zoning application that, if thoughtfully drafted, can provide multiple benefits. In addition to protecting life and property, benefits of floodplain zoning can include resource conservation, open space preservation, public access, and water-quality protection. Floodplain regulations that just meet the minimum requirements of the National Flood Insurance Program are more focused on how to build safely in the floodplain and may not provide the additional benefits.

Learning from others…Rhode Island Restricts Development on Coastal Barriers
At the state level, Rhode Island classifies its barrier islands into three categories based on the level of development present: developed, moderately developed, and undeveloped. In the 1980s, the state banned any new residential and commercial buildings on moderately and undeveloped barrier beaches, 82 percent of the state's barrier beaches, to prevent additional development in these high hazard areas. The state's Coastal Resources Management Program regulations also prohibit the expansion of construction of new public infrastructure such as water, gas, and sewer lines on all the state's barrier islands. www.crmc.ri.gov/regulations.html

Learning from others…Shoreland Zoning Ordinances Required in Wisconsin
Wisconsin requires counties to administer shoreland zoning ordinances that meet the minimum standards of Wisconsin's Shoreland Management Program. These standards are designed "to further safe and healthful conditions; prevent and control water pollution; protect spawning grounds, fish and aquatic life; control building sites, placement of structures and land uses; and reserve shore cover and natural beauty." A model ordinance and *Creating an Effective Shoreland Zoning Ordinance: A Summary of Wisconsin Shoreland Zoning Ordinances* are available online. http://dnr.wi.gov/org/water/wm/dsfm/shore/local.htm

As the climate changes, adjustments will need to be made. Zoning regulations will need to be adaptive. Current regulations may need to be revised to accommodate for new conditions. For example, regulations that limit building height may need to be altered in light of changing elevation requirements. Your state may want to encourage local governments to review the adequacy of their zoning, make changes and additions as appropriate, and to consider climate change in future zoning decisions. As the need for new districts arises, model language can help ease the process and advance state interests.

Subdivision regulations, which are typically linked to zoning regulations but often separate, are also useful tools in limiting development in hazard-prone and sensitive areas. Subdivision regulations go beyond zoning regulations, establishing requirements for lot creation and development. Regulations may limit the subdivision of land in inappropriate areas; specify characteristics such as size, shape, orientation, and layout; set standards for infrastructure, open space, buffers, landscaping, and access/egress; and require hazard assessments and the consideration of impacts on neighboring lands.



Zoning is a regulatory tool that communities can use to implement growth and development management measures.

Redevelopment Restrictions

The most likely places to be affected by the impacts of climate change are those that have been affected by related events in the past. A building lost to one storm is likely to be lost to another if built back on its prestorm footprint and without significant structural improvements. Despite the desire to return to prestorm conditions, it is important to build back right. Combining restrictions with acquisition/demolition/relocation programs provides safer options to property owners in the wake of the loss of or damage to their homes or businesses. Such restrictions will likely be more acceptable if adopted prior to a disaster rather than during recovery.

Restrictions could apply to repetitive losses or severe repetitive losses as defined by FEMA, or they could apply to any structure in a particular area (e.g., the 100- or 500-year floodplain) that is destroyed or substantially damaged. A prohibition on redevelopment of structures destroyed or substantially damaged by storms or chronic erosion would serve multiple purposes. It would protect life and property by removing them from harm's way and allow the natural and beneficial functions of the floodplain to return. However, an outright prohibition is often politically and practically difficult to implement (though less so when public

Learning from others…Maine Restricts Reconstruction of Wave-Damaged Buildings
Maine's Coastal Sand Dune Rules set standards for reconstruction of buildings severely damaged (damage that exceeds 50 percent of a building's value) by ocean waves. Any reconstructed building must meet restrictions on building size, height, and elevation as well as setback requirements, to the extent practicable. However, projects within the coastal sand dune system may not be permitted if "the property may reasonably be expected to be eroded as a result of changes in the shoreline such that the project is likely to be severely damaged after allowing for a two-foot rise in sea level over 100 years." A building located in a V-Zone may not be reconstructed more than once. www.maine.gov/sos/cec/rules/06/chaps06.htm

Combining redevelopment restrictions with acquisition, demolition, relocation programs enables communities to "build back better" after a disaster.

health or access is at stake). Restrictions that attach provisions to reconstruction, such as siting, design, and construction requirements, are often more achievable.

At a minimum, where rebuilding is allowed, general permitting requirements for new construction should be enforced, including for those structures that were nonconforming prior to their loss. In addition, rebuilding after a loss provides an opportunity to include additional measures that will better protect the building and the land on which it resides.

Conservation Easements

A conservation easement is a legal agreement between a landowner and a land trust or government agency that can be used to restrict development in sensitive and hazard-prone areas. Unlike acquisition and open space preservation and conservation, which are also useful tools for managing where development takes place and are discussed in the Loss Reduction and Coastal and Marine Ecosystem Management categories, respectively, easements may not preclude other land uses and allow property to remain in private ownership.

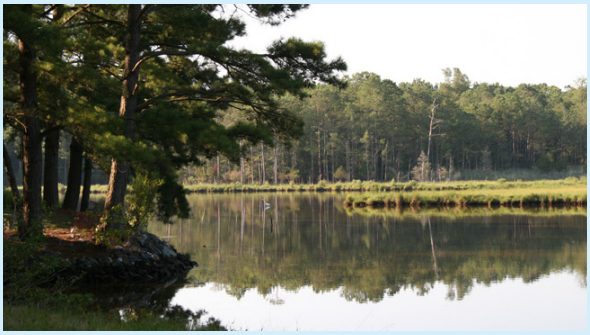
Landowners can sell or donate their easement. Easements that are sold are also known as PDRs (purchase of development rights). Landowners who donate their easement may be eligible for federal or state tax breaks. Easements typically apply in perpetuity and are passed on from owner to owner. Most are placed on individual properties, but they may also be placed on subdivisions or coordinated at a regional scale (e.g., to more effectively manage a strip of shoreline or accommodate beach and wetland migration).

Conservation easements can be placed on the entire property or on select areas and can be written to prohibit all types of development or to impose restrictions and requirements in regard to size, construction, etc.[5] Easements can also be used to ban or set standards for shore protection and restrict

[5] Rolling easements are a type of conservation easement that may or may not be voluntary. For more information, see the Shoreline Management category.

Learning from others…Maryland Program Protects Land through Easements

Maryland's Rural Legacy Program aims to protect large, contiguous tracts of land and other strategic areas from sprawl development and to enhance natural resource, agricultural, forestry and environmental protection. It does so through the acquisition of easements and fee estates from willing landowners and the supporting activities of Rural Legacy Sponsors and local governments. Through the program, 7,200 acres of land have been protected to date in the Coastal Bays Rural Legacy Area through the purchase of easements. www.dnr.state.md.us/land/rurallegacy/



activities that may impair natural processes. And, as appropriate, they can be used to secure public access.

Conservation easements are typically voluntary. As such, landowners have input on their restrictiveness. The voluntary and flexible nature of easements makes them more attractive to landowners but often less effective than regulatory approaches such as setbacks, zoning, etc.[6] A conservation easement program is likely to be most effective when it has strong planning and outreach components that identify lands that would benefit from easements and inform property owners about easements and their benefits.

Compact Community Design

Compact community design[7] allows development to occur while protecting natural resources. It is a pattern of development that aims to use land more efficiently by grouping a mixed-use of buildings together, minimizing their collective footprint, and leaving undeveloped land in its natural state.[8] More open space and fewer impervious surfaces means reduced runoff and flooding. It also means reduced investments in services and infrastructure design, construction, and maintenance. Compact communities are also known for their walkability, thus compact community design also helps mitigate climate change.

The high density development suggested by compact community design can allow for more opportunities to guide development away from sensitive and hazard-prone areas, but without proper planning, it can lead to increased susceptibility to hazards. Any such design must still consider the location of hazard-prone areas as well as the location and carrying capacity of evacuation routes. Compact community design is best implemented in conjunction with zoning ordinances that regulate development in hazard-prone areas and strong building codes.

[6] An alternative to a conservation easement that still allows for development is a transfer of development rights, which is a voluntary, market-based land use mechanism that transfers development rights from sending zones, parcels designated unsafe or in need of protection, to receiving parcels, areas deemed acceptable for additional growth.

[7] Other related concepts include compact building design, conservation design, and clustered development.

[8] Open space preserved through compact community design should be done so in conjunction with plans for green infrastructure and wetland migration corridors, which are discussed later in this chapter.

Compact community design, when combined with protected open space, can provide a natural buffer from coastal hazards, such as storms and sea level rise.

Along heavily developed coastlines, compact community design may be difficult to implement since little undeveloped open land will be available. Nonetheless, there are times when opportunities may present themselves, including when planning economic redevelopment projects, when previous uses on large tracts of land are no longer supported (e.g., military facilities are closed down), and in the aftermath of a disaster.

Loss Reduction

- **Acquisition, Demolition, and Relocation**
- **Setbacks**
- **Building Codes**
- **Retrofitting**
- **Infrastructure Protection**
- **Shore Protection Structures**

The intent of the measures in this category is largely to reduce losses to life and property (e.g., homes, businesses, infrastructure) from the impacts of climate change, primarily the exacerbation of existing hazards, such as storms, floods, and high winds. Some of the measures are more permanent than others, and some more controversial. Some require moving development away from hazard-prone areas, and others provide for protection where development in these areas is allowed or already in place. And, some provide benefits to the natural environment as well as the built environment, while others can negatively affect the natural resources we are also trying to bolster and preserve.

Acquisition, Demolition, and Relocation

The most effective way to reduce losses is to acquire hazard-prone properties, both land and structures, demolish or relocate structures, and restrict all future development on the land. Generally, acquisition is the best and most cost-effective hazard mitigation alternative because it permanently removes people and their homes from harm's way (FEMA 1998). In addition, it can reduce the emotional and financial costs associated with response and recovery from future storms, reduce flooding by restoring natural floodplain functions and increasing flood storage area, and support environmental and public access/recreational goals.

While acquisition serves multiple purposes, this discussion focuses on the acquisition of land and associated structures that are vulnerable to natural hazards. The open space preservation and conservation discussion later in the chapter examines the acquisition of property primarily for natural resource protection.

Acquisition programs, also known as buyout programs, typically acquire land and structures and

Learning from others…Puerto Rico Families Relocated after Hurricane Georges
Following Hurricane Georges in 1998, the Office of the Governor of Puerto Rico created the New Secure Housing Program to relocate families whose homes had been damaged or destroyed by flooding. As part of the program's Toa Baja project, and with funds provided by FEMA's Hazard Mitigation Grant Program, 223 families were relocated. Following acquisition, the City of Toa Baja demolished the remaining structures and cleaned up the site. www.fema.gov/mitigationbp/brief.do?mitssId=748

Learning from others…Two Hundred+ Mississippi Homes Removed from Harm's Way
Following Hurricanes Georges in 1998, Gulfport, Mississippi, implemented a $19 million acquisition project as a result of repetitive coastal flood losses in the Brickyard Bayou neighborhood. With funding from FEMA (and local match), the city acquired and demolished approximately 230 residential buildings, a number of which were repetitive loss properties.

After Hurricane Katrina, damage assessments conducted by FEMA indicated that the majority of the acquired homes would have been flooded by up to six feet of water had they not been removed. Houses just outside the project area sustained significant flood damage. FEMA concluded that the project "essentially paid for itself with losses avoided in this one event." www.fema.gov/library/viewRecord.do?id=1857

require structures to be demolished or relocated and the land to be deeded as open space in perpetuity and restored to its natural condition to allow for more appropriate uses. Factors involved in the decision to demolish or relocate may include cost-effectiveness (some structures are easier and cheaper to move than others), condition of the structures, property owner interests, availability of land for relocation, etc. Acquisition/demolition projects are typically easier to implement than acquisition/relocation projects.

A buyout program can be an effective tool for removing people and development from hazard-prone areas.

It is a good idea to plan for acquisition by identifying and prioritizing properties and structures for acquisition. Target properties may include:

- Properties that have suffered multiple losses (e.g., repetitive loss and severe repetitive loss properties)
- Properties with structures that are substantially damaged or destroyed
- Properties (with and without structures) that are in an identified hazard-prone area (e.g., floodway, sea level rise inundation area, special flood hazard area, erosion hazard area)
- Hazard-prone properties for which retrofitting (e.g., elevating) is not cost-effective
- Properties in potential wetland migration corridors

Learning from others…Alaska Village Plans for Relocation
In 1994, in response to severe erosion problems, now aggravated by climate change, the Village of Newtok, Alaska, began planning for relocation. With input and commitment from village residents, a site approximately nine miles southeast of Newtok was selected and approved by Congress as part of a land exchange with the U.S. Fish and Wildlife Service. In May 2006, the Newtok Planning Group, consisting of federal, state, village, regional, and nongovernmental partners, was formed to accelerate the process by identifying resources and establishing a relocation strategy. While significant progress has been made by the group, including characterizing the site and developing an infrastructure plan, obstacles remain. Funding, in particular, remains a major challenge. www.commerce.state.ak.us/dca/planning/Newtok_Planning_Group_Webpage.htm

Learning from others…Texas Program Offered Financial Assistance for Removal
Under the Texas Open Beaches Act, the state may petition the courts to authorize the removal of any structure on the public beach to ensure the public's access. In 2006, the Texas General Land Office offered financial assistance to homeowners for reimbursement of expenses (up to $50,000) for relocation or demolition of structures that had become located on the public beach easement as a result of weather events or erosion. Priority was given to structures that posed a threat to public health and safety or prevented the public from accessing the beach. In Surfside, Texas, 34 properties were identified as eligible for assistance. Most of the 34 owners accepted assistance from the state or were bought out by FEMA. In September 2008, 10 of the 14 properties still engaged in litigation with the state were destroyed by Hurricane Ike. www.glo.state.tx.us/news/archive/2006/events/beachplan.html

While buyout programs are typically voluntary, where property owners are not required to sell, other tools for acquiring structures and property in hazard-prone areas include exactions and eminent domain. In all cases, a concerted planning effort, involving potential sellers where applicable, should be undertaken to help avoid piecemeal acquisition that might result in coastal blight or a checkerboard pattern of homes and vacant lots that would still require public services and may diminish property values. The actual acquisition may take place in advance of a hazard event or in the wake of one, when funding, and willingness to sell, may be easier to come by and when eminent domain may come into play.

Typically, relocation involves acquiring land and relocating structures out of harm's way rather than demolishing them. Some relocation projects, for example, where the majority of the structures are substantially damaged or destroyed, may involve demolition along with active efforts to relocate people into new homes in safer areas. Relocation may occur at different scales. It may involve moving individual structures or moving neighborhoods. In some cases, it may even involve moving entire communities.

A plan for relocation that identifies potential structures for relocation as well as sites that can accommodate them will ease the process in the context of postdisaster recovery—or in advance of sea level rise inundation. In instances where a homeowner of a habitable structure (i.e., not substantially damaged or destroyed) is interested in acquisition but not relocation, there may be other uses for the building that would justify its relocation (e.g., for local government usage, Habitat for Humanity, domestic violence shelter, etc.).

Setbacks

While setback and buffer regulations as described in this guide are similar in effect, they differ in purpose. The discussion here focuses on the use of setbacks largely for the purpose of protecting structures from hazards by keeping the structures away from a property's most vulnerable areas. As such, they are closely tied to other regulations that manage development in hazard-prone areas, such as redevelopment, floodplain management, and shore protection structure regulations. Subdivision regulations can require lots to be deep enough to accommodate initial setbacks as well as future relocations. And, building codes can ensure structures can be moved with relative ease.

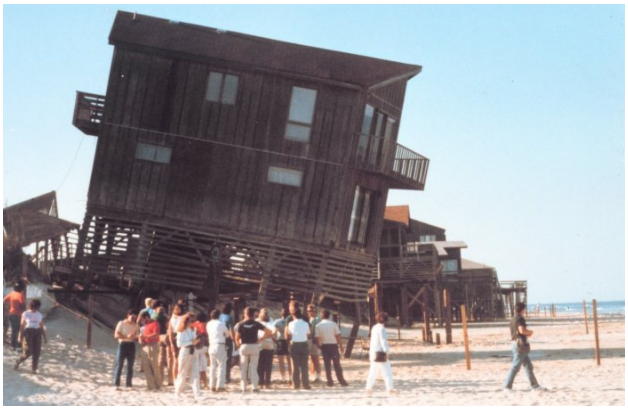
Setbacks may be regulated at the state or local level, or both, and may be based on size or use. Typically, they require structures to be sited at a distance measured inland from a specific shoreline feature, such as a high water mark, vegetation line, dune toe, or bluff crest. This distance may be a fixed number of feet (e.g., 100 feet) or may be based on the long-term annual rate of erosion (e.g., 30 times the long-term annual rate of erosion). Fixed numbers may not be adequate in highly erosive areas and may be too restrictive in others; and setbacks based on long-term average annual rates of erosion do not currently account for how erosion rates will change as sea level rises. Neither allow for catastrophic storms.

Learning from others…Setbacks Prove Effective following Hurricane Floyd
A study conducted for FEMA in North Carolina after Hurricane Floyd illustrated the benefit of setbacks. It examined the cost of flood damage to oceanfront buildings with similar structural characteristics and found flood losses to be highest for structures located directly on the open beach or setback 0–30 feet from the first line of vegetation. The average loss to these structures was twice as high as to those in the 31–100 foot setback area and more than three times the loss experienced by structures 100 feet or more from the shorefront. www.ncfloodmaps.com/pubdocs/pfloydrpt.pdf

A 1990 report from the National Academies recommended minimum development standards for areas experiencing significant erosion based on local rates of erosion (NRC 1990). Specifically, it suggested that no new development should be permitted seaward of 10 times the annual rate of erosion and only readily movable structures should be permitted seaward of 60 times the annual rate of erosion (and even then, most should be landward of 30 times the annual rate of erosion).

These recommendations did not factor in sea or lake level change. New and updated setback regulations could benefit from the following:

- Consideration of a range of sea level rise scenarios and the possibility of catastrophic storms
- Establishment of policies to address the potential for future land loss
- Establishment of policies to address how setbacks and property lines may be affected by declining lake levels
- Selection of multipliers reflecting estimated physical life of structures rather than economic life (length of a 30-year mortgage)
- Examination of vertical (i.e., based on elevation) rather than horizontal setbacks



Setbacks help to protect shorefront structures by requiring them to be built outside of a property's most hazard-prone areas.

Learning from others…North Carolina Bases Erosion Setbacks on Size
In 2009, new setback rules took effect in North Carolina. The new rules, which are administered by the North Carolina Division of Coastal Management, are based solely on size and do away with an exemption in the previous rules treating single-family homes larger than 5,000 square feet differently than other similarly sized structures. The new minimum setback remains 30 times the long-term average annual erosion rate, as measured from the vegetation line, for all structures less than 5,000 square feet. The setback for ALL structures between 5,000 and 9,999 square feet is 60 times the erosion rate. For structures 10,000 square feet and larger, the setback increases incrementally with structure size, reaching a maximum setback of 90 times the erosion rate for structures 100,000 square feet and larger. http://dcm2.ehnr.state.nc.us/News/2009%20releases/setbacks.html; http://dcm2.ehnr.state.nc.us/setbacks.htm

- Disclosure of setback-related threats and what they mean for future property owners (e.g., redevelopment restrictions)
- Regularly scheduled evaluations and updates of requirements and allowance for emergency action if warranted

Building Codes

When a structure is going to be built in a hazard-prone area, it should be done so in a manner that considers the potential impacts of that hazard (e.g., flood, wind) and how best they can be avoided. Building codes that regulate design, construction, and landscaping of new structures can improve the ability of structures in hazard-prone areas to withstand hazard events and can also reduce the effects of high temperatures. They also indirectly protect neighboring structures and natural resources. Building codes that consider future conditions and the potential for climate change and are regularly reviewed and updated based on new information will provide even greater protection.

According to the Institute for Business and Home Safety (IBHS 2005):

> *A building code is the minimum acceptable standard used to regulate the design, construction, and maintenance of buildings for the purpose of protecting the health, safety, and general welfare of the building's users. The purpose of building codes is to build safe buildings, thereby reducing deaths, injuries and property damage. This preserves the built environment, both residential and commercial, reduces public and private disaster aid, and maintains employment in businesses and institutions that otherwise might be forced to close following a catastrophe.*

The level of protection provided by building codes depends on the provisions of the codes as adopted and enforced by state and local governments. State-imposed building codes can help ensure a minimum level of protection. They may apply statewide, with more stringent requirements in hazard-prone areas, or they may apply only in areas susceptible to hazards such as hurricanes. To provide even more protection and address specific needs, states can allow local governments to supplement the state's minimum requirements with additional provisions.

Many states and local building codes are based on model codes founded on established scientific and engineering principles. These model building codes can be modified to better address specific needs and hazards. The International Code Council maintains the most up-to-date and widely adopted model building codes, which incorporate multihazard disaster-resistant

The Institute for Business and Home Safety's (IBHS) Fortified for Safer Living single-family residential construction program is a package of "code-plus" upgrades that greatly increase a new home's resistance to hazards such as hurricanes, floods, and more. Specifically, the program's requirements strengthen a home's outer envelope (roof and wall systems, doors, glazed openings, and the foundation).

Prior to Hurricane Ike, IBHS had designated 13 homes in Gilchrest, Texas, as "Fortified." In general, the Fortified homes performed better than others in the area, most of which were destroyed. Following the storm, all but 3 of the 13 Fortified homes survived, and the 3 that

failed did so because they were struck by "un-Fortified" neighboring houses that had been washed off their foundations. http://disastersafety.org/text.asp?id=fortified

construction standards. These codes include the International Residential Code (single- and two-family structures) and the International Building Code (commercial and multifamily structures). Two consensus standards from the American Society of Civil Engineers (ASCE) are referenced in the International Codes and are also useful resources: ASCE 24-05 Flood Resistant Design and Construction and ASCE 7-05 Minimum Design Loads for Buildings and Other Structures.

"Post-disaster assessments have proven that, in most cases, the use and enforcement of stricter building codes produce buildings that are more resistant to disasters" (FEMA 2000). However, the enforcement of these codes is critical to their success. Local building departments are typically responsible for ensuring builders comply with the codes so structures provide the base-level of protection required by the state or local government. Enforcement activities include permit approval, design and plan review, and site visits. A successful building code program will include regular continual training of enforcement agents as well as education of the building community and property owners.

Flood

In Special Flood Hazard Areas (100-year floodplain), the minimum requirements of the National Flood Insurance Program (NFIP) include requiring permits for new and substantially improved development, elevating the lowest floor of all buildings to or above the Base Flood Elevation (BFE) (alternatively, nonresidential buildings outside of the V-Zone can be dry-floodproofed to the BFE); anchoring structures to prevent flotation, collapse, or lateral movement;

Elevating existing structures can help protect them from storm surge and other flood events.

restricting development in the regulatory floodway; using flood-resistant construction materials and methods that minimize flood damage; and treating substantially improved structures like new buildings that must meet the minimum NFIP standards. Additional rules apply to the construction of the space below the BFE and limit its use to parking, building access, and storage. Buildings constructed in the V-Zone, which is subject to coastal high hazard flooding where waves during the base flood are at least three feet, must also be elevated on pilings or columns (i.e., fill is prohibited), and the bottom of the lowest horizontal structural member must be elevated to or above the BFE.

Since the Digital Flood Insurance Rate Maps that identify where these requirements apply may be out of date, and because they do not reflect future conditions (e.g., sea level rise, growth, etc.), codes

Learning from others…Massachusetts Protects Safety and Natural Resources through Building Codes
The Massachusetts Departments of Environmental Protection and Public Safety worked together to improve public safety and protect natural resource areas through revisions to the Massachusetts Basic Building Code. The revised code establishes special administrative, design, and construction requirements for new and existing buildings and structures located in A-Zones, V-Zones, and coastal wetland resource areas with coastal dunes that provide protection from storms and floods. Changes to the code include requiring two feet of freeboard in the V-Zone and design and construction requirements in coastal dunes that eliminate conflicts between the Wetlands Protection Act regulations and the previous code. www.mass.gov/dep/water/resources/bcbro.htm

that only mimic the NFIP's minimum requirements for construction in the currently mapped flood hazard areas may not be enough to protect people and property from future or present day storms.[9] To provide a higher level of protection and better prepare coastal communities for climate change, state and local governments are encouraged to adopt codes that consider sea level rise and include higher regulatory standards. Examples include:

- Adding freeboard (an additional height requirement above the BFE)[10,11]
- Applying V-Zone requirements to the Coastal A-Zone (area landward of V-Zone that is still subject to storm surge and damaging waves (1.5-3 feet)) or the entire Special Flood Hazard Area
- Applying codes outside of the Special Flood Hazard Area (e.g., to a point landward of the limit of the Special Flood Hazard Area where the ground elevation is equal to that of the adjacent A-Zone's BFE plus freeboard)
- Applying codes to all structures undergoing improvements and repairs

High Winds

Buildings can also be constructed to withstand the direct and indirect impacts of high winds, which are associated with storm intensity. Where high winds are a concern, building codes typically require structures to meet certain performance standards. Roofs, exterior walls, doors (including garage doors), windows, and skylights should be constructed/installed to maintain the integrity of the building envelope and reduce the potential for damage and collapse from wind and wind-borne debris. Increased structural wind-resistance can be achieved by adhering to special design techniques, using stronger, more wind-resistant materials and connections, such as hurricane clips and the bracing of gabled roofs; and protecting openings with impact-resistant materials or shutters.

Hurricane clips help anchor roofs to their main structure to prevent detachment during severe winds.

Learning from others…Florida Building Code Proves Successful

Following Hurricane Andrew, coastal areas of Florida began to use and enforce high wind design provisions for residential housing. When the hurricane season of 2004 struck, the Florida Building Code, which contains the wind-related provisions, had only been in force since 2002, but Charlotte County had been observing them since 1996. A study conducted by the Institute for Business and Home Safety found the frequency and severity of claims in Charlotte County were reduced (60 and 42 percent, respectively) for homes built after the adoption of the modern codes. It also found that the new requirements allowed homeowners to return to their homes more quickly, reducing the disruption to their lives. www.disastersafety.org/text.asp?id=hurricane_charley; www.dca.state.fl.us/fbc/commission/FBC_0606/Report_SurveyProject_Gurley_33006.pdf

[9] One of the objectives of FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) initiative is to provide updated flood hazard data for 100 percent of the nation's populated coastal areas (based on current conditions).

[10] The 2009 edition of the International Residential Code requires one foot of freeboard in the V-Zone and Coastal A- Zone (if delineated).

[11] In a 2006 report, the American Institutes for Research found that that adding freeboard during construction is cost-effective and that reduced flood insurance premiums pay for the cost of freeboard in one to three years in a V-Zone house and in six years in an A-Zone house (Jones et al. 2006).

Retrofitting

Although recent improvements in construction practices and regulations have made new structures less hazard-prone, many existing structures remain vulnerable and will likely be more so as climate changes. And, as these changes are realized and codes evolve to keep up with them, even structures built to or above current codes are likely to become threatened.

Existing structures can be protected from hazards through retrofitting.[12] While retrofitting may not bring a structure "up to code" (unless required during a substantial improvement), it does help existing structures better withstand hazard events and may reduce insurance premiums. Retrofitting techniques exist for a number of hazards, including floods and high winds, and many of them are similar to those required in the construction of new structures.

Examples include:

- Elevating or floodproofing flood-prone structures
- Reinforcing and bracing roofs and garage doors
- Anchoring homes to their foundations
- Installing shutters on windows and other glass openings
- Removing impervious surfaces
- Replacing exterior building components with stronger, more hazard-resistant alternatives

Hurricane shutters can be added to existing structures to reduce the damage caused by wind and water.

Since retrofitting is typically not required, homeowners may not be aware of what they can do to protect their homes and themselves. Regular improvement and maintenance projects provide good opportunities for homeowners to strengthen their homes as well as improve the structure and increase its value. An outreach program can help inform the public about how to incorporate retrofitting into these projects, using the building codes as a guide—with the goal of retrofitting existing structures up to code.

Infrastructure Protection

As described in Chapter 4, infrastructure includes the basic facilities, services, networks, and systems needed for the functioning of a community that if lost or

Learning from others…Florida Program Funded Home Inspections and Retrofitting

In 2006, Florida state lawmakers appropriated funds to create the My Safe Florida Home program to help Floridians identify and make improvements to strengthen their homes against hurricanes through free wind inspections and grant funds. Between 2006 and 2009, when the program expired, the program provided inspections to more than 400,000 homeowners and retrofitted nearly 33,000 homes. An analysis of the program found that for every grant dollar provided, hurricane losses are expected to be reduced by as much as $1.50. This equates to a drop of around $140 million in total losses for the retrofitted homes. www.mysafefloridahome.com/; www.rms.com/Publications/RMS_MSFH_Report_May_2009.pdf

[12] Retrofitting programs that target mitigating climate change (e.g., energy efficiency/weatherization) can be expanded to also consider adaptation.

Learning from others…Massachusetts Considers Sea Level Rise in Infrastructure Siting
In the 1990s, the Massachusetts Water Resources Agency designed and built Boston's Deer Island wastewater treatment plant in consideration of sea level rise. Specifically, the plant was built 1.9 feet higher than required at the time to accommodate the amount of sea level rise projected to occur over the expected lifetime of the facility (~50 years). And, in a nod to climate change mitigation, the plant gets approximately one-quarter of its power needs through on-site renewable energy sources.
www.mwra.com/03sewer/html/sewditp.htm

damaged could cause significant disruption (physically, functionally, and economically). Since infrastructure is critical to the functioning of a healthy community, it must be sited, designed, constructed, and maintained so the provision of services continues uninterrupted. Infrastructure protection entails fortification against the impacts of climate change and, in some cases, shoring up of capacity.

While many of the ideas discussed under building codes and retrofitting also apply to infrastructure, the value of infrastructure, both socially and economically, suggests the need for stricter requirements for new infrastructure construction (e.g., plan for the 500-year event, rather than the 100-year event) and a more concerted effort to retrofit existing facilities and systems. Roads, bridges, water and power utilities, stormwater systems, and other infrastructure that are already worn or overcapacity are likely to be most vulnerable to climate change.[13] Addressing and correcting existing deficiencies needs to be a priority and should be handled concurrently with adjustments necessary to meet projected future conditions and needs. Similarly, adaptation should be considered and incorporated into regular maintenance and upgrade activities.

In general, designing for the future is less expensive than retrofitting, rebuilding, or moving infrastructure. When planning for new infrastructure, siting should be the first consideration. Facilities and system components should not be constructed in hazard-prone (current or projected) or valuable natural resource areas, where possible, or in areas that would encourage undesirable growth. When avoiding these areas is not possible, efforts should be made to design and construct facilities and system components to the highest level of protection feasible in a manner that allows for flexibility and future modifications.

Shore Protection Structures

Shore protection structures protect existing development allowing it to stay in place. However, they often damage or destroy other valuable coastal resources (economic, ecological, recreational, and aesthetic), require substantial expenditure (initial design and construction and maintenance), and create a false sense of security. They may also encourage additional development. Shore protection structures provide an immediate fix that may not be sustainable. Nevertheless, it is understood that in some cases, for the purposes of protecting existing (not future) development, there may be no other acceptable or practical options. Alternatives to shore protection structures are discussed in the Shoreline Management category that follows.

Shore protection structures are designed to reduce flooding/inundation and erosion of land and protect structures and infrastructure. Despite the name, the intent is to protect the built environment and the land it sits on rather than the shore itself.

[13] Onsite sewage disposal systems will also be vulnerable as sea levels rise and their separation from groundwater becomes inadequate.

Most shore protection structures are built parallel or perpendicular to the shoreline:

- **Shore parallel** (seawalls, revetments, bulkheads, breakwaters, rip rap)—These structures help hold the land back from the sea and the sea back from the land and/or dissipate wave energy.
- **Shore perpendicular** (groins, jetties)—These structures interrupt sediment transport and trap sediment to build/rebuild beaches and/or stabilize navigational channels and inlets.

While they may be successful at meeting the level of protection they are designed for, all of these structures disrupt the natural flow of sediment, which may result in the loss of the natural shoreline, coastal habitat, and the associated ecosystem services and amenities, either directly in front of the structure or in adjacent areas. With the exception of breakwaters, which are built offshore, shore parallel structures also inhibit the ability of wetlands to migrate inland as sea level rises and may interfere with public access. In most cases, protection in one area will lead to losses in another (or the demand for more shore protection structures), both to the built and the natural environment.

Large flood control systems like dikes (levees) and movable gates and barriers (e.g., Maeslantkering in the Netherlands and the Thames River Barrier in the United Kingdom) are also being considered as viable defenses against sea level rise. These structures require significant investment and come with their own set of concerns and adverse impacts.

When there are no suitable alternatives, future shore protection structures should be designed and constructed to minimize adverse impacts at the site of the structure as well as to the broader coastal system, based on future climate change projections, and so they are flexible enough to allow for modifications. Existing structures will likely require upgrading, replacement, or removal. All structures will require monitoring and maintenance to ensure they continue to function as planned.

Offshore breakwaters can keep sand onshore, reducing the rate of shoreline erosion.

Shoreline Management

- **Regulation/Removal of Shore Protection Structures**
- **Rolling Easements**
- **Living Shorelines**
- **Beach Nourishment**
- **Dune Management**
- **Sediment Management**

Shoreline management activities aim to preserve the natural shoreline, which in turn provides protection to property, supports coastal habitat and public access, and enhances aesthetic and

Learning from others…California Ties Impact Mitigation to Shoreline Armoring Projects

The California Coastal Act allows for shore protection structures if existing development is in jeopardy of being lost to erosion and no other alternative solution is possible. The California Coastal Commission, which administers the act, requires the negative impacts (i.e., loss of public access) be mitigated when shore protection structures are allowed. While the exact mitigation requirements are site-specific, the commission commonly requires the property owner to dedicate a public access easement seaward of the approved structure to compensate for any loss of the public beach.
http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_mitigation.html

Learning from others…Maine Manages Beaches through Scoring System
The Maine Geological Survey, with support from the Maine Coastal Program, developed a beach scoring system to help manage the state's sandy shoreline along Saco Bay. The study enabled managers to identify beaches where erosion control efforts are needed, prioritize sites, and determine the appropriate action (e.g., beach renourishment, dune restoration, or a combination). Inputs to the scoring system included historical shoreline change data and other physical beach characteristics. http://maine.gov/doc/nrimc/mgs/explore/marine/virtual/scoring/slides.htm

recreational amenities. The measures in this category are mutually reinforcing and could be integrated into a comprehensive shoreline management strategy that identifies needs and explores, combines, and prioritizes actions. While these measures are preferable to shore protection structures, they are not as effective at protecting buildings and infrastructure along the coast as some of the measures described in the Loss Reduction category above, since natural shorelines are more vulnerable to the forces of nature.

Regulation and Removal of Shore Protection Structures

As previously discussed, the use of shore protection structures is only supported as an action of last resort to protect valuable real estate and infrastructure. They often do more harm to the natural shoreline than good. To protect the natural shoreline and the benefits it provides, states can use regulations to limit shoreline hardening as well as to promote alternative forms of protection and to encourage development that reduces the needs for shore protection structures.

Regulations can specify allowable uses, locations, and structures, prohibit new structures, and/or require the removal of existing structures given specified circumstances (e.g., no longer maintained, substantially damaged, need to return land to natural functions, etc.). The size, design, and placement of shoreline stabilization structures can also be regulated to minimize environmental and public access impacts. Regulations that severely restrict the use of shore protection structures or require their removal should also require disclosure of such restrictions in real estate transactions.

Removing or breaching manmade levees can be an effective way to restore natural processes.

Learning from others…North Carolina Prohibits Oceanfront Erosion Control Structures
In North Carolina, permanent erosion control structures are prohibited on the oceanfront since they "may cause significant adverse impacts on the value and enjoyment of adjacent properties or public access to and use of the ocean beach." Included in this ban are bulkheads, seawalls, revetments, jetties, groins, and breakwaters. Such structures may be permitted only under certain circumstances, such as to protect an erosion-threatened bridge that provides the only existing road access to a substantial population on a barrier island or to maintain an existing commercial navigation channel of regional significance. In such cases, the erosion-control structure must not adversely affect adjacent private properties, coastal resources, or public use of the beach. http://dcm2.ehnr.state.nc.us/Rules/Text/t15a-07h.0300.pdf

Learning from others…Rhode Island Prohibits Structural Shoreline Protection along Barriers and Oceanfront
To protect the sediment source of its beaches and preserve natural sand transport, the Rhode Island Coastal Resources Management Council has banned the installation of revetments, bulkheads, seawalls, groins, breakwaters, jetties, and other erosion control structures along all barriers and ocean facing coastline. Structures predating the regulations are allowed to remain, but any structure that is more than 50 percent damaged by a storm or other process must comply with current programmatic requirements and may not be rebuilt. www.crmc.ri.gov/regulations.html

Rolling Easements

Rolling easements are shoreline easements designed to promote the natural migration of shorelines. Typically, rolling easements prohibit shore protection structures, which interfere with natural shoreline processes and movement, but allow other types of development and activities. As the sea rises, the easement, which is usually delineated by a physical characteristic such as the line of vegetation, moves or "rolls" landward, sediment transport and wetland migration occur as nature intended, and public access to the shore is preserved. Since rolling easements reflect changing conditions, they are likely to be a more effective response to the impacts of climate change than traditional zoning, which is based on conditions at the time of the rule making.

Rolling easements, which may be donated, purchased, or regulated, place no restrictions on development. They allow landowners to build anywhere on their property with the understanding that they will not be able to hold back the sea by armoring their shoreline or deny public access. Once the shoreline has eroded to a point where a privately owned structure is on public land, a threat to human health and safety, and/or threatened by flooding and erosion, that structure should be relocated. The possible need for relocation may encourage the building of smaller, more mobile structures that will likely cause less environmental disruption.

Living Shorelines

In low- to medium-energy coastal and estuarine environments and tidally influenced creeks, streams, and rivers, living shorelines can be effective alternatives to shore protection structures in efforts to restore, protect, and enhance the natural shoreline and its environment. Living shorelines use stabilization techniques that rely on vegetative plantings, other organic materials (e.g.,

Learning from others…Texas Protects Public Beach through Rolling Easements
The Texas Open Beaches Act (OBA) aims to protect access to the public beach, which is the area between the mean low tide line and the line of vegetation (including privately owned land) along the Gulf of Mexico. It does so through a rolling public beach easement. As the line of vegetation moves inland due to erosion, so does the public beach. The commissioner of the General Land Office may call for the removal of buildings that end up on the public beach if they interfere with public access or threaten public safety, health, or welfare. The OBA also prohibits structures that would block public access, effectively disallowing shore protection structures. www.glo.state.tx.us/coastal/beachdune.html

Learning from others…Virginia Promotes Living Shorelines
The Virginia Coastal Zone Management Program is working with partners to promote living shorelines. The state's Living Shoreline Strategy, funded through Section 309 of the Coastal Zone Management Act, includes a Living Shoreline Summit (in conjunction with the Maryland Coastal Zone Management Program), revisions to the state's wetlands guidelines, research to further document the habitat value and refine the design of living shorelines, a protocol for determining the feasibility of living shorelines on a reach (shoreline segment) basis, additional shoreline situation reports and shoreline evolution studies to better inform local shoreline management decisions, a shoreline planning guidance document to help localities proactively address shoreline management issues and meet comprehensive planning requirements, a brochure and web site for landowners, and a design manual and training program for contractors.
www.deq.virginia.gov/coastal/livingshore.html

biologs, matting), and sand fill or a hybrid approach combining vegetative planting with low rock sills or footers, living breakwaters (e.g., oysters), or other shore protection structures designed to keep sediment in place or reduce wave energy. The techniques and materials used will depend on site-specific needs and characteristics. There are a number of benefits to living shorelines. Specifically, they:

- Maintain natural shoreline dynamics and sand movement
- Trap sand to rebuild eroded shorelines or maintain the current shoreline
- Provide important shoreline habitat
- Reduce wave energy and coastal erosion
- Absorb storm surge and flood waters
- Filter nutrients and pollutants from the water
- Maintain beach and intertidal areas that offer public access
- Are aesthetically pleasing
- Allow for landward migration as sea levels rise
- Absorb atmospheric carbon dioxide
- Are less costly than shore protection structures

Hybrid shoreline stabilization structures that employ marsh plantings and low rock sills (to protect the vegetation) can help stabilize eroding banks.

In some states, the regulatory framework makes it more difficult to implement living shorelines projects than the traditional shore protection structures previously discussed. Regulations should be reviewed and revised to encourage the use of living shorelines where appropriate.

Beach Nourishment

Beach nourishment is the process of placing sand on an eroding beach, typically making it higher and wider, to provide a buffer against wave action and flooding and/or to improve the recreational value of the beach. In the United States, beach nourishment is preferred over shore protection structures because it preserves the aesthetic and recreational values of protected beaches by mimicking the characteristics of natural beach and dune systems. In addition to protecting the nourished shoreline and landward property and infrastructure, beach nourishment generally benefits, rather than negatively impacts, adjacent

Learning from others…New Jersey Protects Shorefront with Beach Nourishment
In New Jersey, beach nourishment is the preferred approach to dealing with beach erosion and shorefront protection. The New Jersey Department of Environmental Protection's Bureau of Coastal Engineering, in cooperation with the U.S. Army Corps of Engineers, provides beach nourishment and renourishment projects for the purpose of restoring New Jersey's beaches. State funding comes from the Shore Protection Fund, which ensures the availability of funds needed to continue the beach nourishment program and protect New Jersey's coastal communities. www.nj.gov/dep/shoreprotection/nourishment.htm

beaches (e.g., by adding sediment to the system) and may also create, restore, and protect habitat.

Beach nourishment projects require large volumes of sediment compatible with the natural beach. These sediments may come from onshore or offshore sources and may be "beneficial use" sediments from dredging projects. Some projects may include shore protection structures to help retain/protect the added sand (e.g., groins and breakwaters).

Since nourished beaches will be susceptible to the same natural forces as the beaches before them, they will require periodic renourishment. Renourishment intervals typically range from 2 to 10 years but will vary by project, shoreline characteristics, number and intensity of storms, and sea level rise (NRC 1995).

Despite the benefits of beach nourishment, there are some drawbacks to consider. Beach nourishment projects:

- Are very expensive and require regular maintenance at additional costs
- Require large amounts of suitable sediment that may be difficult to come by
- Are difficult to evaluate in terms of benefits and costs due to the uncertainty of project lifetime
- Create a false sense of security that may encourage unwise development
- Can have serious long- and short-term environmental effects at the project and source sites and in nearby areas of the water column and the water bottom

By adding sand to an eroding beach, beach nourishment can protect shorefronts against wave action and flooding.

Dune Management

Sand dunes are important shoreline features and are an environmentally friendly form of shore protection. In addition to serving as buffers against erosion and flooding, which they do by trapping windblown sand, storing excess beach sand, and protecting inland areas against wave runup and overwash, they also provide habitat for wildlife. Dunes, however, are not permanent. So, to retain, enhance, or facilitate the provision of their valuable services, they may be restored or created in conjunction with a beach nourishment project as discussed above or may be managed as part of a separate effort. Since dunes and beaches are interdependent, dune management should be incorporated into a strategy that considers the broader coastal system.

Dune restoration is relatively inexpensive and entails the use of dune grass and other types of native

Learning from others…Connecticut Program Supports Dune Restoration
Connecticut's Department of Environmental Protection provides technical support to towns and citizens for dune restoration and has restored a number of dune areas on state beaches. Planting American beach grass to replace vegetation that has been lost is the primary method used to restore dunes. www.ct.gov/dep/cwp/view.asp?A=2705&Q=323538

Sand dunes serve as buffers against erosion and flooding and provide habitat for wildlife. Vegetation and sand fences can help stabilize dunes.

vegetation and sand fences to capture shifting and blowing sands and stabilize dunes. The use of vegetation and sand fences to build and stabilize dunes is not a quick fix, will only be effective under certain conditions, and may not be effective as a way of encouraging the growth of new dunes where dunes did not exist in the past.

A number of other measures discussed in this guide can be used to manage and protect dunes, vegetation, and associated habitat, including laws and regulations (e.g., zoning, buffers, setbacks, etc.) that restrict development and other harmful activities (e.g., sand mining, foot and vehicular traffic). To continue to allow for public access, dune walkovers or fenced pedestrian paths could be considered in planning and project design.

Sediment Management

Sediment management is an important aspect of shoreline management and supports some of the other measures discussed in this category and the next. It requires an understanding of sedimentation processes in the management area, recognizes the importance of sand and other sediments in protecting, maintaining, and restoring the shoreline and its associated waters and ecosystems, and incorporates activities affecting the erosion, transport, deposition, and removal of sediment. These activities include dredging and placing sediment, building shore protection structures and other structures that trap or divert sediment, and mining.

Learning from others…Michigan Program Protects Unique and Fragile Dunes
Michigan's Sand Dunes Protection and Management Program, administered by the state's Department of Environmental Quality, aims to protect the state's sand dunes by minimizing the impacts of development within designated critical dune areas along the shorelines of Lake Michigan and Superior. It does so through a permit program that regulates earthmoving, vegetation removal, and construction activities within legally defined critical dune areas. Among other things, the standards require new uses to be set back behind the crest of a critical dune, limit the amount of grading and vegetation removal allowed, and prohibit construction on steep slopes. www.michigan.gov/deq/0,1607,7-135-3311_4114---,00.html

Learning from others…California Regionalizes Sediment Management
The California Coastal Sediment Management Master Plan is an ongoing, collaborative effort by the Coastal Sediment Management Workgroup, a partnership of federal and state agencies, to evaluate California's coastal sediment management needs and promote regional, systemwide solutions. The intent of the plan is "the conservation, restoration, and preservation of the valuable sediment resources along the coast of California 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, improve water quality along coastal beaches, and optimize the beneficial use of material dredged from ports, harbors, and other opportunistic sediment sources." It is implemented through region-specific coastal regional sediment management plans, which are prepared by regional entities with oversight and assistance from the workgroup. http://dbw.ca.gov/csmw/default.aspx

Sediment management is best accomplished through a regional effort involving all levels of government and other stakeholders (coastal as well as inland) who share an interest in a sediment system (i.e., a system within which sediment exchange occurs naturally). Regional sediment management "includes the entire environment, from the watershed to the sea; accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, and oceans; and protects and enhances the nation's natural resources while balancing national security and economic needs" (Corps n.d.).

Sediment dredged from navigation and diversion channels can be used to restore and create wetlands.

Any regional sediment management effort should include an emphasis on the beneficial use of dredged material. A sediment management program that recognizes sediment as a valuable resource and links needs with appropriate opportunities will be the most effective at reducing economic and environmental losses associated with climate change. Beneficial use of dredged material involves using sediment dredged from waterways for a productive purpose, such as beach nourishment, habitat restoration and development, public access facilities, and shore protection structures (e.g., levees and dikes), among other things.

Learning from others…Louisiana Regulates Beneficial Use of Dredged Material
In 2009, the Louisiana Department of Natural Resources Office of Coastal Management enacted new rules on the beneficial use of material dredged in projects requiring a coastal use permit. The new rules include four options: 1) implementing a project that makes beneficial use of the dredged material, 2) providing for the use of the dredged material on an approved coastal restoration project, 3) using dredged material at another location that creates the same amount of beneficial use, or 4) making a voluntary contribution to the Coastal Resources Trust Fund (based on the amount of material dredged). http://dnr.louisiana.gov/crm/coastmgt/rules/2009-10.pdf

The EPA's Climate Ready Estuaries program works with National Estuary Programs to help assess climate change vulnerabilities, engage and educate stakeholders, develop and implement adaptation strategies, and share lessons learned with other coastal managers. The Climate Ready Estuaries web site offers information on climate change impacts to different estuary regions, access to tools and resources to monitor changes, and information to help managers develop adaptation plans for estuaries and coastal communities. The program's 2009 progress report describes accomplishments to date, including activities being managed by partners, lessons learned in the adaptation planning process, challenges encountered, and next steps. www.epa.gov/cre/

Coastal and Marine Ecosystem Management

- Ecological Buffer Zones
- Open Space Preservation and Conservation
- Ecosystem Protection and Maintenance
- Ecosystem Restoration, Creation, and Enhancement
- Aquatic Invasive Species Management

Coastal and marine ecosystem management encompasses a number of measures to conserve (or preserve) and restore ecosystems. While many of the measures discussed in other categories can also play a role in ecosystem management (and vice versa), the measures featured in this category are primarily focused on managing for ecological structure and function and protection of biological diversity.[14] Generally, they include activities that create and accommodate new natural areas, refocus management of existing ecosystems, and restore degraded ecosystems.

It is unlikely that ecosystems can be effectively managed to address climate change through a single measure. Traditional activities, adjusted to consider climate change, along with best management practices that reduce existing stressors and a plan that identifies, integrates, and prioritizes related activities, will be pivotal in helping coastal and marine ecosystems adapt to the changing climate. Nevertheless, because of the remaining gaps in our knowledge about ecosystem processes and how they may react to climate change, it is important to include monitoring and remain flexible in any ecosystem management program.

Ecological Buffer Zones

Ecological buffer zones (buffers) are similar to setbacks (and may be included within setbacks), but are typically designed to protect the natural, rather than the built, environment. By protecting natural resources, buffers protect the natural and beneficial functions those resources provide. Protective services include providing habitat and connectivity; minimizing erosion and flooding by stabilizing soil, providing flood storage, and reducing flood velocities; and improving water quality through filtration of harmful sediment, pollutants, and nutrients.

Specifically, buffers are land use regulations designed to reduce the impacts of land uses (e.g., development) on natural resources by providing a transition zone between a resource and human activities. Typically, buffers are maintained in their natural vegetative state and activities such as vegetation removal, soil

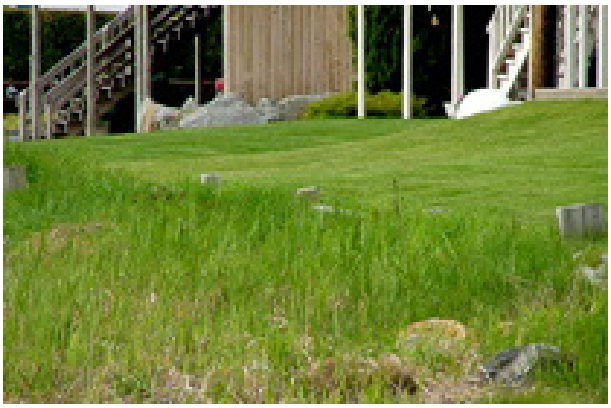
Ecosystem-based management is an innovative approach to addressing the many challenges faced by coastal and marine ecosystems. It considers the whole ecosystem, regardless of political boundaries, including humans and the environment, rather than managing one issue or resource in isolation and is concerned with the sustainability of both human and ecological systems. www.ebmtools.org/

[14] Among other things, healthy ecosystems such as wetlands also protect upland areas from storms and flooding, filter pollutants, and serve to mitigate climate change by enhancing carbon sequestration and reducing emissions that result from degradation.

Learning from others…Rhode Island Uses Buffers to Protect Ecological Systems
The Rhode Island Coastal Resources Management Program defines its coastal buffer zone as "a land area adjacent to a shoreline (coastal) feature that is, or will be, vegetated with native shoreline species and which acts as a natural transition zone between the coast and adjacent upland development." State regulations generally require buffers for new residential, commercial, and industrial development. The vegetation in the buffer must be retained in a natural, undisturbed condition or managed in accordance with a buffer management plan. For residential developments, buffer widths range from 15 to 200 feet and depend on the designated water use category and lot size. Commercial and industrial development buffer requirements are determined on a case-by-case basis. Minimum vegetated buffers of 200 feet are required on all properties adjacent to designated critical habitat areas. In some more developed areas, such as the Metro Bay region, Rhode Island employs an Urban Coastal Greenway that allows for a narrower buffer in return for providing public access and more stormwater control on the site. www.crmc.ri.gov/regulations.html

disturbance, and construction are restricted or prohibited. As climate changes, buffers will also be able to support inland wetland migration as well as carbon sequestration.

The effectiveness of any buffer will depend on several factors, including size, elevation, vegetation, slope, soil, permitted activities, adjacent land uses, stormwater flow, and erosion rate. In addition, effectiveness will also be dependent on property owner compliance and the monitoring and enforcement of buffer regulations. If drafting new or revised buffer regulations, consider these characteristics as well as how buffers, and the natural resources they protect, might be affected by climate change in the next century.



Maintaining natural buffers along shorelines can help protect coastal and marine resources from polluted runoff and homes from erosion. (Note where buffer ends and mowed grass begins.)

Open Space Preservation and Conservation

There are a number of benefits to preserving open space. Open spaces can improve the environment and a community's quality of life and contribute to economic well-being. Specifically, open spaces:

- Protect and provide habitat
- Reduce flooding and stormwater runoff
- Support water quality maintenance
- Promote groundwater recharge
- Provide opportunities for recreation
- Enhance natural and cultural resources
- Sequester carbon
- Allow for evaporative cooling

Open space preservation and conservation can be accomplished through the management of lands dedicated as open space through a number of the measures previously discussed, such as zoning, redevelopment restrictions, acquisition, easements, setbacks, and buffers. While there are costs associated with the management of open space, the public expenditures may be lower than if the land was developed and the provision of full services was required. Management costs could be defrayed by transferring the title to a nonprofit conservation organization.

Open space management plans can be developed to guide the acquisition and use of open space in a manner that fulfills multiple community objectives

Learning from others…New Jersey Land Conservation Targets Hazard-Prone and Protective Lands
New Jersey's Coastal Blue Acres Program, part of the Department of Environmental Protection's Green Acres Program, is designed to provide grants and loans to municipalities or counties to acquire important coastal lands for recreational and conservation purposes. To be eligible for acquisition through the Blue Acres Program, the land must have been severely damaged by storms, threatened by future storms, or serve as a buffer to protect other land from storm damage. The 1995 bond act that created the program appropriated funds for the purchase of undeveloped land in high-risk erosion areas or property that serves important buffering roles (75 percent grant/25 percent loan) and land severely damaged by storms (50 percent grant/50 percent loan). www.state.nj.us/dep/greenacres/

Open spaces can improve the environment and a community's quality of life and contribute to economic well-being.

(e.g., trails, athletic fields, campgrounds, community gardens, wildlife refuges, environmental education centers, etc.). Any such plan should consider the impacts and consequences of climate change, sea level rise and flooding in particular, to ensure that investments are wisely made (land purchase as well as use and amenity placement). Open space management should also consider the key role of open space in green infrastructure and wetland migration programs (see more on these measures in the pages that follow).

Ecosystem Protection and Maintenance

Ecosystems are difficult and costly to repair and replace. It is more desirable to maintain and protect resilient systems. This largely involves reducing the impacts of nonclimate stressors and may include:

- Restricting activities (through regulations if necessary)
- Restoring natural processes, such as water flow and sedimentation (e.g., by removing shore protection structures or upstream dams)
- Encouraging stricter nutrient management
- Reducing land-based pollution
- Modifying harvest or use rates

Learning from others…Florida Considers Climate Change in Land Conservation
Florida Forever, Florida's state land acquisition and conservation program, provides a blueprint for conserving the state's natural and cultural heritage. Administered by Florida Department of Environmental Protection's Division of State Lands, program goals include environmental restoration, water resource development and supply, increased public access, public lands management and maintenance, and increased protection of land through conservation easements. Project prioritization includes consideration of climate-change lands, which are defined as lands "where acquisition or other conservation measures will address the challenges of global climate change, such as through protection, restoration, mitigation, and strengthening of Florida's land, water, and coastal resources." These lands sequester carbon, provide habitat, protect coastal lands or barrier islands, and otherwise mitigate and help adapt to the effects of sea level rise. www.dep.state.fl.us/lands/fl_forever.htm

Marine protected areas (MPAs) are valuable tools for conserving the nation's natural and cultural marine resources as part of an ecosystem approach to management. MPAs conserve natural heritage, cultural heritage, and sustainable production and are designed to maintain ecosystems' natural states and to absorb shocks, particularly in the face of large-scale and long-term changes such as climate change. The National System of MPAs provides benefits to the nation, to participating MPAs, and to ocean stakeholders, including enhanced stewardship, partnership building, and increased support for marine conservation. http://mpa.gov/

- Monitoring and responding to threats like invasive species (see page 92), harmful algal blooms, hypoxia, and coral bleaching
- Conducting outreach and awareness
- Acquiring sensitive lands and/or protective buffers
- Designating and/or connecting protected areas

Facilitating Wetland Migration

Wetlands that are not able to naturally keep up with increased rates of sea level rise through accretion of sediment and organic matter may be able to migrate landward, along with the functions and services they provide, given the proper soil and hydrological conditions and the lack of barriers. However, the ability to migrate and ultimate sustainability will depend on factors such as rate of change, topography, and upland land uses. Although costly and complex, if migration is constrained, wetland loss may be compensated for through the creation of new wetlands in suitable areas.

Steps that can be taken to facilitate wetland migration include:

- Prohibiting and removing shore protection structures that would impede migration
- Acquiring land suitable for migration through easements or acquisition[15]
- Requiring ecological buffer zones, setbacks, and/or rolling easements
- Adhering to the principles of compact community design

Adopting policies that support these activities before the suitable corridors are overly developed will likely be more cost-effective and politically palatable than once development has moved in. Wetland management programs should include analysis of how climate change may affect the coastal wetlands so strategic decisions can be made about land acquisition and other protective measures.

Managing for Ocean Acidification

With the impacts and reversibility of ocean acidification still uncertain, management responses are still being developed. The mitigation of climate change by reducing greenhouse gas emissions may be the best response as adaptation may not be feasible. Currently, recommendations to help reduce the impacts of ocean acidification, in addition to mitigation, include:

- Conserving and restoring natural landscapes
- Reducing land-based sources of pollution and nutrients that contribute to acidification
- Reducing other nonclimate stressors to enhance resilience
- Promoting marine connectivity
- Protecting high biodiversity ecosystems that are likely to be less vulnerable to the impacts of ocean acidification
- Spreading the threat by replicating ecosystems in different areas where pH may vary
- Monitoring and sharing information with researchers and other managers about observed impacts

[15] Acquisition of parcels within identified corridors could be structured to allow landowners continued use or occupancy of their lands (while maintaining wetland values) during their lifetimes, after which ownership would transfer to a designated government agency.

Ecosystem Restoration, Creation, and Enhancement

Unlike the previous measures in this category, many of the activities designed to restore, create, or enhance coastal and marine ecosystems entail manipulation of the physical, chemical, or biological characteristics of a site. While there is considerable scientific confidence in support of activities that reduce nonclimate stressors, the effectiveness of the measures discussed here in helping systems adapt to climate change is not as evident, and their consideration, while still essential, requires a clear understanding of how a system functions and how it might be affected by climate change (CCSP 2008b).

These projects should be designed to withstand the impacts of climate change, incorporating native species that will be able to adapt to anticipated future conditions. The focus should be on maintaining and enhancing connectivity and preserving ecosystem functionality and services rather than re-creating a specific species composition. Representation and replication can help increase the likelihood of ecosystem or habitat survival.[16] Ensuring resilient native species and habitats are well-represented and replicated decreases the possibility of catastrophic events destroying systems.

Specific activities for restoring, creating, or enhancing an ecosystem will vary by ecosystem type as well as by species. Brief descriptions of wetland, coral reef, and artificial reef projects are included below. A more detailed discussion is outside the scope of this document. See the Key Resources at the end of this chapter for more information.

Restoration projects may entail placing and shaping sediment and planting vegetation, in addition to other activities, in order to rebuild degraded wetlands.

Wetlands

Restoration, creation, and enhancement consist of a wide-range of activities and are essential in recovering or replacing ecosystems that have been degraded or destroyed (Interagency Workgroup on Wetland Restoration 2003):

- **Restoration**—Returning a degraded wetland or former wetland to a pre-existing condition or as close to that condition as is possible.
- **Creation**—Converting a nonwetland (either dry land or unvegetated water) to a wetland.

Learning from others…Louisiana Repairs Wetlands with Mississippi River Sediment

The Louisiana Coastal Protection and Restoration Authority and EPA have embarked on a project to build and restore nearly 500 acres of marsh in Lower Jefferson and Plaquemines parishes using sediment from the Mississippi River. The Mississippi River Sediment Delivery System at Bayou Dupont will involve mining sediments from the river and transporting them by pipeline to the designated areas, which are outside the levees. After the material is transported, native vegetation will be planted on the new marsh. The sediment source was chosen because it will be replenished naturally. Pipeline infrastructure will remain in place after the project is complete so it can be used for future projects.
www.lacoast.gov/projects/overview.asp?statenumber=BA%2D39

[16] "Representation refers to protecting a portfolio of variant forms of a species or ecosystem so that, regardless of the climatic changes that occur, there will be areas that survive and provide a source for recovery. Replication centers on maintaining more than one example of each ecosystem or population such that if one area is affected by a disturbance, replicates in another area provide insurance against extinction and a source for recolonization of affected areas" (CCSP 2008b).

Learning from others…South Carolina Habitat Program Employs Community Volunteers
The South Carolina Department of Natural Resources operates a community-based habitat restoration and monitoring program that brings together volunteers and scientists to restore and monitor oyster habitat along the South Carolina coast. The purpose of the South Carolina Oyster Restoration and Enhancement Program is to restore and enhance oyster habitat by planting recycled oyster shells in the intertidal environment to form new, self-sustaining oyster reefs.
http://score.dnr.sc.gov/

Restored, created, and enhanced wetlands serve as storm buffers, improve water quality, provide habitat to fish and wildlife, enhance outdoor recreation opportunities, and more.

- **Enhancement**—Increasing one or more of the functions performed by an existing wetland beyond what currently or previously existed in the wetland. There is often an accompanying decrease in other functions.

Examples of activities associated with these types of projects include planting and seeding, which could include plant species adapted to future climate conditions; waterflow modification; sediment diversion and/or placement; filling canals; recontouring topography; dredging and removal of fill materials; prohibition and removal of shore protection structures and other barriers that impede natural processes; water quality improvements; and invasive species control.

Any project designed to restore, establish, or enhance an ecosystem will require planning, long-term management, monitoring, and, possibly, land acquisition. In general, of the three project types, restoration is the most likely to be successful (Interagency Workgroup on Wetland Restoration 2004). The outcomes of projects that create new ecosystems or new ecosystem services are more uncertain, especially when the additional uncertainties of climate change are factored in. Wetland creation is usually difficult and typically requires a lot more planning and effort than restoration projects. Generally, it is easier to create wetlands from open water than it is to convert uplands. In either case, one type of ecosystem is likely to be destroyed in order to establish the new one. Tradeoffs will need to be made and understood.

Coral

Restoring damaged coral reef ecosystems is an important part of protecting and preserving ecosystem health. Reef restoration can help prevent further degradation and facilitate the natural recovery process. Future work on developing restoration strategies may ultimately make reefs more resilient to the impacts of climate change. To date, most restoration efforts have been focused on repairing damage caused by human impacts, such as vessel groundings and anchoring, and these efforts serve to restore natural function, structure, and diversity among injured reefs. Managers have conducted pilot projects on applying restoration techniques that may be used to respond to climatic event disturbances, such as coral bleaching, and disease mortality events.

Coral reef restoration largely entails stabilizing and repairing the damaged framework, recreating topography, and transplanting corals dislodged, propagated in nurseries, and/or relocated from other suitable sources (e.g., corals "orphaned" as a result of coastal construction projects). Restoration of natural processes may also include ecological approaches

such as reinstating herbivores, protecting herbivore populations, enhancing recruitment, and reducing the prevalence of disease. Restoration projects are difficult and expensive and may take decades to demonstrate their success. Thus, they require sound planning, long-term management, experimentation, and monitoring.

Artificial Reefs

Artificial reefs are constructed of a wide variety of man-made materials and placed underwater to restore, create, or enhance ecosystems, typically as a fisheries management tool. "Properly constructed and strategically sited artificial reefs can enhance fish habitat, provide more access to quality fishing grounds, benefit fishermen and the economies of shore communities, increase total fish biomass within a given area, and provide managers with another option for the conservation and management of fishery resources" (NOAA 2007b). Artificial reefs may also serve as breakwaters, protecting shorelines from erosion, and provide recreational opportunities.

NOAA's 2007 *National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs* outlines the state's role in planning for artificial reef construction and maintaining regulatory and quality control to ensure all artificial reefs in state waters:[17]

- Have biological justification relating to present and future fishery management needs
- Will have minimal negative effects on existing fisheries and/or conflicts with other uses
- Will have minimal negative effects on other natural resources and their future use
- Use materials that have long-term compatibility with the aquatic environment[18]
- Are monitored to determine whether reefs meet permit terms and conditions and are functioning as anticipated

The use of artificial reefs is a complex issue that requires planning, long-term monitoring, and evaluation to ensure the anticipated benefits are derived. There is still considerable debate on how artificial reefs impact the natural aquatic community into which they are introduced. "Improperly planned, constructed, or managed reefs may be ineffective, may cause conflict among competing user groups at the reef site, may increase the potential to overharvest targeted species, or may damage natural habitats. In such cases the benefits from the planned objectives of these structures may be negated" (NOAA 2007b). In some instances, artificial reefs may not be allowed in "Special Aquatic Sites," which are areas possessing special ecological characteristics of productivity,

Learning from others…Mississippi Rebuilds Artificial Reefs

Mississippi's Department of Marine Resources Artificial Reef Bureau, in partnership with Mississippi Gulf Fishing Banks, is working to rebuild fishing reefs destroyed by Hurricane Katrina. About 90 percent of Mississippi's inshore and offshore artificial reefs were destroyed by the storm. As of early 2010, 100 percent of the inshore reefs and 65 to 70 percent of offshore reefs had been rebuilt. Cultch material is often made up of crushed limestone, concrete, or other suitable material. In addition, the state constructed an artificial reef off the undeveloped Deer Island using debris from storm-damaged bridges to help slow erosion of the island, which provides protection to the mainland, and enhance recreational fishing in the area. www.dmr.state.ms.us/Fisheries/Reefs/artificial-reefs.htm

[17] While not explicitly mentioned in the plan, the mention of future needs and uses in these requirements suggests a need to consider how these needs and uses may be affected by climate change.

[18] "The collective experience of the state artificial reef managers over the past several decades has revealed that a number of secondary use materials are unsuitable as artificial reef material. Among those that have been found to be persistently problematic are: wood; fiberglass; plastic; light vehicle bodies; fiberglass boats and boat molds; railroad boxcars; and light gauge metal items, such as refrigerators, washing machines, and clothes dryers" (NOAA 2007b). The plan also advises against using tires in artificial reef construction.

habitat, wildlife protection, or other important and easily disrupted ecological values (e.g., coral reefs, sanctuaries and refuges, and vegetated shallows).

Aquatic Invasive Species Management

Climate-driven changes are likely to combine with other stressors to further increase the vulnerability of natural systems to invasive species (Karl et al. 2009). Changes in climate may alter pathways; influence establishment, spread, and distribution; and affect the ability of native systems to repel invasion. Impacts are likely to vary by region as well as species. Some species, both desirable and invasive, may thrive under new conditions; others may find them unsuitable (EPA 2008). Despite the uncertainties, aquatic invasive species management plays a critical role in overall ecosystem management and should be planned and implemented in a manner that is flexible and considers and monitors for potential changes.

The Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990, amended by the National Invasive Species Act of 1996, calls for states to develop aquatic invasive species management plans. By incorporating climate change into these plans, they could serve as the basis for modifying management activities (prevention, control, eradication) to meet changing conditions. In a 2008 report, the EPA's National Center for Environmental Assessment recommended the following initial steps:

- Incorporate climate change considerations into leadership and coordination activities
- Identify new aquatic invasive species threats as a result of climate change

Aquatic invasive species like the zebra mussel can upset ecosystems, threaten native species, damage structures, and cause other serious problems.

- Identify ecosystem vulnerabilities and improve methods to increase ecosystem resilience
- Evaluate the effectiveness of control mechanisms under changing conditions
- Manage information systems to include considerations of changing conditions

An aquatic invasive species program may include "research to assess current and future invasive threats or identify pathways; detection of newly established species (e.g., monitoring, surveys, inspection); import, introduction, or release requirements for species (e.g., permits and licenses); transport and shipping requirements; quarantine; education and public awareness efforts; control (e.g., biological, chemical, and manual); emergency

Learning from others…Massachusetts Plans for Aquatic Invasive Species
With leadership from the Massachusetts Office of Coastal Zone Management, the Massachusetts Aquatic Invasive Species Working Group, composed of state and federal agencies and nonprofit organizations, works to minimize the impacts of aquatic invasive species in the state. The group published the Massachusetts Aquatic Invasive Species Management Plan in 2002 and focuses on prevention and education; early detection, monitoring, and species identification; rapid response; and control. One program component is the Marine Invader Monitoring and Information Collaborative, a network of trained community groups and citizens that uses a standardized monitoring protocol to collect aquatic invasive species data and information. www.mass.gov/czm/invasives/

response efforts; and restoration of degraded areas to increase resilience against reinvasion" (EPA 2008). Importantly, an aquatic invasive species program that considers climate change will include a comprehensive monitoring system that can detect new aquatic invasive species and changes in existing ones and how they affect the management area.

Water Resource Management and Protection

- Stormwater Management
- Green Infrastructure
- Water Supply Management

Many of the impacts of climate change will be related to water, either too much of it, or not enough. A number of the measures discussed throughout this chapter can be used to help protect coastal communities from too much water—sea level rise and other types of inundation, in particular. This category includes measures that can be taken to manage stormwater, urban shallow flooding that tends to result from heavy precipitation events rather than rising waters, and to manage water supplies in anticipation of dry periods and corresponding water shortages. These are activities that, along with floodplain management, would benefit from being managed together as part of a comprehensive integrated water resources management program.

Detention basins can be designed to mimic natural ponds with gentle side slopes and native vegetation, which help prevent erosion and suspension of sediment and intercept pollutants from runoff.

Stormwater Management

In general, the purpose of stormwater management is to control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff. However, it also plays an important role in preventing damage to the built environment and the natural systems that protect it.

Existing drainage systems may be ill-equipped to handle the amount of stormwater runoff that will accompany the more intense rainfall events expected in the future. Those in low-lying areas will be further challenged by losses in elevation attributed to rising sea levels. To accommodate for these changes, coastal communities may need to modify and enhance the capacity of their drainage systems and should consider climate change when implementing and updating existing stormwater management plans. Modifications and enhancements may include:[19]

- Updating stormwater regulations
- Incorporating green infrastructure (see next page)

Learning from others...Maryland Funds Stormwater Enhancements to Address Climate Change
As part of its Coast-Smart Communities Initiative, Maryland's Department of Natural Resources is providing financial and technical assistance to coastal communities to address the impacts of sea level rise and climate change. One of the first four projects selected under the initiative will allow for improvements to Caroline County's floodplain and stormwater management programs. The project will include consolidation of and changes to the two ordinances to meet and exceed state requirements, public outreach, and input to a forthcoming rezoning process, which will consider natural resource protection and public safety issues. www.dnr.state.md.us/CoastSmart/

[19] Since some modifications and enhancements could encourage growth in the short-term, growth controls may also be needed.

- Limiting/removing impervious surfaces
- Acquiring easements for new and wider drainage ditches
- Implementing and enforcing stream dumping regulations
- Improving carrying and storage capacity of streams, channels, and basins through ongoing maintenance
- Installing larger pipes and culverts
- Adding pumps
- Creating retention and detention basins
- Converting culverts to bridges

By capturing runoff from impervious surfaces, such as roofs, roads, and driveways, rain gardens allow water to seep slowly into the ground and help protect nearby waterbodies by reducing runoff and filtering pollutants.

Green Infrastructure

As it relates to water resource management and protection, "green infrastructure" is a comprehensive approach that promotes the use of natural and built systems to improve infiltration, evapotranspiration, capture, and reuse of stormwater at regional, community, and site scales. It uses soil and vegetation in lieu of or in addition to the "hard" or "gray" infrastructure typically used to divert, store, and treat stormwater. Some aspects of green infrastructure will need to be managed through regulations (e.g., land use, building codes) and land acquisition programs; others will be most effective when promoted through outreach, education, and training.

Learning from others…Georgia Manual Promotes Green Infrastructure along Coast
The Coastal Stormwater Supplement to the Georgia Stormwater Management Manual provides Georgia's coastal communities with guidance on an integrated, green infrastructure-based approach to natural resource protection, stormwater management, and site design that can be used to better protect coastal Georgia's natural resources from the negative impacts of land development and nonpoint source pollution. The manual seeks to shift the focus of stormwater management efforts from postconstruction alleviation of impacts to preconstruction prevention. www.georgiaepd.org/Documents/CoastalStormwaterSupplement.html

Learning from others…Green Infrastructure Plays Key Role in Wisconsin Stormwater Management
Established by Wisconsin state law, the Metropolitan Milwaukee Sewerage District is a regional government agency that provides water reclamation and flood management services. To help reduce the number of combined sewer overflow events and improve the water quality in Lake Michigan, the agency has invested in a number of green infrastructure projects. Programs include "Green Seams," a land acquisition program, and the Lake Michigan Rain Gardens Initiative. The agency also promotes downspout disconnection and has partnered with local businesses and municipalities to make rain barrels accessible to the public. http://v3.mmsd.com/

By helping to maintain and restore natural hydrology and removing nutrients, pathogens, and pollutants from stormwater, these approaches:

- Improve water quality and groundwater recharge
- Reduce stormwater flooding
- Protect ecosystems
- Provide habitat
- Provide recreational opportunities
- Improve aesthetics

In general, regional green infrastructure is an interconnected network of natural lands and waters that provide essential environmental functions (e.g., wetlands, floodplains, and forests) and the buffers that protect them. Examples of community and site-level green infrastructure practices that may help coastal communities adapt to climate change include:

- Vegetated swales and media strips
- Urban forestry
- Porous pavement
- Rain gardens
- Green roofs
- Rain barrels and cisterns
- Downspout disconnection

Water Supply Management

Since climate change will likely negatively affect both water quantity and quality, and coastal populations will continue to grow, water supply managers must be prepared to respond to associated changes in supply

Learning from others…California Unites Land Use and Water Supply Planning
California state law requires cities and counties to link water supply information with certain land use decisions. Specifically, for proposed housing developments of 500 or more homes, it requires local water agencies to verify there is enough water to serve the project for at least 20 years, including long periods of drought. www.water.ca.gov/urbanwatermanagement/

Learning from others…Regional Compact Protects Valuable Water Resources in Great Lakes
In December 2005, the governors of the eight Great Lakes states endorsed the Great Lakes-St. Lawrence River Basin Water Resources Compact to protect and preserve the Great Lakes, and it has since been enacted into law in each state. The compact calls for each state to:

- Develop and maintain a water resources inventory
- Develop its own water conservation and efficiency goals and objectives consistent with basinwide goals and objectives
- Develop and implement a water conservation and efficiency program
- Prohibit new or increased diversions
- Manage and regulate new or increased withdrawals and consumptive uses in accordance with the compact

- Collectively conduct a periodic assessment of the cumulative impacts of withdrawals, diversions, and consumptive uses, which should consider climate change

www.cglg.org/projects/water/Agreement-Compact.asp

and demand. Water conservation, recovery, and reuse will be central to efforts to protect sustainable water supplies. Examples of activities to support these efforts or provide additional protection include the following:

- Encouraging changes in behavior (incentives)
- Modifying water utility operations
- Diversifying water supplies
- Integrating groundwater and surface water management
- Increasing storage capacity
- Employing new technologies
- Revising drought and water plans
- Revising/implementing regulations and building codes
- Modifying water pricing
- Reallocating water distribution
- Increasing use of water markets
- Relocating/retrofitting existing infrastructure
- Incorporating green infrastructure

Future planning should consider the multiple climate change phenomena that will affect water supplies and the supporting infrastructure. In addition, it should allow for flexibility to make adjustments as needed based on enhanced projections, seasonal forecasts, and observed changes.

Key Resources

General

- Adapting to Coastal Climate Change: A Guidebook for Development Planners, U.S. Agency for International Development. www.crc.uri.edu/index.php?actid=366
- Advanced Floodplain Management Concepts (training), Federal Emergency Management Agency. http://training.fema.gov/EMICourses/
- Coastal No Adverse Impact, Association of State Floodplain Managers. www.floods.org/index.asp?menuid=340&firstlevelmenuid=187&siteid=1
- Coastal Training Program, National Estuarine Research Reserve System. www.nerrs.noaa.gov/Training.aspx
- Community Rating System, FEMA. www.fema.gov/business/nfip/crs.shtm
- DisasterSafety.org, Institute of Business and Home Safety. www.disastersafety.org/
- Developing the [Hazard] Mitigation Plan: Identifying Actions and Implementing Strategies, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Guidance on Water and Adaptation to Climate Change, United Nations Economic Commission for Europe. www.unece.org/env/documents/2009/Wat/mp_wat/ECE_MP.WAT_30_E.pdf
- Integrating Historic Property and Cultural Resource Considerations into Hazard Mitigation Planning, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Introduction to Hazard Mitigation (online training), FEMA. http://training.fema.gov/EMIWeb/IS/
- Local Strategies for Addressing Climate Change, NOAA Coastal Services Center. www.csc.noaa.gov/publications.html
- Managing Coastal Erosion, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=1446
- Managing Floodplain Development through the National Flood Insurance Program (training), FEMA. http://training.fema.gov/EMICourses/
- Mitigating Shore Erosion along Sheltered Coasts, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=11764
- National Flood Insurance Plan/Community Rating System (training), FEMA. http://training.fema.gov/EMICourses/
- Negotiating for Coastal Resources (training), NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/negotiating_coastal.html
- Planning for Climate Change, NOAA Estuarine Reserves Division. http://nerrs.noaa.gov/CTPIndex.aspx?ID=455
- Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook/
- Shoreline Management: Alternatives to Hardening the Shore, NOAA Office of Ocean and Coastal Resource Management. http://coastalmanagement.noaa.gov/shoreline.html
- Special Area Management Plans. NOAA Office of Ocean and Coastal Resource Management. http://coastalmanagement.noaa.gov/special.html
- Synthesis of Adaptation Options for Coastal Areas, EPA Climate Ready Estuaries. www.epa.gov/cre/adaptationoptions.html

- U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory. http://chl.erdc.usace.army.mil/
- Using the Hazard Mitigation Plan to Prepare Successful Mitigation Projects, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs, U.S. Army Corps of Engineers. http://140.194.76.129/publications/eng-circulars/

Impact Identification and Assessment

See also Key Resources in Chapter 4.

- Climate Prediction Center, NOAA National Weather Service. www.cpc.ncep.noaa.gov/
- CoastWatch, NOAA National Environmental Satellite, Data, and Information Service. http://coastwatch.noaa.gov/
- Coral Reef Watch, NOAA National Environmental Satellite, Data, and Information Service. http://coralreefwatch.noaa.gov/
- Integrated Coral Observing Network, NOAA. http://ecoforecast.coral.noaa.gov/
- National Estuarine Research Reserve System Research. NOAA Estuarine Reserves Division. www.nerrs.noaa.gov/Research.aspx
- National Water Information System. U.S. Geological Survey. http://waterdata.usgs.gov/nwis
- NOAA Climate Service. www.climate.gov/
- NOAAWatch: NOAA's All Hazard Monitor, NOAA. www.noaawatch.gov/
- nowCoast, NOAA Office of Coast Survey. http://nowcoast.noaa.gov/
- Science-Based Monitoring Restoration Monitoring of Coastal Habitats, NOAA National Centers for Coastal Ocean Science. http://coastalscience.noaa.gov/ecosystems/estuaries/restoration_monitoring.html
- Tides and Currents, NOAA Center for Operational Oceanographic Products and Services. http://tidesandcurrents.noaa.gov/
- U.S. Drought Portal. National Integrated Drought Information System. www.drought.gov/
- U.S. Water Monitor. U.S. Geological Survey. http://watermonitor.gov/
- WaterWatch, U.S. Geological Survey. http://water.usgs.gov/waterwatch/

Awareness and Assistance

- Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decisionmaking, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- Building Public Support for Floodplain Management, Association of State Floodplain Managers. www.floods.org/ace-files/documentlibrary/Publications/BPS_Guidebook_2_1_10.pdf
- Climate Literacy—The Essential Principles of Climate Science: A Guide for Communities and Individuals, U.S. Climate Change Science Program. www.globalchange.gov/resources/educators/climate-literacy
- Communicating Sustainability, United Nations Environment Programme. www.unep.fr/scp/publications/details.asp?id=DTI/0679/PA
- Education and Outreach Training, U.S. Fish and Wildlife Service National Conservation Training Center. http://nctc.fws.gov/

- ICLEI Resource Guide: Outreach and Communications, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/engaging-your-community/
- Risk Behavior and Risk Communication: Synthesis and Expert Interviews, NOAA Coastal Services Center. www.csc.noaa.gov/publications.html
- Seven Cardinal Rules of Communication, EPA. www.epa.gov/CARE/library/7_cardinal_rules.pdf

Growth Management

- Coastal Community Planning and Development (training), NOAA Coastal Services Center. www.csc.noaa.gov/training/ccpd.html
- Hazard Mitigation: Integrating Best Practices into Planning, American Planning Association, FEMA. www.fema.gov/library/viewRecord.do?id=4267
- Smart Growth for Coastal and Waterfront Communities, NOAA, EPA, International City/County Management Association, Rhode Island Sea Grant. http://coastalsmartgrowth.noaa.gov/

Loss Reduction

- Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, FEMA. www.fema.gov/rebuild/mat/fema55.shtm
- Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings, FEMA. www.fema.gov/library/viewRecord.do?id=2441
- Engineering Principles and Practices of Retrofitting Floodprone Residential Structures, FEMA. www.fema.gov/library/viewRecord.do?id=1645
- FEMA Mitigation Assessment Team Reports, FEMA. www.fema.gov/rebuild/mat/mat_reprts.shtm
- Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding, FEMA. www.fema.gov/library/viewRecord.do?id=1420
- Implementing Floodplain Land Acquisition Programs in Urban Localities, University of North Carolina Center for Urban & Regional Studies. http://people.vanderbilt.edu/~james.c.fraser/publications/Floddplain%20Project%20Report.Final.pdf
- International Code Council (codes available for purchase). www.iccsafe.org/
- Introduction to Residential Coastal Construction (online training), FEMA. http://training.fema.gov/EMIWeb/IS/
- Local Officials Guide for Coastal Construction, FEMA. www.fema.gov/library/viewRecord.do?id=3647
- [Hazard] Mitigation Best Practices Portfolio, FEMA. www.fema.gov/plan/prevent/bestpractices/
- Retrofitting Flood-Prone Residential Buildings (training), FEMA. http://training.fema.gov/EMICourses/
- Sea Level Rise Planning Maps: Showing the Likelihood of Shore Protection. http://plan.risingsea.net/
- Selecting Appropriate [Hazard] Mitigation Measures for Floodprone Structures, FEMA. www.fema.gov/library/viewRecord.do?id=2737

Shoreline Management

- Beach Nourishment, U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory, http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;192
- Beach Nourishment and Protection, National Research Council of the National Academies. http://books.nap.edu/catalog.php?record_id=4984

- Beneficial Use of Dredged Material, U.S. Army Corps of Engineers. http://el.erdc.usace.army.mil/dots/budm/budm.cfm
- Living Shorelines, NOAA Restoration Center. http://habitat.noaa.gov/restoration/techniques/livingshorelines.html
- Regional Sediment Management, U.S. Army Corps of Engineers. www.wes.army.mil/rsm/
- Shore Protection Assessment: How Beach Nourishment Works, U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory. http://chl.erdc.usace.army.mil/pub-beachnourishment

Coastal and Marine Ecosystem Management

- Adaptive Management: The U.S. Department of the Interior Technical Guide, U.S. Department of the Interior. www.doi.gov/initiatives/AdaptiveManagement/documents.html
- Addressing Elevation and Inundation Issues in Habitat Restoration Planning and Implementation, NOAA National Ocean Service. http://response.restoration.noaa.gov/cpr/library/publications.html
- Aquatic Nuisance Species Task Force. http://anstaskforce.gov/default.php
- Climate Ready Estuaries Coastal Toolkit. EPA Climate Ready Estuaries. www.epa.gov/cre/toolkit.html
- Ecosystem-Based Management Tools Network. www.ebmtools.org/
- Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research, EPA National Center for Environmental Assessment. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=188305
- GIS Tools for Strategic Conservation Planning (training), NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/training/gisforscp.html
- Habitat Priority Planner: A New Planning Tool for Coastal Communities, NOAA Coastal Services Center. www.csc.noaa.gov/hpp/
- An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement, Interagency Workgroup on Wetland Restoration. www.lsu.edu/sglegal/pdfs/WetlandsUsersGuide.pdf
- National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs, NOAA National Marine Fisheries Service. www.nmfs.noaa.gov/sfa/PartnershipsCommunications/NARPwCover3.pdf
- National Conservation Training Center, U.S. Fish and Wildlife Service. http://nctc.fws.gov/
- NOAA Habitat Program. http://habitat.noaa.gov/
- NOAA National Marine Protected Areas Center. http://mpa.gov/
- NOAA Restoration Center. http://habitat.noaa.gov/restoration/
- Planner's Guide to Wetland Buffers for Local Governments, Environmental Law Institute. www.elistore.org/reports_detail.asp?ID=11272
- Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources, U.S. Climate Change Science Program. www.globalchange.gov/publications/reports/scientific-assessments/saps
- A Reef Manager's Guide to Coral Bleaching, Great Barrier Reef Marine Park Authority, NOAA, and the International Union for the Conservation of Nature. www.coris.noaa.gov/activities/reef_managers_guide/
- Strategies for Managing the Effects of Climate Change on Wildlife and Ecosystems, The H. John Heinz III Center for Science, Economics and the Environment. www.heinzcenter.org/publications/

Water Resource Management and Protection

- EPA Stormwater Program, EPA, Office of Water. http://cfpub.epa.gov/npdes/home.cfm?program_id=6
- Low Impact Development, EPA, Office of Wetlands, Oceans, and Watersheds. www.epa.gov/nps/lid/
- Managing Wet Weather with Green Infrastructure, EPA, Office of Wastewater Management. http://cfpub.epa.gov/npdes/home.cfm?program_id=298
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scale. EPA Office of Research and Development. www.epa.gov/smartgrowth/water_scorecard.htm
- Water Resources of the United States. U.S. Geological Survey. http://water.usgs.gov/

Evaluate, Select, and Prioritize Actions

- Benefit Cost Analysis, FEMA. www.fema.gov/government/grant/bca.shtm
- Benefit-Cost Analysis: Entry-Level Training, FEMA. http://training.fema.gov/EMICourses/
- Project Design and Evaluation (training), NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/project_design.html
- Using Benefit-Cost Review in [Hazard] Mitigation Planning, FEMA. www.fema.gov/plan/mitplanning/resources.shtm

CHAPTER 6 PLAN IMPLEMENTATION AND MAINTENANCE

This final chapter of the planning guide discusses implementing the plan; tracking, evaluating, and communicating plan progress; and updating the plan, which are all critical to the climate change adaptation plan's overall success. In each of these steps, it is important to remember that the science is evolving, and to account for this, planning will need to be ongoing and flexible.

To support these efforts, consider:

- Continuing to convene the planning team on a regular basis (or as needed) for consistency in ongoing planning efforts and to serve as a forum for climate change adaptation issues
- Instituting regular communications among planning team members to maintain momentum
- Continuing outreach efforts to inform and engage the public and other stakeholders
- Building and strengthening partnerships with other governments (federal, state, and local), nonprofits, and the private sector
- Working with elected officials to maintain support and visibility

The steps described in this chapter include:

- Step 4.1: Adopt the Plan
- Step 4.2: Implement the Plan
- Step 4.3: Integrate Plan Findings into Other State Planning Efforts and Programs
- Step 4.4: Track, Evaluate, and Communicate Plan Progress
- Step 4.5: Update the Plan

Step 4.1: Adopt the Plan

The plan will benefit from endorsement by the heads of the implementing agencies and formal adoption, whether by the governor, legislature, or an appropriate state agency. Formal adoption will demonstrate your state's commitment to climate change adaptation while also legitimizing the plan and authorizing its implementation.

Step 4.2: Implement the Plan

Once the plan has been adopted, make it known. It will likely contain actions that require stakeholder support, even action. Make sure each stakeholder group knows the plan is moving forward, what that means to them, and how they can continue to contribute to the state's climate change adaptation efforts.

With the strategy (goals and actions) in place and the plan approved, focus on the actions the planning team has selected. The action plans will guide the implementation of the individual actions.

One of the biggest challenges to the implementation of climate change adaptation actions is funding. This will likely require creativity and networking and will be an ongoing effort. Currently, there is not a lot of funding directly targeted at climate change adaptation. But, there are a number of grant opportunities for restoration, conservation, hazard mitigation, infrastructure (e.g., installing new/updating existing), and community and economic development.

Think about how funds from multiple sources can be combined as well as how you can work with other jurisdictions (states and local governments), regional organizations, and nongovernmental organizations to pool resources to meet complementary needs. Planning team members should think about the grants they have applied for in the past and how these funding vehicles might also support adaptation activities. Funding may also be available through nonprofit organizations (e.g., environmental advocacy groups), private foundations, and businesses. In addition to funding, these groups may also be able to provide in-kind goods and services.

It is likely that over the next few years, grant programs will be created or modified to fund climate change adaptation actions. The planning team may want to assign a team member or subgroup the responsibility of tracking relevant grant opportunities.

Sources of Federal Funding

In addition to funding available through the Coastal Zone Management Program and other programs administered by NOAA, a number of other federal agencies offer funding for activities that support climate change adaption. Agencies that administer such programs include, but are not limited to FEMA, EPA, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers. For some programs, applications must be for actions consistent with the goals and objectives identified in associated federally approved plans. Thus, to maximize funding opportunities, it is a good idea to align climate change adaptation planning with other federally supported planning activities.

Learning from others…Energy and Climate Collaborative Guides Implementation of Climate Action Plan in New Hampshire

Recognizing that implementation requires a high degree of coordination and integration, as well as flexibility, accountability, transparency, communication, and ongoing assessment and reporting, the authors of the New Hampshire Climate Action Plan, which includes adaptation, recommended formation of a public/private partnership, the New Hampshire Energy and Climate Collaborative, to oversee and guide implementation of the plan. The primary purpose of the collaborative is to track and facilitate implementation of the plan's recommendations and to report to the governor, legislature, and general public on progress toward achieving the desired outcomes. http://nhcollaborative.org/

Appendix A provides more information about some of the funding programs the planning team may be able to take advantage of to help the state adapt to climate change.

Sources of State and Local Funding

Where possible, try to get funding for adaptation incorporated into existing state budgets (e.g., capital improvement or operating budgets). Alternatively, traditional sources of state and local government funding include, but are not limited to: [1]

- General taxes
- Impact fees
- Property taxes
- General obligation bonds
- Sales taxes
- Revenue bonds
- Special tax districts
- Certificates of participation
- Use fees
- Leases (land and water)

Step 4.3: Integrate Plan into Other State Planning Efforts and Programs

As discussed in Chapters 3 and 4, there are a number of other state plans and programs that will have a role in adapting to climate change along the coast. The planning team considered these plans and programs in the adaptation plan and incorporated information and projects as appropriate. Likewise, other plans and programs should consider the adaptation plan, and climate change in general, as they are developed and updated. These other plans and programs can benefit from the adaptation plan's vulnerability assessment, and may even be the vehicles used to implement adaption actions identified by the planning team.

Step 4.4: Track, Evaluate, and Communicate Plan Progress

To ensure effectiveness of the adaptation plan and demonstrate its progress, the planning team, or some iteration of it, will need to continuously track the actions and evaluate the overall plan's progress toward meeting its goals. By designing a tracking and evaluation process upfront, the planning team will be in a good position to keep up the momentum gained during other steps of the planning process.

Including schedules, milestones, and evaluation plans in individual action plans will ease this review process. Evaluation of the overall success of the plan can also be achieved by monitoring changes in vulnerability as identified in the original plan. However, since the timing of climate change impacts is still uncertain, it may be difficult to assess level of success (or lack thereof) in the plan's early years. Some impacts, which will occur regardless of climate change (e.g., hazard events), may be easier to monitor than those that are likely to occur more slowly over time, like sea level rise.

Things to consider when designing the tracking and evaluation process include:

- How often should the planning team meet to review the plan and discuss its progress?
- How will the planning team keep elected officials apprised of progress and obstacles?
- How will progress be communicated to other stakeholders outside of the planning team?
- How should progress be reported (e.g., create a progress report template for actions)?
  - Is the action complete?
  - If the action is ongoing, what was accomplished during the reporting period?
  - Were there any unexpected problems, obstacles, or delays associated with the action? If so, how were they overcome?
  - Have there been any indicators of success or failure of implemented actions in meeting the intended goals? Any losses avoided?

[1] The ability of local governments to raise funds depends on your state's legal and regulatory framework.

Learning from others…Post-Storm Assessment Demonstrates Success in Florida
In 1995, Hurricane Opal demonstrated the success of more stringent land use and building codes, such as those associated with Florida's Coastal Construction Control Line (CCCL), in reducing storm-related damage. The CCCL was established in the 1980s by the state's Department of Environmental Protection (DEP) to strengthen land use and building construction standards (e.g., foundation, elevation, wind load) in coastal high hazard areas. According to the DEP, wave erosion caused by Hurricane Opal damaged or destroyed more structures than any other storm in the 20 years prior. A damage assessment conducted after the storm revealed that of the 576 major habitable structures seaward of the CCCL that were constructed to meet the higher standards, none were substantially damaged. On the other hand, of the 1,366 major habitable structures seaward of the CCCL that were constructed prior to the CCCL (or not permitted by the state), 768 (56 percent) received substantial damage (FEMA 1997). www.fema.gov/library/viewRecord.do?id=1712

- Were there any unintended consequences (positive or negative) due to implementation of an action?
- Are there any new stressors or challenges that may hinder action-specific or overall success? If so, can anything be done to overcome them?

This regular review also provides the planning team with an opportunity to make changes to the plan, goals, or actions based on lessons learned or new information. The plan update, as described in the next section, allows for these types of changes on a larger scale, but instances may arise that call for making adjustments between scheduled updates (e.g., disasters may provide opportunities for adaptation to be incorporated into recovery efforts).

Where successes are evident, promote them. Where there are challenges to implementation, modify or replace the action. In both instances, think about how the lessons learned can be applied elsewhere. Use the media and the other outreach vehicles identified in the planning process to communicate progress and elicit feedback.

Step 4.5: Update the Plan

Climate change adaptation plans are living documents that need to be updated to achieve maximum effectiveness. So, in addition to reviewing the status of the plan and the actions on a regular basis (and making revisions as appropriate), you should plan a full-scale update every few years (e.g., every three to five years) as determined by the planning team or as needed (e.g., in the wake of a catastrophe). Plan ahead for the update and assign ongoing data monitoring and collection tasks to team members or subgroups.

When updating the plan, consider following a process similar to the one outlined in this guide:

- ☐ Reconvene the planning team, altering its composition as needed
- ☐ Continue involving the public and other stakeholders
- ☐ Review the vulnerability assessment and make changes to priorities, as necessary, based on:
  - Observed changes
  - New climate science findings/projections
  - Recent hazard events
  - Changes to exposure
  - Changes in adaptive capacity
  - Completed actions
- ☐ Review the goals from the initial plan and make changes, as necessary, based on revised vulnerabilities and priorities
- ☐ Review the actions from the initial plan and reprioritize, change, delete, or add actions based on lessons learned as well as new goals and changes in adaptive capacity
- ☐ Review the implementation and evaluation process and make adjustments as appropriate

Finally, include in the plan update a status review of the actions identified in the previous version of the plan. And, document examples of successes, challenges, and lessons learned.

Key Resources

Funding

- The Catalog of Federal Domestic Assistance, General Services Administration. www.cfda.gov/
- Compendium of Federal Funding Sources for State and Tribal Wetlands Programs, UNC Environmental Finance Center, EPA. www.efc.unc.edu/publications/pdfs/wetlands/CompendiumofWetlandsFederalFundingSourcesNationalPrograms.pdf
- Federal Funding Programs, EPA, Office of Wetlands, Oceans, and Watersheds. www.epa.gov/owow/funding/federal.html
- Funding Opportunities for Coastal Managers (includes links to grant writing guides), NOAA Coastal Services Center. www.csc.noaa.gov/funding/
- Guidebook of Financial Tools: Paying for Environmental Systems, EPA. www.epa.gov/efinpage/publications/GFT2008.pdf

Other

- Adapting to Coastal Climate Change: A Guidebook for Development Planners, U.S. Agency for International Development. www.crc.uri.edu/index.php?actid=366
- Bringing the Plan to Life: Implementing the Hazard Mitigation Plan, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Developing the Mitigation Plan: Identifying Actions and Implementing Strategies, FEMA. www.fema.gov/plan/mitplanning/resources.shtm
- Developing and Promoting Mitigation Best Practices and Case Studies, FEMA. www.fema.gov/library/viewRecord.do?id=1774
- Planning for Meaningful Evaluation (training). NOAA Coastal Services Center. www.csc.noaa.gov/cms/cls/evaluation.html
- Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments, ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook/
- Telling the Tale of Disaster Resistance. A Guide to Capturing and Communicating the Story, FEMA. www.fema.gov/library/viewRecord.do?id=1762
- Using the Hazard Mitigation Plan to Prepare Successful Mitigation Projects, FEMA. www.fema.gov/plan/mitplanning/resources.shtm

Appendix A: Potential Federal Funding Sources

The programs in the table below are examples of the types of programs that may provide funding indirectly or directly for activities that support climate change adaptation. The list is not comprehensive, and availability of funds may vary from one year to the next. General contact information is provided, but, in most cases, your best contact is the parallel state agency or the regional federal office. An ongoing monitoring of Grants.gov is a good way to keep up with federal funding opportunities.

Program Name/ CFDA Number	Description	Contact Information
Grants.gov	Source to find and apply for federal government grants.	Grants.gov www.grants.gov/
Catalog of Federal Domestic Assistance	Database of federal programs.	Catalog of Federal Domestic Assistance www.cfda.gov/
U.S. Department of Commerce		
Coastal Zone Management Administration Awards CFDA 11.419	Financial assistance for implementation and enhancement of state coastal management programs, which aim to preserve, protect, develop, and where possible restore and enhance the resources of the nation's coastal zone.	NOAA/National Ocean Service Office of Ocean and Coastal Resource Management (301) 713-3155 http://coastalmanagement.noaa.gov/programs/czm.html
Coastal and Estuarine Land Conservation Program CFDA 11.419	Financial assistance for land acquisition to protect important coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses.	NOAA/National Ocean Service Office of Ocean and Coastal Resource Management (301) 713-3155 http://coastalmanagement.noaa.gov/land/
Coral Reef Conservation Grant Program CFDA 11.419	Financial assistance for broad-based coral reef conservation activities (including management and monitoring).	NOAA/National Ocean Service Office of Ocean and Coastal Resource Management (301) 713-3155 http://coralreef.noaa.gov/aboutcrcp/workwithus/funding/welcome.html

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of Commerce (cont'd)		
National Estuarine Research Reserve CFDA 11.420	Financial assistance for development, land acquisition, monitoring, research, education, operation, and facilities construction for National Estuarine Research Reserves for the purpose of creating natural field laboratories to gather data and make studies of and educate people about the natural and human processes occurring within the estuaries of the coastal zone.	NOAA/National Ocean Service Office of Ocean and Coastal Resource Management (301) 713-3155 http://nerrs.noaa.gov/
Community-Based Restoration Program CFDA 11.463	Financial assistance to implement on-the-ground habitat restoration projects to benefit marine, estuarine, and riparian habitats, including but not limited to salt marshes, seagrass beds, coral reefs, mangrove forests, and freshwater habitat important to anadromous fisheries, predominantly in coastal areas around the United States.	NOAA/National Marine Fisheries Service Office of Habitat Conservation (301) 713-0174 www.habitat.noaa.gov/funding/crp.html
Climate and Societal Interactions Program CFDA 11.431	Financial assistance for research, outreach, and education activities that enhance the capacity of key socioeconomic sectors to respond to and plan for a changing climate through the use of climate information and related decision-support resources.	NOAA/Office of Oceanic and Atmospheric Research Climate Program Office www.cpo.noaa.gov/cpo_pa/
Economic Adjustment Assistance Program CFDA 11.307	Financial assistance to address the needs of communities experiencing adverse economic changes that may occur suddenly or over time, including but not limited to those caused by federally declared disasters.	Economic Development Administration[1] www.eda.gov/AboutEDA/Programs.xml
Public Works and Economic Development Program CFDA 11.300	Financial assistance to help the nation's most distressed communities revitalize, expand and upgrade their physical infrastructure to attract new industry, encourage business expansion, diversify local economies, and generate or retain long-term private sector jobs and investments.	Economic Development Administration[1] www.eda.gov/AboutEDA/Programs.xml

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of Homeland Security		
Hazard Mitigation Grant Program CFDA 97.039	Financial assistance to implement long-term hazard mitigation measures to reduce the loss of life and property after a major disaster declaration.	Federal Emergency Management Agency[2] Risk Reduction Division (866) 222-3580 hmagrantshelpline@dhs.gov www.fema.gov/government/grant/hmgp/
Pre-Disaster Mitigation Program CFDA 97.047	Financial assistance for hazard mitigation planning and the implementation of hazard mitigation projects that reduce injuries, loss of life, and damage and destruction of property prior to a disaster.	Federal Emergency Management Agency[2] Risk Reduction Division (866) 222-3580 hmagrantshelpline@dhs.gov www.fema.gov/government/grant/pdm/
Flood Mitigation Assistance Program CFDA 97.029	Financial assistance to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program (NFIP). The long-term goal is to reduce or eliminate claims under the NFIP through mitigation activities.	Federal Emergency Management Agency[2] Risk Reduction Division (866) 222-3580 hmagrantshelpline@dhs.gov www.fema.gov/government/grant/fma/
Repetitive Flood Claims Program CFDA 97.092	Financial assistance to reduce or eliminate the long-term risk of flood damage to structures insured under the NFIP that have had one or more claims for flood damage and that cannot meet the requirements of the Flood Mitigation Assistance program for either cost-share or capacity to manage the activities.	Federal Emergency Management Agency[2] Risk Reduction Division (866) 222-3580 hmagrantshelpline@dhs.gov www.fema.gov/government/grant/rfc/
Severe Repetitive Loss Program CFDA 97.110	Financial assistance to reduce or eliminate the long-term risk of flood damage to severe repetitive loss structures insured under the NFIP.	Federal Emergency Management Agency[2] Risk Reduction Division (866) 222-3580 hmagrantshelpline@dhs.gov www.fema.gov/government/grant/srl/
Public Assistance Grant Program CFDA 97.036	Financial assistance so communities can quickly respond to and recover from major disasters or emergencies declared by the President, includes funding for the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain private nonprofit organizations and encourages their protection from future events by providing assistance for hazard mitigation during the recovery process.	Federal Emergency Management Agency[2] Public Assistance Division www.fema.gov/government/grant/pa/

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of Homeland Security (cont'd)		
Community Assistance Program State Support Services Element CFDA 97.023	Financial assistance to states to provide technical assistance to NFIP communities and to evaluate community performance in implementing NFIP floodplain management activities with the additional goal of building state and community floodplain management expertise and capability.	Federal Emergency Management Agency[2] www.fema.gov/plan/prevent/floodplain/fema_cap-ssse.shtm
U.S. Environmental Protection Agency		
Wetland Program Development Grants CFDA 66.461; 66.462	Financial assistance to enhance and build programs that protect, manage, and restore wetlands.	Office of Wetlands, Oceans, and Watersheds[3] (800) 832-7828 wetlands.helpline@epa.gov www.epa.gov/owow/wetlands/
National Estuary Program CFDA 66.456	Financial assistance to protect and restore estuaries and estuarine watersheds designated by the EPA administrator as estuaries of national significance.	Office of Wetlands, Oceans, and Watersheds[3] www.epa.gov/owow/estuaries/
Nonpoint Source Implementation Grants CFDA 66.460	Financial assistance for implementing EPA-approved Section 319 nonpoint source management programs.	Office of Wetlands, Oceans, and Watersheds[3] (202) 566-1155 www.epa.gov/owow/nps/cwact.html
U.S. Department of Defense		
Estuary Habitat Restoration Program	Financial and technical assistance for estuary habitat restoration projects that result in improving degraded estuaries or estuary habitat or creating estuary habitat, with the goal of attaining a self-sustaining system integrated into the surrounding landscape.	U.S. Army Corps of Engineers[4] Civil Works www.usace.army.mil/CECW/ERA/
Beach Erosion Control Projects CFDA 12.101	Financial and technical assistance to control beach and shore erosion to public shores through projects not specifically authorized by Congress.	U.S. Army Corps of Engineers[4] Civil Works
Flood Control Projects CFDA 12.106	Financial and technical assistance to reduce flood damages through projects not specifically authorized by Congress.	U.S. Army Corps of Engineers[4] Civil Works
Aquatic Plant Control CFDA 12.100	Financial and technical assistance for the control of obnoxious aquatic plants in rivers, harbors, and allied waters. The program is designed to deal primarily with weed infestations of major economic significance.	U.S. Army Corps of Engineers Aquatic Plant Control Operations Support Center (800) 291-9405

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of Defense (cont'd)		
Protection of Essential Highways, Highway Bridge Approaches, and Public Works CFDA 12.105	Financial and technical assistance to provide bank protection of highways, highway bridges, essential public works, churches, hospitals, schools, and other nonprofit public services endangered by flood-caused erosion.	U.S. Army Corps of Engineers[4] Civil Works
Snagging and Clearing for Flood Control CFDA 12.108	Financial and technical assistance to reduce flood damages by channel clearing and excavation, with limited embankment construction by use of materials from the clearing operation only.	U.S. Army Corps of Engineers[4] Civil Works
Aquatic Ecosystem Management and Restoration	Financial and technical assistance to restore degraded aquatic ecosystem structure, function, and dynamic processes to a less degraded, more natural condition, which will involve consideration of the ecosystem's natural integrity, productivity, stability, and biological diversity.	U.S. Army Corps of Engineers[4] Civil Works
Beneficial Uses of Dredged Materials	Financial and technical assistance to protect, restore, and create aquatic and wetland habitats in connection with dredging of an authorized navigation project.	U.S. Army Corps of Engineers[4] Civil Works
Project Modifications for Improvement of the Environment	Financial and technical assistance for planning, engineering and design, and construction of projects to restore ecosystems degraded by a previously constructed Corps of Engineers project. Projects typically involve environmental restoration of aquatic, floodplain, and upland areas.	U.S. Army Corps of Engineers[4] Civil Works
U.S. Department of the Interior		
North American Wetlands Conservation Act CFDA 15.623	Financial assistance for long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats.	U.S. Fish and Wildlife Service[5] Division of Bird Habitat Conservation (703) 358-1784 dbhc@fws.gov www.fws.gov/birdhabitat/Grants/NAWCA/
National Coastal Wetlands Conservation Grant Program CFDA 15.614	Financial assistance for acquisition, restoration, management, or enhancement of coastal wetlands.	U.S. Fish and Wildlife Service[5] Division of Habitat and Resource Conservation (703) 358-2236 www.fws.gov/coastal/CoastalGrants/

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of the Interior (cont'd)		
Cooperative Endangered Species Conservation Fund CFDA 15.615	Financial assistance for a wide array of voluntary conservation projects for candidate, listed, and recently recovered species. Projects include habitat restoration, species status surveys, public education and outreach, captive propagation and reintroduction, nesting surveys, genetic studies, development of management and habitat conservation plans, and land acquisition.	U.S. Fish and Wildlife Service Endangered Species Program[6] www.fws.gov/endangered/grants/
State (Tribal) Wildlife Grants CFDA 15.634; 15.639	Financial assistance to develop and implement programs for the benefit of wildlife and their habitat.	U.S. Fish and Wildlife Service[5] Wildlife and Sport Fish Restoration Program http://wsfrprograms.fws.gov/Subpages/GrantPrograms/GrantProgramsIndex.htm
Landowner Incentive Program CFDA 15.633	Financial assistance to establish or supplement landowner incentive programs that provide technical or financial assistance to private landowners for the protection and management of habitat to benefit federally listed, proposed, or candidate species, or other at-risk species on private lands.	U.S. Fish and Wildlife Service[5] Wildlife and Sport Fish Restoration Program http://wsfrprograms.fws.gov/Subpages/GrantPrograms/GrantProgramsIndex.htm
Land and Water Conservation Fund CFDA 15.916	Financial assistance for the preparation of statewide comprehensive outdoor recreation plans and acquisition and development of outdoor recreation areas and facilities.	National Park Service[7] www.nps.gov/ncrc/programs/lwcf/
U.S. Department of Housing and Urban Development		
Community Development Block Grant Program CFDA 14.218; 14.228	Financial assistance for the development of viable urban communities, which means providing decent housing and a suitable living environment and by expanding economic opportunities, principally for persons of low- and moderate-income. Under certain circumstances, funding may be used to meet urgent needs where existing conditions pose a serious and immediate threat to the health or welfare of the community.	Community Planning and Development[8] www.hud.gov/offices/cpd/communitydevelopment/programs/

Program Name/ CFDA Number	Description	Contact Information
U.S. Department of Agriculture		
Urban and Community Forestry Program CFDA 10.675	Financial assistance to plan for, establish, manage, and protect trees, forests, green spaces, and related natural resources in and adjacent to cities and towns.	U.S. Forest Service[9] State and Private Forestry www.fs.fed.us/spf/
Watershed Protection and Flood Prevention CFDA 10.904	Financial and technical assistance for works of improvement to protect, develop, and utilize the land and water resources in watersheds.	Natural Resources Conservation Service[10] Conservation Planning and Technical Assistance Division www.nrcs.usda.gov/programs/watershed/

Regional Contacts:

[1] www.eda.gov/AboutEDA/Regions.xml
[2] www.fema.gov/about/regions/
[3] www.epa.gov/epahome/regions.htm
[4] www.usace.army.mil/about/Pages/Locations.aspx
[5] www.fws.gov/coastal/CoastalGrants/contactUs.html
[6] www.fws.gov/endangered/regions/
[7] www.nps.gov/ncrc/programs/lwcf/contact_list.html
[8] www.hud.gov/offices/cpd/about/staff/fodirectors/
[9] www.fs.fed.us/ucf/contact_regional.html
[10] www.nrcs.usda.gov/about/directory/specialists.html

Appendix B: Federal Laws and Executive Orders Relevant to Climate Change on the Coast

Some of the federal laws and presidential executive orders that are relevant to climate change on the coast are summarized below. They are listed alphabetically and encompass all amendments. Dates indicate the year the law was originally passed.

Laws as codified can be accessed at http://uscode.house.gov/lawrevisioncounsel.shtml. Executive orders can be accessed at www.archives.gov/federal-register/executive-orders/.

Laws

Title	Description	Lead Agency(s)
Clean Water Act (Federal Water Pollution Control Act) (1972) 33 U.S.C. 1251 et seq.	Established the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Includes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Provides loans and grants to local governments for wastewater treatment, nonpoint source pollution control, and estuary protection.	• U.S. Army Corps of Engineers • U.S. Environmental Protection Agency
Coastal Barrier Resources Act (1982) 16 U.S.C. 3501 et seq.	Restricts federal expenditures that might encourage or support development, including flood insurance, within the Coastal Barrier Resources System, which consists of undeveloped coastal barriers along the Atlantic, Gulf, and Great Lakes coasts.	• U.S. Fish and Wildlife Service
Coastal Wetlands Planning, Protection, and Restoration Act (1990) 16 U.S.C. 3951 et seq.	Established the National Coastal Wetlands Conservation Grant Program to provide funding for acquisition, restoration, management and enhancement of coastal wetlands.	• U.S. Fish and Wildlife Service
Coastal Zone Management Act (1972) 16 U.S.C. 1451 et seq.	Provides for management of coastal resources, including the Great Lakes, and balances economic development with environmental conservation. Outlines and provides financial support for the National Coastal Zone Management Program and the National Estuarine Research Reserve System. Recognizes the need for coastal states to anticipate and plan for sea level rise.	• NOAA/National Ocean Service

Title	Description	Lead Agency(s)
Coral Reef Conservation Act (2000) 16 U.S.C. 6401 et seq.	Established the National Coral Reef Action Strategy, Coral Reef Conservation Program, and Coral Reef Conservation Fund to provide funding and promote effective management and use of sound science to preserve, sustain, and restore valuable coral reef ecosystems.	• NOAA/National Ocean Service
Endangered Species Act (1973) 16 U.S.C. 1531 et seq.	Provides for the conservation of endangered and threatened species of fish, wildlife, and plants and the ecosystems on which they depend. Authorizes the determination and listing of species as endangered and threatened. Prohibits unauthorized taking, possession, sale, and transport of endangered species. Provides funding to acquire land for the conservation of listed species and to support state programs.	• NOAA/National Marine Fisheries Service • U.S. Fish and Wildlife Service
Estuary Protection Act (1968) 16 U.S.C. 1221 et seq.	Encourages consideration in planning and development activities of the value of estuaries and the need to protect, conserve, and restore them.	• U.S. Fish and Wildlife Service
Estuary Restoration Act (2000) 33 U.S.C. 2901 et seq.	Made restoring estuaries a national priority. Promotes the restoration of estuary habitat by forging effective partnerships among public agencies and between the public and private sectors, providing financial and technical assistance for estuary habitat restoration projects, and developing and enhancing monitoring and research capabilities.	• Natural Resources Conservation Service • NOAA/National Marine Fisheries Service/National Ocean Service • U.S. Army Corps of Engineers • U.S. Environmental Protection Agency • U.S. Fish and Wildlife Service
Federal Water Project Recreation Act (1965) 16 U.S.C. 4601K-12 et seq.	Requires that recreation and fish and wildlife enhancement be given full consideration in federal water development projects (e.g., navigation, flood control, reclamation, hydroelectric projects). Authorizes funding for land acquisition to establish refuges for migratory waterfowl.	• U.S. Fish and Wildlife Service
Fish and Wildlife Coordination Act (1934) 16 U.S.C. 661 et seq.	Provides for protection of fish and wildlife when federal actions result in the control or modification of a natural stream or body of water. Requires federal agencies to consider the effect that water-related projects would have on fish and wildlife resources, take action to prevent loss or damage to these resources, and provide for the development and improvement of these resources.	• NOAA/National Marine Fisheries Service • U.S. Fish and Wildlife Service
Fish and Wildlife Conservation Act (1980) 16 U.S.C. 2901 et seq.	Authorizes financial and technical assistance to states for development, revision, and implementation of conservation plans and programs for nongame fish and wildlife.	• U.S. Fish and Wildlife Service
Magnuson-Stevens Fishery Conservation and Management Act (1976) 15 U.S.C. 1801 et seq.	Provides for management and conservation of marine fisheries in U.S. federal waters through regional fishery management councils. Promotes rebuilding overfished fisheries, protecting essential fish habitat, and reducing bycatch. Mandates the use of annual catch limits and accountability measures to end overfishing.	• NOAA/National Marine Fisheries Service

Title	Description	Lead Agency(s)
Marine Mammal Protection Act (1972) 16 U.S.C. 1361 et seq.	Restricts the taking and importing of marine mammals and marine mammal products. Calls for an ecosystem approach to natural resource management and conservation.	• NOAA/National Marine Fisheries Service • U.S. Fish and Wildlife Service
National Environmental Policy Act (1969) 42 U.S.C. 4321 et seq.	Requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions (including financing) and reasonable alternatives to those actions.	• U.S. Environmental Protection Agency
National Flood Insurance Act (1968) 42 U.S.C. 4001 et seq.	Established the National Flood Insurance Program to provide protection (insurance) against flood losses and encourage sound land use. Requires communities to participate in the flood insurance program as a condition of future federal financial assistance. Requires the purchase of flood insurance by property owners who are being assisted by federal programs or by federally supervised, regulated, or insured agencies or institutions in the acquisition or improvement of land or facilities (e.g., mortgages) in special flood hazard areas.	• Federal Emergency Management Agency
National Historic Preservation Act (1966) 16 U.S.C. 470 et seq.	Directs federal agencies to consider the effects of their actions (including financing) on historic properties (e.g., districts, buildings, structures, sites, or objects) in their decision making.	• National Park Service
National Marine Sanctuaries Act (1972) 16 U.S.C. 1431 et seq.	Authorizes the designation and protection of areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, or aesthetic qualities as national marine sanctuaries.	• NOAA/National Ocean Service
National Park Service Organic Act (1916) 16 U.S.C. 1 et seq.	Established the National Park Service to conserve, promote, and regulate the use of federal areas designated as part of the Natural Park System.	• National Park Service
National Wildlife Refuge System Administration Act (1966) 16 U.S.C. 668dd, 668ee	Provides for the administration and management of the national wildlife refuge system, including wildlife refuges, areas for the protection and conservation of fish and wildlife threatened with extinction, wildlife ranges, game ranges, wildlife management areas and waterfowl production areas.	• U.S. Fish and Wildlife Service
Non-Indigenous Aquatic Nuisance Prevention and Control Act (1990) 16 U.S.C. 4701 et seq.	Provides for prevention and control of infestations of the coastal inland waters of the United States by the zebra mussel and other nonindigenous aquatic nuisance species through ballast water management, research, and financial assistance.	• NOAA • U.S. Army Corps of Engineers • U.S. Coast Guard • U.S. Fish and Wildlife Service • U.S. Environmental Protection Agency

Title	Description	Lead Agency(s)
North American Wetlands Conservation Act (1989) 16 U.S.C. 4401 et seq.	Provides for the conservation of North American wetland ecosystems for waterfowl, other migratory birds, fish, and wildlife through a nonregulatory, incentive-based program that encourages public-private partnerships and provides financial assistance for projects.	• U.S. Fish and Wildlife Service
Resource Conservation and Recovery Act (1976) 42 U.S.C. 6901 et seq.	Authorizes control of hazardous waste generation, transportation, treatment, storage, and disposal. Establishes a framework for the management of nonhazardous solid waste.	• U.S. Environmental Protection Agency
Rivers and Harbors Appropriation Act (1899) 33 U.S.C. 401 et seq.	Prohibits navigational obstructions, including alteration (e.g., excavation and fill) of the course, location, condition, or capacity of any navigable water of the United States. Regulates the construction of wharves, piers, jetties, bulkheads, and similar structures in ports, rivers, canals, or other areas used for navigation.	• U.S. Army Corps of Engineers
Robert T. Stafford Disaster Relief and Emergency Assistance Act (1974) 42 U.S.C. 5121 et seq.	Established the process through which the federal government provides assistance to state and local governments to alleviate the suffering and damage which result from disasters. Encourages and provides funding for hazard mitigation and requires state and local hazard mitigation plans for some types of assistance.	• Federal Emergency Management Agency
Safe Drinking Water Act (1974) 42 U.S.C. 300f et seq.	Authorized establishment of national health-based standards to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells.	• U.S. Environmental Protection Agency
Water Resources Development Act (multiple years) 33 U.S.C. 2201 et seq.	Authorizes funding for water-related projects, including beach nourishment, clean water, and flood control programs.	• U.S. Army Corps of Engineers
Watershed Protection and Flood Prevention Act (1954) 16 U.S.C. 1001 et seq.	Authorizes technical and financial assistance to state and local governments for planning and installing watershed projects to address natural resource issues such as flooding and sedimentation.	• Natural Resources Conservation Service
Wild and Scenic Rivers Act (1968) 16 U.S.C. 1271 et seq.	Established the National Wild and Scenic Rivers System to protect and preserve rivers that possess scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values as well as their immediate environments.	• Bureau of Land Management • National Park Service • U.S. Fish and Wildlife Service • U.S. Forest Service

Executive Orders

Title	Description
Executive Order 11988 Floodplain Management (1977) Codified under 42 U.S.C. 4321	Directs federal agencies to provide leadership and take action to reduce the risk of flood loss; to minimize the impact of floods on human safety, health, and welfare; and to restore and preserve the natural and beneficial values served by floodplains by evaluating the potential effects of any actions (federally conducted, approved, or funded) they may take in a floodplain and avoiding harm where practicable.
Executive Order 11990 Protection of Wetlands (1977) Codified under 42 U.S.C. 4321	Directs federal agencies to provide leadership and take action to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands by evaluating the potential effects of any actions (federally conducted, approved, or funded) they may take in a wetland and avoiding harm where practicable.
Executive Order 12898 Environmental Justice (1994) Codified under 42 U.S.C. 4321	Directs federal agencies to make achieving environmental justice part of their missions by identifying and addressing disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.
Executive Order 13089 Coral Reef Protection (1998) Codified under 16 U.S.C. 6401	Established the United States Coral Reef Task Force to lead U.S. efforts to preserve and protect coral reef ecosystems. Directs federal agencies to ensure, to the extent practicable, that actions they authorize, fund, or carry out do not degrade these ecosystems.
Executive Order 13112 (1999) Codified under 42 U.S.C. 4321	Established the Invasive Species Council. Requires federal agencies to address invasive species concerns and to not authorize or carry out new actions that would cause or promote the introduction of invasive species to minimize the economic, ecological, and human health impacts that invasive species cause.
Executive Order 13158 Marine Protected Areas (2000) Codified under 16 U.S.C 1431	Established the Marine Protected Areas Center. Directs federal agencies to work with government and nongovernmental partners to increase protection and sustainable use of ocean resources by strengthening and expanding a national system of marine protected areas (MPA). Directs federal agencies to avoid harm to MPAs through the actions they authorize, fund, or carry out.
Executive Order 13514 Federal Leadership in Environmental, Energy, and Economic Performance (2009)	Requires agencies to participate in the interagency Climate Change Adaptation Task Force to develop a U.S. strategy for adaptation to climate change and approaches through which the policies and practices of the agencies can be made compatible with and reinforce the strategy.
Executive Order 13547 Stewardship of the Ocean, Our Coasts, and the Great Lakes (2010)	Establishes a national policy to ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources, enhance the sustainability of ocean and coastal economies, preserve our maritime heritage, support sustainable uses and access, provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification, and coordinate with our national security and foreign policy interests.

Appendix C: Regional Climate Change Summaries

Projections of future climate change can be made with increased confidence at the regional level as climate modeling and downscaling capabilities continue to improve. However, changes in precipitation are more difficult to project than changes in temperature. Confidence in projected changes is also higher for the winter and spring seasons than for the summer and fall. Furthermore, average temperature changes are not as important as the projected increases of the minimum and maximum temperature. All regions will continue to experience considerable decadal variation due to events such as El Niño.

With these points in mind, this appendix summarizes regional, climate-related changes that have been observed over the twentieth century or are projected to occur at some time during or by the end of the twenty-first century. These results have been excerpted from the U.S. Global Change Research Program's *Global Climate Change Impacts in the United States*, (Karl et al. 2009), unless otherwise indicated.

Northeast (Maine to Virginia)

The following changes in climatic conditions have been observed in the Northeast:

- Since 1970, the average air temperature has increased by 2°F; the rise in temperature during the winter was 4°F.
- Days with temperatures over 90°F have become more frequent.
- An increasing trend in precipitation has been observed throughout much of the year and, most notably, over the last 50 years, the number of days with very heavy precipitation has increased.
- Winter precipitation has come more typically as rain rather than as snow, leading to reduced snowpack.
- Winter ice is disappearing earlier from lakes and rivers, and river flows are peaking earlier in the spring as the snow melts.
- Average sea surface temperature levels have been increasing in the North Atlantic.
- In the mid-Atlantic region from New York to North Carolina, rates of relative sea level rise ranged between 2.4 and 4.4 mm/year (~.094 and .173 in) or about .3 m (~11.8 in) over the twentieth century (CCSP 2009c); low-lying topography and a high storm frequency make this area particularly vulnerable.

The following climate-related changes are projected for the Northeast:

- Air temperature will rise an additional 2.5 to 4°F in winter and 1.5 to 3.5°F in summer over the next several decades.
- Under a higher emissions scenario, by late this century:
  - The summer heat would occur three weeks earlier and end three weeks later and the average number of days above 100°F for certain cities would increase,
  - Short-term droughts are projected to occur as frequently as once each summer in the Catskill and Adirondack Mountains and across the New England states, and
  - Winters will be shorter with fewer cold days, more precipitation, and a reduced snow season.
- Severe flooding due to sea level rise and heavy downpours is likely to occur more frequently.

- The densely populated coasts of the Northeast face substantial increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands.
- As the average temperatures of the ocean continue to increase, the center of lobster fisheries is projected to continue its northward shift and the cod fishery on Georges Bank is likely to be diminished.

Southeast (includes Gulf of Mexico States)

The following changes in climatic conditions and impacts have been observed in the Southeast:

- Since 1970, the annual average temperature has risen about 2°F, with the greatest change occurring during the winter.
- The number of freezing days has declined by four to seven days per year for most of the region since the mid-1970s.
- Since 1901, there has been a 30 percent increase in precipitation during the fall (except in southern Florida). Summer and winter precipitation declined.
- There has been an increase in heavy downpours in many parts of the region.
- The percentage of the region experiencing moderate to severe drought increased over the past three decades.
- Barrier islands are losing land at an increasing rate, reducing their protective function.
- The destructive potential of Atlantic hurricanes has increased since 1970, correlated with an increase in sea surface temperature. A similar relationship with the frequency of landfalling hurricanes has not been established.
- An increase in average summer wave heights along the U.S. Atlantic coastline since 1975 has been attributed to a progressive increase in hurricane power.

The following climate-related changes are projected for the Southeast:

- Quality of life will be affected by increasing heat stress, water scarcity, and severe weather events.
- Warming in all seasons will continue and the rate of warming will increase through the end of the century.
- The greatest increases in temperature are expected in the summer, and the number of very hot days will increase at a greater rate than the average temperature.
- Average temperatures are projected to rise from between 4.5°F to about 9°F by the 2080s, depending upon the degree to which emissions are controlled.
- Higher temperatures will lead to an increased frequency, intensity, and duration of drought across the region.
- An increase in average sea level of up to two feet or more and the likelihood of increased hurricane intensity and associated storm surge are likely to be among the most costly consequences of climate change for this region.
- The intensity of Atlantic hurricanes is likely to increase this century with higher peak wind speeds, rainfall intensity, and storm surge. Increased intensity will further affect low-lying coastal ecosystems and coastal communities along the Gulf and South Atlantic coastal margin; increase inland and coastal flooding, coastal erosion rates, wind damage to coastal forests, and wetland loss; and exacerbate the risk to people, personal property, and public infrastructure.
- More frequent storm surge flooding and permanent inundation of coastal ecosystems and communities is likely in some low-lying areas, particularly along the central Gulf Coast where the land surface is sinking.
- The salinity of estuaries, coastal wetlands, tidal rivers, and shallow aquifers is likely to increase.

- Ecological thresholds are expected to be crossed throughout the region, causing major disruptions to ecosystems and to the benefits they provide to people.
- Decreased water availability due to increased temperature and longer periods of time between rainfall events, in addition to an increase in demand, is very likely to affect the region's economy as well as its natural systems.

Midwest (Great Lakes)

The following changes in climatic conditions have been observed in the Midwest in recent decades:

- Average temperatures have increased, particularly during the winter.
- Precipitation in summer and winter has been above average for the last three decades, the wettest period in a century.
- Heavy downpours are twice as frequent as they were a century ago, and two record-breaking floods occurred in the past 15 years.
- There has been a decrease in lake ice throughout the region and in the Great Lakes.

The following climate-related changes are projected for the Midwest:

- Heat waves are expected to be more frequent, severe, and longer lasting.
- Precipitation is expected to increase in winter and spring and to become more intense throughout the year, leading to more pronounced flooding/runoff conditions.
- The likelihood of drought will increase in the summer, with water levels declining in rivers, streams, and wetlands.
- Great Lake levels are expected to fall no more than a foot under a lower emissions scenario and between one and two feet under a higher emissions scenario. The greater the temperature rise, the higher the likelihood of a larger decrease in lake levels. There are also potential impacts on beaches, coastal ecosystems, dredging requirements, infrastructure, and shipping.
- Stratification of lake waters will occur earlier and for longer periods during the summer, increasing the risk of oxygen-poor or oxygen-free dead zones that kill fish and other living things.
- Aquatic ecosystem disruptions are likely to be compounded by invasions by non-native species. Native species are expected to decline.

Southwest

The following changes in climatic conditions have been observed in the Southwest:

- The average temperature in the Southwest has increased about 1.5°F compared to a 1960-1979 baseline period.
- As of 2009, much of the region remained in a drought that began around 1999; the most severe western drought in the last 110 years, which has been exacerbated by record warming.
- Precipitation generally decreased during the summer and fall in the Southwest, while winter and spring have had increases in precipitation.

The following climate-related changes are projected for the Southwest:

- By 2100, the average annual temperature is expected to rise from about 4 to 10°F above the 1960–1979 baseline period; summer temperature increases are expected to be greater than the annual average increase in some areas.
- There is an increased probability of drought.
- Increased flood risk in the Southwest is likely to result from a combination of decreased snow cover on the lower slopes of high mountains and an increased fraction of winter precipitation falling as rain and therefore running off more rapidly. The increase in rain on snow events will also result in rapid runoff and flooding.
- Changes in the timing and amount of river flow during the winter and spring in the Sacramento-San Joaquin River Delta is expected to double the risk of flooding by mid-century and increase it by a factor of eight by 2100.

- There is presently no consensus on how the region's summer monsoon (rainy season) might change in the future.
- Limitations imposed on water supply by projected temperature increases are likely to be made worse by substantial reductions in rain and snowfall in the spring months, when precipitation is most needed to fill reservoirs to meet summer demand.

Northwest

The following changes in climatic and related conditions have been observed in the Northwest:

- The region experienced an average temperature increase of 1.5°F over the last century, with some areas having an average increase of up to 4°F.
- Higher cool season temperatures have resulted in more precipitation falling as rain rather than snow and leading to an earlier snowmelt.
- The April 1 snowpack has declined substantially throughout the region. The average decline in the Cascade Mountains was about 25 percent over the past 40 to 70 years, with most of this due to the 2.5°F increase in cool season temperatures over that period.
- The timing of the peak spring runoff has been shifting over the past 50 years with the peak of spring runoff shifting from a few days earlier in some places to as much as 25 to 30 days earlier in others.
- A low oxygen dead zone off the coast of Washington and Oregon is believed to be driven by climate change.
- Ocean acidification is occurring along the Northwest coast.

The following climate-related changes are projected for the Northwest:

- Temperatures are projected to increase another 3 to 10°F by 2100.
- Increases in winter precipitation and decreases in summer precipitation are projected, though these projections are less certain than those for temperature.
- Heavier winter rainfall suggests an increase in saturated soils and, therefore, an increased number of landslides on coastal bluffs, which will be especially problematic in areas where there has been intensive development on unstable slopes. Sea level rise will exacerbate these conditions.
- Further declines in the region's snowpack are expected, with variations due to latitude, elevation, and proximity to the coast. A decline in the April 1 snowpack in the Cascades of 40 percent is projected by the 2040s.
- The trend in the earlier timing of the peak spring runoff is projected to continue, with shifts anticipated of 20 to 40 days. However, major shifts in the timing of runoff are not expected in areas dominated by rain instead of snow.
- Extreme high and low streamflows are also projected to change. Increased winter rainfall is expected to lead to more flooding in some areas, and low flows in the late summer are projected to decrease further.
- Sea level rise along vulnerable coastlines will result in increased erosion and the loss of land. Some areas in the Northwest are experiencing falling sea levels due to uplift. A mid-range estimate of 13 inches by 2100 has been made for the Puget Sound basin.
- Salmon and other coldwater species will experience additional stresses as a result of rising water temperatures and declining summer streamflows.

Alaska

The following changes in climatic conditions and impacts have been observed in Alaska:

- Higher temperatures are contributing to earlier spring snowmelt, reduced sea ice, widespread glacier retreat, and permafrost warming.
- Between 1970 and 2000, the snow-free season increased by approximately 10 days across Alaska, primarily due to earlier snowmelt in the spring.

- Increased evaporation, combined with thawing of permafrost, has resulted in declines in the area of closed-basin lakes over the past 50 years.
- Increasing storm activity in autumn in recent years has delayed or prevented barge operations that supply coastal communities with fuel.
- High-wind events have become more frequent along the western and northern coasts. The same regions are experiencing increasingly long sea-ice-free seasons and hence longer periods during which coastal areas are especially vulnerable to wind and wave damage.
- Coastal erosion is causing the shorelines of some areas to retreat at average rates of tens of feet per year. The ground beneath several native communities is literally crumbling into the sea.
- The rate of erosion along Alaska's northeastern coastline has doubled over the past 50 years.
- The Bering Sea pollock fishery has experienced major declines in recent years.

The following climate-related changes are projected for Alaska:

- Average annual temperatures in Alaska are projected to rise about 3.5 to 7°F by the middle of this century and 5 to 13°F by the end of the century.
- Higher temperatures are expected to continue to reduce Arctic sea ice coverage, which will increase coastal erosion and flooding associated with coastal storms and alter the timing and location of plankton blooms, which is expected to drive major shifts of marine species.
- Storm activity is expected to increase in the Bering Sea. An increase in the frequency and/or intensity of Arctic Ocean storms is also expected.
- Increases in evaporation due to higher air temperatures are expected to lead to drier conditions overall and an increased likelihood of summer drought.
- Marine ecosystems will experience continued perturbations, including northward shifts, with consequences for the commercial fishery and for the food supplies of indigenous populations.

Islands

While changes in temperature and sea level have been observed for several decades, the following climate-related changes are projected for the Pacific and Caribbean islands:

- Air and ocean surface temperature are expected to increase.
- The number of heavy rain events is very likely to increase.
- In the Pacific islands, the rainy season may shift from winter to summer.
- In the Caribbean, total annual precipitation will decline, particularly under higher emissions scenarios.
- Hurricane (typhoon) wind speeds and rainfall rates are likely to increase with continued warming.
- Islands and other low-lying coastal areas will be at increased risk from coastal inundation due to sea level rise and storm surge, with major implications for coastal communities, infrastructure, natural habitats, and resources.
- The availability of freshwater is likely to be reduced, with significant implications for island communities, economies, and resources.

Select Bibliography

Association of State Floodplain Managers (ASFPM). 2007. *Coastal No Adverse Impact Handbook*. AFSPM. www.floods.org/index.asp?menuid=340&firstlevelmenuid=187&siteid=1

———. 2010. *Building Public Support for Floodplain Management*. ASFPM. www.floods.org/ace-files/documentlibrary/Publications/BPS_Guidebook_2_1_10.pdf

American Planning Association (APA). 2008. *Policy Guide on Planning and Climate Change*. APA. www.planning.org/policy/guides/

Boateng, I. 2008. *Integrating Sea-Level Rise Adaptation into Planning Policies in the Coastal Zone*. Presented at the Federation of International Surveyors Working Week 2008: Integrating Generations. www.fig.net/pub/fig2008/papers/ts03f/ts03f_03_boateng_2722.pdf

Bostrom, A. and D. Lashof. 2007. Weather or Climate Change? In *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*. S. Moser and L. Dilling, eds. Cambridge University Press.

Brekke, L.D., J.E. Kiang, J. R. Olsen, R.S. Pulwarty, D.A. Raff, D.P. Turnipseed, R.S. Webb, and K.D. White. 2009. *Climate Change and Water Resources Management: A Federal Perspective*. Circular 1331. U.S. Geological Survey. http://pubs.usgs.gov/circ/1331/

Bullock, J.A., G.D. Haddow, and K.S. Haddow. 2009. *Global Warming, Natural Hazards, and Emergency Management*. CRC Press.

Burby, R.J. 2005. Have State Comprehensive Planning Mandates Reduced Insured Losses from Natural Disasters? *Natural Hazards Review*. 6, no. 2 (May 2005): 67-81.

———, R.E. Deyle, D.R. Godschalk, and R.B. Olshansky. 2000. Creating Hazard Resilient Communities through Land-Use Planning. *Natural Hazards Review*. 1, no. 2 (May 2000): 99-106.

Climate Change Science Program (CCSP). 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. L. Clarke, J. Edmonds, J. Jacoby, H. Pitcher, J. Reilly, R. Richels, and E. Parson. (authors). Synthesis and Assessment Product 2.1. Department of Energy, Office of Biological and Environmental Research. www.globalchange.gov/publications/reports/scientific-assessments/saps

———. 2008a. *Climate Models: An Assessment of Strengths and Limitations. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. D.C. Bader, C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian and M.H. Zhang (authors). Synthesis and Assessment Product 3.1. Department of Energy, Office of Biological and Environmental Research. www.globalchange.gov/publications/reports/scientific-assessments/saps

———. 2008b. *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. S. H. Julius and J.M. West, eds. Synthesis and Assessment Product 4.4. U.S. Environmental Protection Agency. www.globalchange.gov/publications/reports/scientific-assessments/saps

———. 2008c. *Weather and Climate Extremes in a Changing Climate; Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray, eds. Synthesis and Assessment Product 3.3. National Oceanic and Atmospheric Administration. www.globalchange.gov/publications/reports/scientific-assessments/saps

———. 2009a. *Climate Literacy—The Essential Principles of Climate Science: A Guide for Communities and Individuals*. U.S. Global Change Research Program. www.globalchange.gov/resources/educators/climate-literacy

———. 2009b. *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. J.G. Titus, K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (authors). Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency. www.globalchange.gov/publications/reports/scientific-assessments/saps

Climate Change Work Group. 2008. *The Role of Coastal Zone Management Programs in Adaptation to Climate Change. Second Annual Report of the Coastal States Organization's Climate Change Work Group*. Coastal States Organization. www.coastalstates.org/Publications-News/

Coastal Barrier Resources Act. 1982. 16 U.S.C. § 3501 et seq. www.fws.gov/habitatconservation/cbra4.html

Coastal Zone Management Act (CZMA). 1972. 16 U.S.C. § 1451 et seq. http://coastalmanagement.noaa.gov/czm/czm_act.html

Conde, C. and K. Lonsdale. 2004. Engaging Stakeholders in the Adapatation Process. In *Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures*. B. Lim and E. Spanger-Siegfried, eds. Cambridge University Press. http://content.undp.org/go/cms-service/stream/asset/?asset_id=2200849

Cooperative Program for Operational Meteorology, Education and Training (Meted). 2009. *Climate Change: Fitting the Pieces Together*. Web training. University Corporation for Atmospheric Research. www.meted.ucar.edu/broadcastmet/climate/

Costanza, R., O. Pérez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder. 2008. The Value of Coastal Wetlands for Hurricane Protection. *AMBIO: A Journal of the Human Environment*. 37, no. 4 (June 2008): 241–48. www.allenpress.com/pdf/AMBI-37-4-241.pdf

Cruce, T.L. 2009. *Adaptation Planning: What U.S. States and Localities Are Doing*. Pew Center on Global Climate Change. www.pewclimate.org/hottopics/adaptation

Dolan, A.H. and I.J. Walker. 2004. Understanding Vulnerability of Coastal Communities to Climate Change Related Risks. *Journal of Coastal Research*. Special Issue 39 (2004). www.coastalcommunities.ns.ca/documents/dolan.pdf

Economic Commission for Europe, Convention on the Protection and Use of Transboundary Watercourses and International Lakes (ECE). 2009. *Guidance on Water and Adaptation to Climate Change*. United Nations. www.unece.org/env/documents/2009/Wat/mp_wat/ECE_MP.WAT_30_E.pdf

Federal Emergency Management Agency (FEMA). 1991. *Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program*. FEMA. http://epa.gov/climatechange/effects/downloads/flood_insurance.pdf

———. 1997. *Multi-Hazard Identification and Risk Assessment*. FEMA. www.fema.gov/library/viewRecord.do?id=2214

———. 1997. *Report on Costs and Benefits of Natural Hazard Mitigation*. FEMA 294. FEMA. www.fema.gov/library/viewRecord.do?id=1712

———. 1998. *Property Acquisition Handbook for Local Communities*. FEMA 317. FEMA. www.fema.gov/government/grant/resources/acqhandbook.shtm

———. 2000. *Rebuilding for a More Sustainable Future: An Operational Framework*. FEMA 365. FEMA. www.fema.gov/library/viewRecord.do?id=1429

———. 2001. *Understanding Your Risks: Identifying Hazards and Estimating Losses*. FEMA 386-2. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2002. *Getting Started: Building Support for Mitigation Planning*. FEMA 386-1. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2003. *Bringing the Plan to Life: Implementing the Hazard Mitigation Plan*. FEMA 386-4. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2003. *Developing the Mitigation Plan: Identifying Mitigation Actions and Implementation Strategies*. FEMA 386-3. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2006. *Hurricane Katrina in the Gulf Coast: Mitigation Assessment Team Report, Building Performance Observations, Recommendations, and Technical Guidance*. FEMA 549. FEMA. www.fema.gov/library/viewRecord.do?id=1857

———. 2007a. *National Flood Insurance Program Community Rating System Coordinator's Manual*. FIA-15/2007. FEMA. http://training.fema.gov/EMIWeb/CRS/

———. 2007b. *Selecting Appropriate Mitigation Measures for Floodprone Structures*. FEMA 551. FEMA. www.fema.gov/library/viewRecord.do?id=2737

———. 2007c. *Using Benefit-Cost Review in Mitigation Planning*. FEMA 386-5. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2008. *Using the Hazard Mitigation Plan to Prepare Successful Mitigation Projects*. FEMA 386-9. FEMA. www.fema.gov/plan/mitplanning/resources.shtm

———. 2009a. *Hazard Mitigation Assistance Unified Guidance*. FEMA. www.fema.gov/government/grant/hma/

———. 2009b. *Homeowner's Guide to Retrofitting:Six Ways to Protect Your Home From Flooding*. FEMA P-312. FEMA. www.fema.gov/library/viewRecord.do?id=1420

———. 2009c. *Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report, Building Performance Observations, Recommendations, and Technical Guidance*. FEMA 757. FEMA. www.fema.gov/library/viewRecord.do?id=3577

Feenstra, J.F, I. Burton, J.B., Smith, and R.S.J. Tol, eds. 1998. *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Version 2.0. United Nations Environment Programme. http://dare.ubvu.vu.nl/bitstream/1871/10440/1/f1.pdf

General Services Administration (GSA). n.d. *Catalog of Federal Domestic Assistance*. Web site. GSA. https://www.cfda.gov/

Godschalk, D.R, R. Norton, C. Richardson, and D. Salvesen. 2000. Avoiding Coastal Hazard Areas: Best State Mitigation Practices. *Environmental Geosciences*. 7, no. 1 (2000): 13-22.

Gurley, K. 2006. *Post 2004 Hurricane Field Survey: An Evaluation of the Relative Performance of the Standard Building Code and the Florida Building Code*. Florida Department of Community Affairs. www.dca.state.fl.us/fbc/commission/FBC_0606/Report_SurveyProject_Gurley_33006.pdf

H. John Heinz III Center for Science, Economics, and the Environment (Heinz Center). 1999. *The Hidden Costs of Coastal Hazards: Implications for Risk Assessment and Mitigation*. Island Press.

———. 2008. *Strategies for Managing the Effects of Climate Change on Wildlife and Ecosystems*. Heinz Center. www.heinzctr.org/publications/

Hassan, R., R. Scholes, and N. Ash, eds. 2005. *Ecosystems and Human Well-Being: Current State and Trends*, Volume 1. Millennium Ecosystem Assessment Series. Island Press. www.millenniumassessment.org/en/Global.aspx

Hazard Mitigation Technical Assistance Partnership, Inc. and French & Associates, Ltd. 2000. *Evaluation of CRS Credited Activities During Hurricane Floyd*. Federal Emergency Management Agency. www.ncfloodmaps.com/pubdocs/pfloydrpt.pdf

Higgins, M. 2008. Legal and Policy Impacts of Sea Level Rise to Beaches and Coastal Property. *Sea Grant Law and Policy Journal*. 1, no. 1 (2008): 43-64. http://nsglc.olemiss.edu/SGLPJ/SGLPJarchive.htm

ICLEI–Local Governments for Sustainability. 2009. *ICLEI Resource Guide: Outreach and Communications*. ICLEI. www.icleiusa.org/action-center/engaging-your-community/

Institute for Business and Home Safety (IBHS). 2005. *The Benefits of Statewide Building Codes*. IBHS. www.ibhs.org/building_codes/downloads/20051110_153713_20651.pdf

———. 2007. *Hurricane Charley: The Benefits of Modern Wind Resistant Building Codes on Hurricane Claim Frequency and Severity*. IBHS. www.disastersafety.org/text.asp?id=hurricane_charley

———. 2009. *Hurricane Ike: Nature's Force vs. Structural Strength*. IBHS. http://disastersafety.org/text.asp?id=fortified

Interagency Workgroup on Wetland Restoration. 2003. *An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service and U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds. www.lsu.edu/sglegal/pdfs/WetlandsUsersGuide.pdf

Intergovernmental Panel on Climate Change (IPCC). 2000. *Special Report on Emissions Scenarios*. N. Nakicenovic and R. Swart, eds. Cambridge University Press. www.ipcc.ch/publications_and_data/publications_and_data_reports.htm

———. 2007a. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, eds. Cambridge University Press. www.ipcc.ch

———. 2007b. *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds. Cambridge University Press. www.ipcc.ch/

———. 2007c. *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri and A. Reisinger, eds. IPCC. www.ipcc.ch/

J. Fraser, R. Elmore, D. Godschalk, and W. Rohe. 2003. *Implementing Floodplain Land Acquisition Programs in Urban Localities*. University of North Carolina at Chapel Hill, Center for Urban and Regional Studies. http://people.vanderbilt.edu/~james.c.fraser/publications/Floddplain%20Project%20Report.Final.pdf

Jacob, J.S. and S. Showalter. 2007a. *The Resilient Coast: Policy Frameworks for Adapting the Built Environment to Climate Change and Growth in Coastal Areas of the U.S. Gulf of Mexico*. Texas Sea Grant College Program. www.urban-nature.org/publications/publications.htm

———. 2007b. *The Resilient Coast: Policy Frameworks for Adapting Coastal Wetlands to Climate Change and Growth in Coastal Areas of the U.S. Gulf of Mexico*. Texas Sea Grant College Program. www.urban-nature.org/publications/publications.htm

Jones, C.P., W.L. Coulbourne, J. Marshall, and S.M. Rogers, Jr. 2006. *Evaluation of the National Flood Insurance Program's Building Standards*. American Institutes for Research. www.fema.gov/library/viewRecord.do?id=2592

Karl, T.R., J.M. Melillo, and T.C. Peterson, eds. 2009. *Global Climate Change Impacts in the United States. A State of Knowledge Report from the U.S. Global Change Research Program*. Cambridge University Press. www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

Knogge, T., M. Schirmer, and B. Schuchardt. 2004. Landscape-Scale Socio-Economics of Sea Level Rise. *Ibis*. 146, suppl. 1 (2004): 11–17.

Mahmouda, M., Y. Liu, H. Hartmann, S. Stewart, T. Wagener, D. Semmens, R. Stewart, et al. 2009. A Formal Framework for Scenario Development in Support of Environmental Decision-Making. *Environmental Modeling and Software*. 24 (2009): 798–808.

Marine Law Institute of the University of Maine School of Law, the Maine Geological Survey, and the Maine State Planning Office. 1995. *Anticipatory Planning for Sea-Level Rise along the Coast of Maine*. EPA-230-R-95-900. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation. http://epa.gov/climatechange/effects/coastal/SLRAnticipatory.html

Mileti, D. 1999. *Second National Assessment on Natural and Related Technological Hazards*. National Academies Press (Joseph Henry Press).

Moser, S.C. 2009. *Good Morning America! The Explosive U.S. Awakening to the Need for Adaptation*. National Oceanic and Atmospheric Administration, Coastal Services Center. www.csc.noaa.gov/publications.html

Moser, S. and L. Dilling, eds. 2007. *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*. Cambridge University Press.

Multihazard Mitigation Council. 2005. *Natural Hazard Mitigation Saves*. National Institute of Building Sciences. www.nibs.org/index.php/mmc/projects/nhms/

National Assessment Synthesis Team. 2000a. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*. U.S. Global Change Research Program. www.globalchange.gov/publications/reports/scientific-assessments/first-national-assessment

———. 2000b. *U.S. National Assessment of the Potential Consequences of Climate Variability and Change Scenarios and Data*. U.S. Global Change Research Program. www.usgcrp.gov/usgcrp/nacc/background/scenarios/

National Ocean Economics Program (NOEP). 2009a. *Ocean and Coastal Economies*. Web site. NOEP. www.oceaneconomics.org/Market/

———. 2009b. *State of the U.S. Ocean and Coastal Economies*. NOEP. www.oceaneconomics.org/NationalReport/

National Oceanic and Atmospheric Administration (NOAA). 2007a. *Introduction to Stakeholder Participation*. NOAA Coastal Services Center. www.csc.noaa.gov/stakeholder/

———. 2007b. *National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs*. NOAA. www.nmfs.noaa.gov/sfa/PartnershipsCommunications/NARPwCover3.pdf

———. 2008. *National Oceanic and Atmospheric Administration Strategic Plan FY 2009-2014*. NOAA Office of Program Planning and Integration. www.ppi.noaa.gov/PPI_Capabilities/Documents/Strategic_Plans/FY09-14_NOAA_Strategic_Plan.pdf

———. 2009a. *Coastal Inundation Mapping Guidebook*. NOAA Coastal Services Center. www.csc.noaa.gov/digitalcoast/inundation/_pdf/guidebook.pdf

———. 2009b. *Local Strategies for Addressing Climate Change*. NOAA Coastal Services Center. www.csc.noaa.gov/publications.html

———. 2010a. *Billion Dollar U.S. Weather Disasters, 1980-2009*. NOAA National Climatic Data Center. www.ncdc.noaa.gov/oa/reports/billionz.html

———. 2010b. *State of the Climate-Global Analysis: January 2010*. NOAA National Climatic Data Center. www.ncdc.noaa.gov/sotc/

———. n.d. *Artic Change: A Near-Realtime Artic Change Indicator Website*. Web site. NOAA Arctic Research Office. www.arctic.noaa.gov/detect/land-permafrost.shtml

———. n.d. *Fisheries Economics of the U.S., 2008*. NOAA National Marine Fisheries Service, Office of Science and Technology. www.st.nmfs.noaa.gov/st5/publication/

———. n.d. *Shoreline Management: Alternatives to Hardening the Shore*. NOAA Office of Ocean and Coastal Resource Management. http://coastalmanagement.noaa.gov/shoreline.html

———, U.S. Environmental Protection Agency, International City County Management Association, Rhode Island Sea Grant. 2009. *Smart Growth for Coastal and Waterfront Communities*. National Oceanic and Atmospheric Administration. http://coastalsmartgrowth.noaa.gov/

National Research Council (NRC), Committee on Beach Nourishment and Protection. 1995. *Beach Nourishment and Protection*. National Academies Press. www.nap.edu/catalog.php?record_id=4984

———, Committee on Coastal Erosion Zone Management. 1990. *Managing Coastal Erosion*. National Academies Press. http://books.nap.edu/catalog.php?record_id=1446

———, Committee on Mitigating Shore Erosion along Sheltered Coasts. 2007. *Mitigating Shore Erosion along Sheltered Coasts*. National Academies Press. http://books.nap.edu/catalog.php?record_id=11764

Nichols, S.S. and C. Bruch. 2008. New Framework for Managing Dynamic Coasts: Legal and Policy Tools for Adapting U.S. Coastal Zone Management to Climate Change. *Sea Grant Law and Policy Journal*. 1, no. 1 (2008): 19-42. http://nsglc.olemiss.edu/SGLPJ/SGLPJarchive.htm

Perkins B., D. Ojima, D., and R. Corell. 2007. *A Survey of Climate Change Adaptation Planning*. H. John Heinz III Center for Science, Economics, and the Environment. www.heinzctr.org/publications/meeting_reports.shtml

Pew Center on Global Climate Change and the Pew Center on the States (Pew Center). 2009. *Climate Change 101: Adaptation*. Pew Center. www.pewclimate.org/global-warming-basics/climate_change_101

Rubinoff, P., N.D. Vinhateiro, and C. Piecuch. 2008. *Summary of Coastal Program Initiatives that Address Sea Level Rise as a Result of Global Climate Change*. Rhode Island Sea Grant. www.seagrant.noaa.gov/focus/documents/hrcc/slr_policies_summary_mar6_final.pdf

Ruth, M., D. Coelho, and D. Karetnikov. 2007. *The U.S. Economic Impacts of Climate Change and the Costs of Inaction*. University of Maryland, Center for Integrative Environmental Research. www.cier.umd.edu/climateadaptation/

Schiermeier, Q. 2010. The Real Holes in Climate Science. *Nature*. 463 (Jan. 21, 2010): 284-87. www.nature.com/news/2010/100120/full/463284a.html

Schwab, J.,K.C. Topping, C.C. Eadie, R.E. Deyle, and R.A. Smith. 1998. Planning for Post-Disaster Recovery and Reconstruction. Planning Advisory Service Report Number 483/484. *American Planning Association*. www.fema.gov/library/viewRecord.do?id=1558

Secretariat of the Convention on Biological Diversity. 2009. *Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*. Technical Series No. 41. Convention on Biological Diversity. https://www.cbd.int/doc/publications/cbd-ts-41-en.pdf

Snover, A.K., L. W. Binder, J. Lopez, and E. Willmott. 2007. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. ICLEI–Local Governments for Sustainability. www.icleiusa.org/action-center/planning/adaptation-guidebook

Solomon, S., G. Plattner, R. Knutti, and P. Friedlingstein. 2009. Irreversible Climate Change Due to Carbon Dioxide Emissions. *Proceedings of the National Academy of Sciences*. 106, no. 6 (Feb. 10, 2009): 1704-09. www.pnas.org/content/early/2009/01/28/0812721106.short

Titus, J.G. 1998. Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches without Hurting Property Owners. *Maryland Law Review*. 57, no. 4 (1998): 1279-399. http://epa.gov/climatechange/effects/coastal/SLRTakings.html

———, D.E. Hudgens, D.L. Trescott, M. Craghan, W.H. Nuckols, C.H. Hershner, and J. M. Kassakian. 2009. State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level along the U.S. Atlantic Coast. *Environmental Research Letters*. 4, no. 4 (2009). http://risingsea.net/ERL/

U.S. Agency for International Development (USAID). 2009. *Adapting to Coastal Climate Change: A Guidebook for Development Planners*. USAID. www.crc.uri.edu/index.php?actid=366

U.S. Army Corps of Engineers (USACE). 2007. *Shore Protection Assessment: Beach Nourishment—How Beach Renourishment Projects Work*. USACE Coastal and Hydraulics Laboratory. http://chl.erdc.usace.army.mil/pub-beachnourishment

———. 2010. *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs*. EC 1165-2-211. USACE Civil Works. http://140.194.76.129/publications/eng-circulars/

U.S. Environmental Protection Agency (EPA). 2008. *Effects of Climate Change for Aquatic Invasive Species and Implications for Management and Research*. EPA/600/R-08/014. EPA National Center for Environmental Assessment. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=188305

———. 2009a. *Synthesis of Adaptation Options for Coastal Areas*. EPA 430-F-08-024. EPA Climate Ready Estuaries Program. www.epa.gov/cre/adaptationoptions.html

———. 2009b. *Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scale*. EPA 231B09001. EPA Development, Community and Environment Division and Office of Wetlands, Oceans, and Watersheds. www.epa.gov/smartgrowth/water_scorecard.htm

———. 2010. *Climate Change Indicators in the United States*. EPA 430-R-10-007. EPA Climate Change Division. www.epa.gov/climatechange/indicators.html

UK Climate Impacts Programme. 2007. *Identifying Adaptation Options*. UK Climate Impacts Programme. www.ukcip.org.uk/index.php?option=com_content&task=view&id=23&Itemid=127

Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko. 2007. Linking Vulnerability, Adaptation, and Resilience Science to Practice: Pathways, Players, and Partnerships. *Global Environmental Change*. 17, no. 3-4 (2007): 349-64.

Young, M. 2009. *Analyzing the Effects of the My Safe Florida Home Program on Florida Insurance Risk*. Risk Management Solutions. www.rms.com/Publications/RMS_MSFH_Report_May_2009.pdf

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