



Climate Change Impacts in the United States

CHAPTER 28 ADAPTATION

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28 ADAPTATION

KEY MESSAGES

- 1. Substantial adaptation planning is occurring in the public and private sectors and at all levels of government; however, few measures have been implemented and those that have appear to be incremental changes.**
- 2. Barriers to implementation of adaptation include limited funding, policy and legal impediments, and difficulty in anticipating climate-related changes at local scales.**
- 3. There is no “one-size fits all” adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress.**
- 4. Climate change adaptation actions often fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be incorporated into existing decision-making processes.**
- 5. Vulnerability to climate change is exacerbated by other stresses such as pollution, habitat fragmentation, and poverty. Adaptation to multiple stresses requires assessment of the composite threats as well as tradeoffs among costs, benefits, and risks of available options.**
- 6. The effectiveness of climate change adaptation has seldom been evaluated, because actions have only recently been initiated and comprehensive evaluation metrics do not yet exist.**

Over the past few years, the focus moved from the question “Is climate changing?” to the equally important question: “Can society manage unavoidable changes and avoid unmanageable changes?”^{1,2} Research demonstrates that both mitigation (efforts to reduce future climate changes) and adaptation (efforts to reduce the vulnerability of society to climate change impacts) are needed in order to minimize the damages from human-caused climate change and to adapt to the pace and ultimate magnitude of changes that will occur.^{3,4,5}

Adaptation and mitigation are closely linked; adaptation efforts will be more difficult, more costly, and less likely to succeed if significant mitigation actions are not taken.^{2,6} The study and application of adaptation in the climate change realm is nascent compared to the many analyses of mitigation policies and practices to reduce emissions. Uncertainties about future socioeconomic conditions as well as future climate changes can make it difficult to arrive at adaptation decisions now. However, the pace and magnitude of projected change emphasize the need to be prepared for a wide range and intensity of climate impacts in the future. Planning and managing based on the climate of the last century means that tolerances of some infrastructure and species will be exceeded.^{5,7,8} For example, building codes and landscaping

ordinances will likely need to be updated not only for energy efficiency but also to conserve water supplies, protect against disease vectors, reduce susceptibility to heat stress, and improve protection against extreme events.^{5,9} Although there is uncertainty about future conditions, research indicates that intelligent adaptive actions can still be taken now.^{10,11} Climate change projections have inherent uncertainties, but it is still important to develop, refine, and deploy tools and approaches that enable iterative decision-making and increase flexibility and robustness of climate change responses (Ch. 2: Our Changing Climate).¹²

Climate change affects human health, natural ecosystems, built environments, and existing social, institutional, and legal arrangements. Adaptation considerations include local, state, regional, national, and international issues. For example, the implications of international arrangements need to be considered in the context of managing the Great Lakes, the Columbia River, and the Colorado River to deal with drought.^{13,14} Both “bottom up” community planning and “top down” national strategies¹¹ may help regions deal with impacts such as increases in electrical brownouts, heat stress, floods, and wildfires. Such a mix of approaches will require

cross-boundary coordination at multiple levels as operational agencies integrate adaptation planning into their programs.

Adaptation actions can be implemented reactively, after changes in climate occur, or proactively, to prepare for projected changes.¹¹ Proactively preparing can reduce the harm from certain climate change impacts, such as increasingly intense extreme events, shifting zones for agricultural crops, and rising sea levels, while also facilitating a more rapid and efficient response to changes as they happen. This chapter highlights

efforts at the federal, regional, state, tribal, and local levels, as well as initiatives in the corporate and non-governmental sectors to build adaptive capacity and resilience in response to climate change. While societal adaptation to *climate variability* is as old as civilization itself,¹⁵ the focus of this chapter is on preparing for unprecedented human-induced *climate change* through adaptation. A map of illustrative adaptation activities and four detailed case examples that highlight ongoing adaptation activity across the U.S. are provided in Section 4 of this chapter.

ADAPTATION KEY TERMS DEFINITIONS*

Adapt, Adaptation: Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Adaptive Capacity: The potential of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, and cope with the consequences.

Mitigation: Technological change and substitutions that reduce resource inputs and emissions per unit of output. Although several social, economic, and technological actions would reduce emissions, with respect to climate change, mitigation means implementing actions to reduce greenhouse gas emissions or increase the amount of carbon dioxide absorbed and stored by natural and man-made carbon sinks (see Ch. 27: Mitigation).

Multiple Stressors: Stress that originates from different sources that affect natural, managed, and socioeconomic systems and can cause impacts that are compounded and sometimes unexpected. An example would be when economic or market stress combines with drought to negatively impact farmers.

Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Risk: A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur.

Vulnerability: The degree to which a system is susceptible to, or 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 variation to which a system is exposed, its sensitivity, and its adaptive capacity.

*Definitions adapted from (IPCC 2007; ¹⁶ NRC 2007, ¹⁷ 2010¹¹).

Adaptation Activities in the United States

Federal Government

Federal leadership, guidance, information, and support are vital to planning for and implementing adaptation actions at all scales and in all affected sectors of society (Table 28.1).^{11,18,19,20} Several new federal climate adaptation initiatives and strategies have been developed in recent years, including:

- Executive Order (EO) 13514, requiring federal agencies to develop recommendations for strengthening policies and programs to adapt to the impacts of climate change;²¹
- the release of President Obama's Climate Action Plan in June 2013, which has as one of its three major pillars, preparing the United States for the impacts of climate change, including building stronger and safer communities and infrastructure, protecting the economy and natural resources, and using sound science to manage climate impacts;²²
- the creation of an Interagency Climate Change Adaptation Task Force (ICCATF) (now the Council on Climate Preparedness and Resilience, per Executive Order 13653²³) that led to the development of national principles for adaptation and

is leading to crosscutting and government-wide adaptation policies;

- the development of three crosscutting national adaptation strategies focused on integrating federal, and often state, local, and tribal efforts on adaptation in key sectors: 1) the National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate;²⁴ 2) the National Fish, Wildlife and Plants Climate Adaptation Strategy;²⁵ and 3) a priority objective on resilience and adaptation in the National Ocean Policy Implementation Plan;²⁶
- a new decadal National Global Change Research Plan (2012–2021) that includes elements related to climate adaptation, such as improving basic science, informing decisions, improving assessments, and communicating with and educating the public;²⁷
- the development of several interagency and agency-specific groups focused on adaptation, including a “community of

practice” for federal agencies that are developing and implementing adaptation plans, an Adaptation Science Workgroup inside the U.S. Global Change Research Program (USGCRP), and several agency specific climate change and adaptation task forces; and

- a November 2013 Executive Order entitled “Preparing the United States for the Impacts of Climate Change” that, among other things, calls for the modernizing of federal programs to support climate resilient investments, managing lands and waters for climate preparedness and resilience, the creation of a Council on Climate Preparedness and Resilience, and the creation of a State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience.²³

Federal agencies are all required to plan for adaptation. Actions include coordinated efforts at the White House, regional and cross-sector efforts, agency-specific adaptation plans, as well as support for local-level adaptation planning and action. Table 28.1 lists examples, but is not intended as a comprehensive list.

Table 28.1. Examples of Individual Federal Agency Actions to Promote, Implement, and Support Adaptation at Multiple Scales*

Agency	Component	Action	Description
All Federal Agencies		Developed Adaptation Plans as part of their annual Strategic Sustainability Performance Plans	The 2012 Strategic Sustainability Performance Plans for Federal agencies contain specific sections on adaptation. Agencies are required to evaluate climate risks and vulnerabilities to manage both short- and long-term effects on missions and operations.
Department of Health and Human Services (HHS)	Centers for Disease Control and Prevention (CDC)	Climate-Ready States and Cities Initiative	Through their first climate change cooperative agreements in 2010, CDC awarded \$5.25 million to ten state and local health departments to assess risks and develop programs to address climate change related challenges.
Department of Agriculture (USDA)		Integrating climate change objectives into plans and networks	USDA is using existing networks such as the Cooperative Extension Service, the Natural Resource Conservation Districts, and the Forest Service’s Climate Change Resource Center to provide climate services to rural and agricultural stakeholders.
USDA	Forest Service	Developed a <i>National Roadmap for Responding to Climate Change</i> and a <i>Guidebook for Developing Adaptation Options</i> , among many resources	The <i>National Roadmap</i> was developed in 2010 to identify short- and long-term actions to reduce climate change risks to the nation’s forests and grasslands. The <i>Guidebook</i> builds on this previous work and provides science-based strategic and tactical approaches to adaptation.
Department of Commerce (DOC)	NOAA	Supporting research teams and local communities on adaptation-related issues and develops tools and resources	Through the Regional Integrated Sciences and Assessments (RISAs) program, develop collaboration between researchers and managers to better manage climate risks. Through the Regional Climate Centers (RCCs) and the Digital Coast partnership, deliver science to support decision-making.
Department of Defense (DoD)		Developed a DoD Climate Change Adaptation Roadmap	DoD released its initial Department-level Climate Change Adaptation Roadmap in 2012. The Roadmap identifies four goals that serve as the foundation for guiding the Department’s response to climate change that include using a robust decision making approach based on the best available science.

Table 28.1. Examples of Individual Federal Agency Actions to Promote, Implement, and Support Adaptation at Multiple Scales* (Continued)

DoD	U.S. Army Corps of Engineers (USACE), Civil Works Program	Developed climate change adaptation plan; making progress in priority areas including vulnerability assessments and development of policy and guidance	The USACE Civil Works Program initial climate change adaptation plan in 2011 has a goal to reduce vulnerabilities and improve resilience of water resources infrastructure impacted by climate change. Vulnerability assessments and pilot projects are in progress. Other guidance is underway.
DoD	Department of the Navy	Developed road maps for adaptation in the Arctic and across the globe	The Navy Arctic Roadmap (November 2009) promotes maritime security and naval readiness in a changing Arctic. The Climate Change Roadmap (May 2010) examines broader issues of climate change impacts on Navy missions and capabilities globally.
Department of Energy (DOE)		Develop higher spatial and temporal scales of climate projections and integrate adaptation and climate considerations into integrated assessments	Develops community-based, high-resolution (temporal and spatial) models for climate projections and integrated assessment models that increasingly reflect multi-sectoral processes and interactions, multiple stressors, coupled impacts, and adaptation potential.
DOE		Developed climate change adaptation plan, and completed comprehensive study of vulnerabilities to the energy sector of climate change and extreme weather	The 2013 DOE Report “U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather” examines current and potential future impacts of climate trends and identifies activities underway and potential opportunities to enhance energy system climate preparedness and resilience.
Department of Homeland Security (DHS)	Federal Emergency Management Agency (FEMA)	Works with communities across the Nation to help them prioritize their activities to reduce risks	FEMA released a Climate Change Adaptation Policy Statement establishing the Agency’s approach to supporting the Department in ensuring resilience to disasters in the face of climate change. FEMA’s action areas focus on developing actionable “future risk” tools, enabling state and local adaptation, and building resilience capabilities.
Department of the Interior (DOI)	Fish and Wildlife Service (FWS)	Developed a FWS climate change strategic plan (2010) and established a network of Landscape Conservation Cooperatives (LCCs)	Established a framework to help ensure the sustainability of fish, wildlife, plants, and habitats in the face of climate change. Created a network of 22 LCCs to promote shared conservation goals, approaches, and resource management planning and implementation across the United States.
DOI	U.S. Geological Survey (USGS)	Established a network of Climate Science Centers (CSCs)	DOI operates a National Climate Change and Wildlife Center and eight regional CSCs, which provide scientific information and tools that land, water, wildlife, and cultural resource managers and other stakeholders can apply to anticipate, monitor, and adapt to climate change.
DOI	National Park Service (NPS)	Climate Change Response Strategy (2010), Climate Change Action Plan (2012), and Green Parks Plan (2012)	NPS actions span climate change science, adaptation, mitigation, and communication across national parks, including exhibits for park visitors, providing climate trend information for all national parks, risk screening and adaptation for coastal park units, and implementing scenario planning tools.
DOI	Bureau of Land Management (BLM)	Rapid Ecoregional Assessments (REAs)	REAs synthesize information about resource conditions and trends within an ecoregion; assess impacts of climate change and other stressors; map areas best-suited for future development; and establish baseline environmental conditions, against which to gauge management effectiveness.

Table 28.1. Examples of Individual Federal Agency Actions to Promote, Implement, and Support Adaptation at Multiple Scales* (Continued)

Department of Transportation (DOT)	Federal Highway Administration (FHWA)	Developed Risk Assessment Model for transportation decisions	DOT worked with five local and state transportation authorities to develop a conceptual Risk Assessment Model to identify which assets are: a) most exposed to climate change threats and/or b) associated with the most serious potential consequences of climate change threats. Completed November 2011.
DOT		Comprehensive study of climate risks to Gulf Coast transportation infrastructure followed by in-depth study of Mobile, AL	Phase 1 of the 2008 study assessed transportation infrastructure vulnerability to climate change impacts across the Gulf. Phase 2, to be completed in 2013, focuses on Mobile, AL. This effort will develop transferable tools for transportation planners.
Environmental Protection Agency (EPA)		Established the Climate Ready Estuaries program, the Climate Ready Water Utilities initiative, and a tribal climate change adaptation planning training program	These selected EPA initiatives provide resources and tools to build the capacity of coastal managers, water utilities, and tribal environmental professionals to plan for and implement adaptation strategies.
National Aeronautics and Space Administration (NASA)		Initiated NASA's Climate Adaptation Science Investigator (CASI) Workgroup to partner NASA scientists, engineers, and institutional stewards	The CASI team builds capacity to address climate change at NASA facilities by downscaling facility-specific climate hazard information and projections; conducting customized climate research for each location; and leading resilience and adaptation workshops that spur community-based responses.

*Material provided in table is derived directly from Agency representatives and Agency websites. These are select examples and should not be considered all-inclusive.

Federal agencies can be particularly helpful in facilitating climate adaptation by:

- fostering the stewardship of public resources and maintenance of federal facilities, services, and operations such as defense, emergency management, transportation, and ecosystem conservation in the face of a changing climate;^{11,28,29,30}
- providing usable information and financial support for adaptation;^{11,20,30}
- facilitating the dissemination of best practices and supporting a clearinghouse to share data, resources, and lessons learned;^{11,20,31}
- dealing with and anticipating impacts that cross geopolitical boundaries, assisting in disaster response, and supporting flexible regulatory frameworks;^{11,30}
- ensuring the establishment of federal policies that allow for “flexible” adaptation efforts and take steps to avoid unintended consequences;^{30,32} and
- building public awareness.³³

States

States have become important actors in national climate change related efforts. State governments can create policies and programs that encourage or discourage adaptation at other governance scales (such as counties or regions)³⁴ through regulation and by serving as laboratories for innovation.^{35,36} Although many of these actions are not specifically designed to address climate change, they often include climate adaptation components.

Many state-level climate change-specific adaptation actions focus on planning. As of 2013, fifteen states had completed climate adaptation plans; four states were in the

process of writing their plans; and seven states had made recommendations to create state-wide adaptation plans.³⁷

In addition to formal adaptation plans, numerous states have created sector-specific plans that consider long-term climate change (Figure 28.1). For example, at least 16 states have biodiversity conservation plans that focus on preparing for long-term changes in climate.³⁸ In addition to planning, some states have created legislation and/or programs that are either directly or indirectly targeted at reducing climate vulnerabilities (Table 28.2).

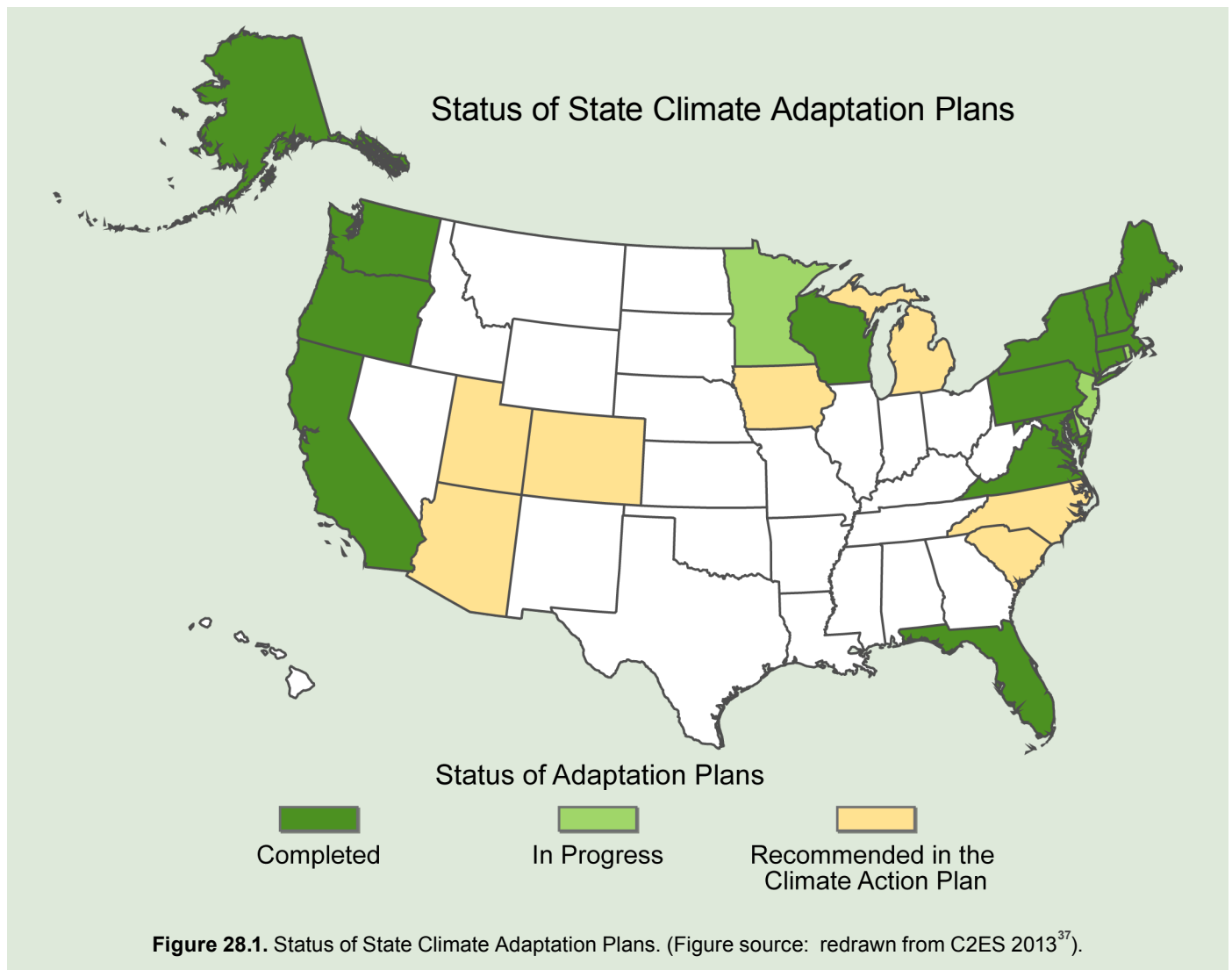


Table 28.2. Examples of State-Level Adaptation Activities*

State	Adaptation Action
Alaska	Alaska Climate Change Impact Mitigation Program provides funds for hazard impact assessments to evaluate climate change related impacts, such as coastal erosion and thawing permafrost. ³⁹
California	Building standards mandating energy and water efficiency savings, advancing both adaptation and mitigation; State Adaptation Plan calls for 20% reduction in per capita water use. ⁴⁰
Florida	Law supporting low water use landscaping techniques. ⁴¹
Hawaii	Water code that calls for integrated management, preservation, and enhancement of natural systems. ⁴²
Kentucky	<i>Action Plan to Respond to Climate Change in Kentucky: A Strategy of Resilience</i> , which identifies six goals to protect ecosystems and species in a changing climate. ⁴³
Louisiana	<i>Comprehensive Master Plan for a Sustainable Coast 2012</i> includes both protection and restoration activities addressing land loss from sea level rise, subsidence, and other factors over the next 50 years. ⁴⁴
Maine	The <i>Maine Sand Dune Rules</i> require that structures greater than 2,500 square feet be set back at a distance that is calculated based on the future shoreline position and considering two feet of sea level rise over the next 100 years. ⁴⁵
Maryland	Passed <i>Living Shorelines Act</i> to reduce hardened shorelines throughout the state; ⁴⁶ passed “Building Resilience to Climate Change” policy which establishes practices and procedures related to facility siting and design, new land investments, habitat restoration, government operations, research and monitoring, resource planning, and advocacy.
Montana	Maintains a statewide climate change website to help stakeholders access relevant and timely climate information, tools, and resources.
New Mexico	The Active Water Resource Management program allows for temporary water rights changes in real time in case of drought. ⁴⁷
Pennsylvania	Enacted polices to encourage the use of green infrastructure and ecosystem-based approaches for managing storm water and flooding. ⁴⁸
Rhode Island	Requires public agencies considering land-use applications to accommodate a 3- to 5-foot rise in sea level.
Texas	Coordinated response to drought through National Integrated Drought Information System (NIDIS); RISAs (Southern Climate Impacts Planning Program [SCIPP], Climate Assessment for the Southwest [CLIMAS]); and state and private sector partners through anticipatory planning and preparedness (for example, implemented in 2011 drought). ⁴⁸

*This list contains selected examples of state-level adaptation activities and should not be considered all-inclusive.

Tribal Governments

Tribal governments have been particularly active in assessing and preparing for the impacts of climate change (see Ch. 12: Indigenous Peoples). For example:

- Adaptation planning in Point Hope, Alaska, emphasizes strategies for enhancing community health.⁴⁹
- In Newtok, Alaska, the village council is leading a land-acquisition and planning effort to relocate the community, because climate change induced coastal erosion has destroyed essential infrastructure, making the current village site unsafe.⁵⁰
- The Tulalip Tribes in Washington State are using traditional knowledge gleaned from elders, stories, and songs and combining this knowledge with downscaled climate data to inform decision-making.⁵¹ Also in Washington State, the Swinomish Indian Tribal Community integrated climate change into decision-making in major sectors of the Swinomish Community, such as education, fisheries, social services, and human health.⁵²
- The Haudenosaunee Confederacy in the northeastern U.S. is addressing climate impacts by preserving a native food base through seed-banking (Ch. 12: Indigenous Peoples).⁵¹

Local and Regional Governments

Most adaptation efforts to date have occurred at local and regional levels.^{53,54,55,56,57} Primary mechanisms that local governments are using to prepare for climate change include land-use planning; provisions to protect infrastructure and ecosystems; regulations related to the design and construction of buildings, roads, and bridges; and emergency preparation, response, and recovery (Table 28.3).^{9,45,56,58}

According to a recent survey of 298 U.S. local governments, 59% indicated they are engaged in some form of adaptation

planning.⁵⁹ Local adaptation planning and actions are unfolding in municipalities of varying sizes and in diverse geographical areas. Communities such as Keene, New Hampshire; New York City, New York; King County, Washington; and Chicago, Illinois are vanguards in the creation of climate adaptation strategies.^{9,11,60} In addition to local government action, regional agencies and regional aggregations of governments are becoming significant climate change adaptation actors.^{8,57}

Table 28.3. Examples of Local and Regional Adaptation Activities*

Local or Regional Government	Adaptation Action
Satellite Beach, FL	Collaboration with the Indian River Lagoon National Estuary Program led to efforts to try to incorporate sea level rise projections and policies into the city's comprehensive growth management plan. ⁵⁴
Portland, OR	Updated the city code to require on-site stormwater management for new development and re-development. Provides a downspout disconnection program to help promote on-site stormwater management. ⁶¹
Lewes, DE	In partnership with Delaware Sea Grant, ICLEI-Local Governments for Sustainability, the University of Delaware, and state and regional partners, the City of Lewes undertook a stakeholder-driven process to understand how climate adaptation could be integrated into the hazard mitigation planning process. Recommendations for integration and operational changes were adopted by the City Council and are currently being implemented. ⁶²
Groton, CT	Partnered with federal, state, regional, local, non-governmental, and academic partners through the EPA's Climate Ready Estuaries program to assess vulnerability to and devise solutions for sea level rise. ⁶³
San Diego Bay, CA	Five municipalities partnered with the port, the airport, and more than 30 organizations with direct interests in the Bay's future to develop the San Diego Bay Sea Level Rise Adaptation Strategy. The strategy identified key vulnerabilities for the Bay and adaptation actions that can be taken by individual agencies, as well as through regional collaboration. ⁹
Chicago, IL	Through a number of development projects, the city has added 55 acres of permeable surfaces since 2008 and has more than four million square feet of green roofs planned or completed. ⁶⁴
King County, WA	Created King County Flood Control District in 2007 to address increased impacts from flooding through activities such as maintaining and repairing levees and revetments, acquiring repetitive loss properties, and improving countywide flood warnings. ⁶⁵
New York City, NY	Through a partnership with the Federal Emergency Management Agency (FEMA), the city is updating FEMA Flood Insurance Rate Maps based on more precise elevation data. The new maps will help stakeholders better understand their current flood risks and allow the city to more effectively plan for climate change. ⁶⁶
Southeast Florida Climate Change Compact	Joint commitment among Broward, Miami-Dade, Palm Beach, and Monroe Counties to partner in reducing heat-trapping gas emissions and adapting to climate impacts, including adaptation in transportation, water resources, natural resources, agriculture, and disaster risk reduction. Notable policies emerging from the Compact include regional collaboration to revise building codes and land development regulations to discourage new development or post-disaster redevelopment in vulnerable areas. ⁶⁷
Phoenix, AZ; Boston, MA; Philadelphia, PA; and New York, NY	Climate change impacts are being integrated into public health planning and implementation activities that include creating more community cooling centers, neighborhood watch programs, and reductions in the urban heat island effect. ^{9,68,69}
Boulder, CO; New York, NY; and Seattle, WA	Water utilities in these communities are using climate information to assess vulnerability and inform decision-making. ⁶¹
City of Philadelphia	In 2006, the Philadelphia Water Department began a program to develop a green stormwater infrastructure, intended to convert more than one-third of the city's impervious land cover to "Greened Acres": green facilities, green streets, green open spaces, green homes, etc., along with stream corridor restoration and preservation. ⁵

*This table includes select examples of local and regional adaptation activities and should not be considered all-inclusive.

There is no one-size-fits-all adaptation solution to the challenges of adapting to climate change impacts, as solutions will differ depending on context, local circumstance, and scale as well as on local culture and internal capacity.^{9,31}

Non-governmental and Private Sector

Many non-governmental entities have been significant actors in the national effort to prepare for climate change by providing assistance that includes planning guidance, implementation tools, contextualized climate information, best practice exchange, and help with bridging the science-policy divide to a wide array of stakeholders (Table 28.4).^{70,71} The Nature Conservancy, for example, established the Canyonlands Research Center in Monticello, Utah, to facilitate research and develop conservation applications for resource issues under the multi-stresses of climate change and land-use demands in the Colorado Plateau region.⁷²

With regard to the private sector, evidence from organizations such as the Carbon Disclosure Project (CDP) and the Securities and Exchange Commission's (SEC) Climate Change 10-K Disclosure indicate that a growing number of companies are beginning to actively address risks from climate change (Table 28.5).⁷³ The World Business Council for Sustainable Development (WBCSD) and the Center for Climate and Energy Solutions (C2ES) have identified three types of risks driving private sector adaptation efforts, including risks to core operations, the value chain, and broader changes in the economy and infrastructure (see Figure 28.2).^{74,75,76}

This analysis is supported by responses to the 2011 CDP, and suggests that companies are concerned about how changes in



This one-acre stormwater wetland was constructed in Philadelphia to treat stormwater runoff in an effort to improve drinking water quality while minimizing the impacts of storm-related flows on natural ecosystems.

the climate will impact issues such as feedstock, water supply and quality, infrastructure, core operations, supply chains, and customers' ability to use (and their need for) services.⁷³

Some companies are taking action to not only avoid risk, but to explore potential opportunities that may emerge in a changing climate, such as developing new products and services, developing or expanding existing consulting services, expanding into new operational territories, extending growing seasons and hours of operation, and responding to increased demand for existing products and services.^{73,75,77,78}

Table 28.4. Examples of Non-governmental Adaptation Efforts and Services*

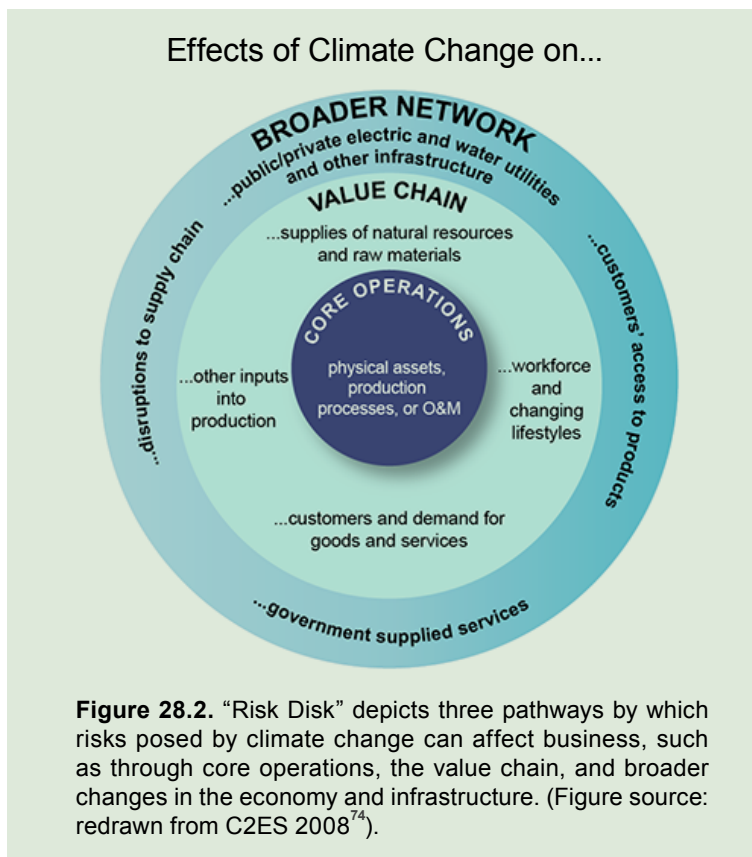
Types of Adaptation Efforts and Services	Examples of Organizations Providing Services
Adaptation planning assistance, including creation of guides, tools, and templates	Center for Climate Strategies, ICLEI-Local Governments for Sustainability, International Institute for Sustainable Development, Natural Resources Defense Council, The Nature Conservancy, World Resources Institute, World Wildlife Fund
Networking and best practice exchange	C40 Cities Climate Leadership Group, Adaptation Network, Center for Clean Air Policy, Climate Adaptation Knowledge Exchange, ICLEI-Local Governments for Sustainability, Institute for Sustainable Communities, Urban Sustainability Directors Network, World Business Council for Sustainable Development
Climate information providers	Union of Concerned Scientists, Urban Climate Change Research Network, Stockholm Environment Institute–U.S. Center
Policy, legal, and institutional support	Center for Climate and Energy Solutions (formerly Pew Center on Global Climate Change), Georgetown Climate Center
Aggregation of adaptation-pertinent information	Carbon Disclosure Project, Climate Adaptation Knowledge Exchange, Georgetown Climate Center

*This list contains examples of non-governmental organizations providing the identified services and should not be considered all-inclusive or a validation of actions claimed by the organizations.

Table 28.5. Examples of Private Sector Actions to Adapt to Climate Risks as Reported to the Carbon Disclosure Project*

Company	Sector	Climate Risk	Examples of Actions Undertaken
Coca-Cola Company	Consumer Staples	Changes in physical climate parameters; Changes in other climate-related developments	Coca-Cola is working around the world to replenish the water used in finished beverages by participating in locally relevant water projects that support communities and nature. Since 2005, the Coca-Cola system has engaged in more than 320 projects in 86 countries. The range of community projects includes watershed protection; expanding community drinking water and sanitation access; water for productive use, such as agricultural water efficiency; and education and awareness programs. (http://www.thecoca-colacompany.com/citizenship/conservation_partnership.html)
ConAgra Foods, Inc.	Consumer Staples	Company experienced weather-related sourcing challenges, such as delayed tomato harvesting due to unseasonably cool weather, and difficulty sourcing other vegetables due to above normal precipitation.	As part of its business continuity planning, ConAgra Foods has analyzed its supply risk to develop strategic partnerships with suppliers, minimize sole-sourced ingredients, and identify alternate suppliers and contract manufacturers to minimize production disruptions in the instance of an unexpected disruption in supply. (http://company.conagrafoods.com/phoenix.zhtml?c=202310&p=Policies_Environment)
Constellation Brands	Consumer Staples	Changes in physical climate parameters; Changes in other climate-related developments	Constellation has already taken adaptation actions, particularly in California where water availability is an issue, to manage or adapt to these risks. Constellation is working with numerous organizations to help fund industry-based research to determine potential climate change impacts on vineyard production.
Munich Re	Reinsurance	Changes in regulation; Changes in physical climate parameters; Changes in other climate-related developments	Since 2007, a Group-wide climate change strategy covering all aspects of climate change – for example, weather-related impacts, regulatory impacts, litigation and health risks, etc. – has supported their core corporate strategy. The strategy is based on five pillars: mitigation, adaptation, research, in-house carbon dioxide reduction, and advocacy. (http://www.munichre.com/en/group/focus/climate_change/default.aspx)
Pacific Gas and Electric Company (PG&E)	Utilities	Changes in regulation; changes in physical climate parameters; Changes in other climate-related developments	PG&E's adaptation strategies for potential increased electricity demand include expanded customer energy efficiency and demand response programs and improvements to its electric grid. PG&E is proactively tracking and evaluating the potential impacts of reductions to Sierra Nevada snowpack on its hydroelectric system and has developed adaptation strategies to minimize them. Strategies include maintaining higher winter carryover reservoir storage levels, reducing conveyance flows in canals and flumes in response to an increased portion of precipitation falling as rain, and reducing discretionary reservoir water releases during the late spring and summer. PG&E is also working with both the U.S. Geological Survey (USGS) and the California Department of Water Resources to begin using the USGS Precipitation-Runoff Modeling System (PRMS) watershed model, to help manage reservoirs on watersheds experiencing mountain snowpack loss. (http://www.pge.com/about/environment/commitment/)
SC Johnson & Son, Inc.	Household Products	Changes in physical climate parameters	SC Johnson is adjusting to the various physical risks that climate change imposes through a diversified supplier and global manufacturing base. In March 2009, SC Johnson announced a broad ingredient communication program. SC Johnson assesses risks along each ingredient's supply chain to ensure that the company is sourcing from a geographically diverse supplier base. In addition to evaluating product ingredients, SC Johnson has also diversified its operations around the world, allowing it to maintain business continuity in the face of a regional climate change related disruption. (http://www.scjohnson.com/en/commitment/overview.aspx)
Spectra Energy, Inc.	Energy	Changes in regulation; Changes in physical climate parameters; Changes in other climate-related developments	Spectra Energy uses a corporate-wide risk analysis framework to ensure the oversight and management of its four major risk categories: financial, strategic, operational, and legal risks. Physical risks posed by climate change fall within these categories and the company uses risk management committees to ensure that all material risks are identified, evaluated, and managed prior to financial approvals of major projects. (http://www.spectraenergy.com/Sustainability/)

* This list contains examples of private sector actions to adapt to climate risks as reported to the Carbon Disclosure Project and should not be considered all-inclusive or a validation of actions claimed by the organizations.



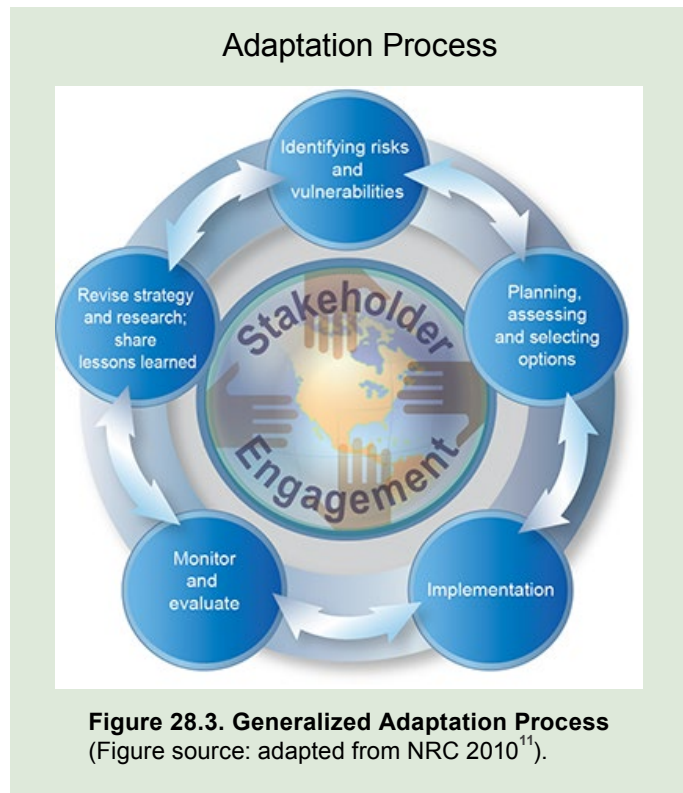
Section 1: Adaptation Process

General patterns in adaptation processes are beginning to emerge, with similarities discernible across sectors, systems, and scales.^{53,78,79}

This is not a stepwise or linear process; various stages can be occurring simultaneously, in a different order, or be omitted completely. However, as shown clockwise in Figure 28.3, the process generally involves characterizing vulnerability, developing options, implementing actions, monitoring outcomes, and reevaluating strategies. Each of these is described in more detail below.

Identifying and Understanding Risk, Vulnerabilities, and Opportunities

Most adaptation actions are currently in the initial phase, with many actors focusing on identifying the relevant climate risks and conducting current and future risk and vulnerability assessments of their assets and resources.^{8,11,59,80,81,82} In 2011, only 13% of 298 U.S. municipalities surveyed had completed vulnerability or risk assessments, but 42% expected to complete an assessment in the future.⁵⁹ At least 21 state fish and wildlife agencies have undertaken climate vulnerability assessments or recently completed an assessment of a particular species, habitat, or both.³⁸ Multiple qualitative and quantitative methods are used to understand climate vulnerability and risk, including case studies and analogue analyses, scenario analyses, sensitivity analyses, monitoring of key species, and peer information sharing.^{8,28,83,84}



Planning, Assessing, and Selecting Options

Once risks and vulnerabilities are understood, the next stage typically involves identifying, evaluating, and selecting options for responding to and managing existing and future changes in the climate.²⁸ Decision support planning methods and associated tools help to identify flexible and context-relevant adaptation activities for implementation.^{11,79} Participatory approaches support the integration of stakeholder perspectives and context-specific information into decision-making.^{85,86} This approach can include having community members and governing institutions work collectively to define the problem and design adaptation strategies that are robust while being sensitive to stakeholder values.^{86,87} Moreover, regional collaboration has emerged as an effective strategy for defining common approaches to reducing potential threats, selecting metrics for tracking purposes, and creating governance structures to help navigate political challenges.^{67,88} As discussed above, a number of government and other organizations have developed plans with identified adaptation options.

Common approaches to adaptation planning include “mainstreaming” or integrating climate adaptation into

existing management plans (for example, hazard mitigation, ecosystem conservation, water management, public health, risk contingency, and energy) or developing stand-alone adaptation plans.^{68,82,89,90}

Many frameworks, tools, and approaches have emerged to help decision-makers make decisions in light of both uncertainty and the need to achieve multiple societal goals.^{7,79} Some of these, however, are specific to particular localities or resources, are not easy to use by the intended audiences, do not adequately evaluate tradeoffs, and require sophisticated knowledge of climate change.⁹¹ In general, these approaches promote options that allow reversibility, preserve future options, can tolerate a variety of impacts, and are flexible, such that mid-course adjustments are possible.^{32,92} Among these approaches are Robust Decision Making (RDM), Iterative Risk Management (IRM), Adaptive Management or Co-Management, Portfolio Management, and Scenario Planning (see Ch. 26: Decision Support for more on decision frameworks, processes, and tools).^{7,11,28,54,93,94,95,96,97}

Implementation

There is little peer-reviewed literature on adaptation actions, or evaluations of their successes and failures.^{11,36,81,98} Many of the documents submitted as part of this Third National Climate Assessment (NCA) process indicate that adaptation actions are being implemented for a variety of reasons. Often, these are undertaken with an aim toward reducing current vulnerabilities to hazards or extreme weather events, such as

forest thinning and fuel treatments that reduce fire hazards in national forests or through the diversification of supply chain sourcing in the private sector.^{72,73} Additionally, an increasing movement toward mainstreaming climate adaptation concerns into existing processes means that discerning unique climate adaptation activities will be a challenge.^{82,99}

Monitoring and Evaluation

There is little literature evaluating the effectiveness of adaptation actions.^{9,72,79,86} Evaluation and monitoring efforts, to date, have focused on the creation of process-based rather than outcome-based indicators.^{86,90} A number of efforts are underway to create indicators related to climate adaptation,²⁷ including work by the National Climate Assessment and Development Advisory Committee Indicators Working Group¹⁰⁰

and the U.S. Environmental Protection Agency.¹⁰¹ Part of monitoring should include accounting for costs of adaptation. To be sure, this may be difficult to account for because of challenges in attribution of climate events to climate change versus climate variability. A few studies summarize projected future costs of adaptation.^{102,103}

Revise Strategies/Processes and Information Sharing

Uncertainty about future climate as well as population growth, economic development, response strategies, and other social and demographic issues can stymie climate adaptation activity.^{95,104,105} Through iterative processes, however, stakeholders can regularly evaluate the appropriateness of planned and implemented activities and revise them as new information becomes available.^{11,28,84} Additionally, the sharing of best practices and lessons learned can be pivotal means to advancing understanding and uptake of climate adaptation activity.^{82,86} The use of established information-sharing

networks, such as regional climate initiatives, are illustrations of the types of networks that have supported stakeholder adaptation activity to-date.^{9,76,79,86}

Section 2: Barriers to Adaptation and Examples of Overcoming Barriers

Despite emerging recognition of the necessity of climate change adaptation, many barriers still impede efforts to build local, regional, and national-level resilience. Barriers are obstacles that can delay, divert, or temporarily block the adaptation process,¹⁰⁶ and include difficulties in using climate change projections for decision-making; lack of resources to begin and sustain adaptation efforts; lack of coordination and collaboration within and across political and natural system boundaries as well as within organizations; institutional constraints; lack of leadership; and divergent risk perceptions/cultures and values (Table 28.6).^{11,20,107} Barriers are

distinguished from physical or ecological limits to adaptation, such as physiological tolerance of species to changing climatic conditions that cannot be overcome (except with technology or some other physical intervention).^{8,54,108}

Despite barriers, individuals within and across sectors and regions are organizing to collectively overcome barriers and adapt to climate change. In many cases, lessons learned from initial programs help inform future adaptation strategies. Figure 28.4 highlights ongoing climate adaptation activities that have overcome some of these barriers in different regions led

Table 28.6. Summary of Adaptation Barriers

Barrier	Specific Examples
Climate Change Information and Decision-Making References: 7,8,10,11,14,17,31,32,42,59,68,69,72,82,90,93,104,109,110,111,112	<ul style="list-style-type: none"> • Uncertainty about future climate impacts and difficulty in interpreting the cause of individual weather events • Disconnect between information providers and information users • Fragmented, complex, and often confusing information • Lack of climate education for professionals and the public • Lack of usability and accessibility of existing information • Mismatch of decision-making timescales and future climate projections
Lack of Resources to Begin and Sustain Adaptation Efforts References: 8,13,42,51,54,59,81,82,111,112,113,114	<ul style="list-style-type: none"> • Lack of financial resources / no dedicated funding • Limited staffing capacity • Underinvestment in human dimensions research
Fragmentation of Decision-Making References: 8,14,31,32,51,68,115,116	<ul style="list-style-type: none"> • Lack of coordination within and across agencies, private companies, and non-governmental organizations • Uncoordinated and fragmented research efforts • Disjointed climate related information • Fragmented ecosystem and jurisdictional boundaries
Institutional Constraints References: 8,13,42,51,54,97,113,117,118,119	<ul style="list-style-type: none"> • Lack of institutional flexibility • Rigid laws and regulations • No legal mandate to act • Use of historical data to inform future decisions • Restrictive management procedures • Lack of operational control or influence
Lack of Leadership References: 30,96,112,113,119,120,121	<ul style="list-style-type: none"> • Lack of political leadership • Rigid and entrenched political structures • Polarization
Divergent Risk Perceptions, Cultures, and Values References: 51,71,82,116,117,120,122	<ul style="list-style-type: none"> • Conflicting values/risk perceptions • Little integration of local knowledge, context, and needs with traditional scientific information • Cultural taboos and conflict with cultural beliefs • Resistance to change due to issues such as risk perception

by state, local, and private actors in the United States. It is not a comprehensive compilation of national adaptation activity, but is intended to identify some of the variety of adaptation efforts taking place across the country.

In addition, Section 4 of this chapter provides four in-depth case studies of climate adaptation strategies at different scales, with multiple stakeholders, and tackling different challenges. Each of these case studies highlights the different ways stakeholders are approaching adaptation.

- Through the creation of the National Integrated Drought Information System (NIDIS), the Federal Government, in partnership with the National Drought Mitigation Center (NDMC), states, tribes, universities, and others, has improved capacity to proactively manage and respond to drought-related risks and impacts through: 1) the provision of drought early warning information systems with local/regional input on extent, onset, and severity; 2) a web-based drought portal featuring the U.S. Drought Monitor and other visualization tools; 3) coordination of research in support and use of these systems; and 4) leveraging of existing partnerships, forecasting, and assessment programs.
- In the Colorado River Basin, water resource managers, government leaders, federal agencies, tribes, universities, non-governmental organizations (NGOs), and the private sector are collaborating on strategies for managing water under a changing climate through partnerships like the Western Governors' Association (WGA) and WestFAST (Western Federal Agency Support Team).
- In Wisconsin, the Northern Institute of Applied Climate Science and the U.S. Forest Service, working with multiple partners, initiated a "Climate Change Response Framework" integrating climate-impacts science with forest management.
- In Cape Cod, Massachusetts, the U.S. Department of Transportation's Volpe Center worked with federal, regional, state, and local stakeholders to integrate climate change mitigation and adaptation considerations into existing and future transportation, land-use, coastal, and hazard-mitigation processes.

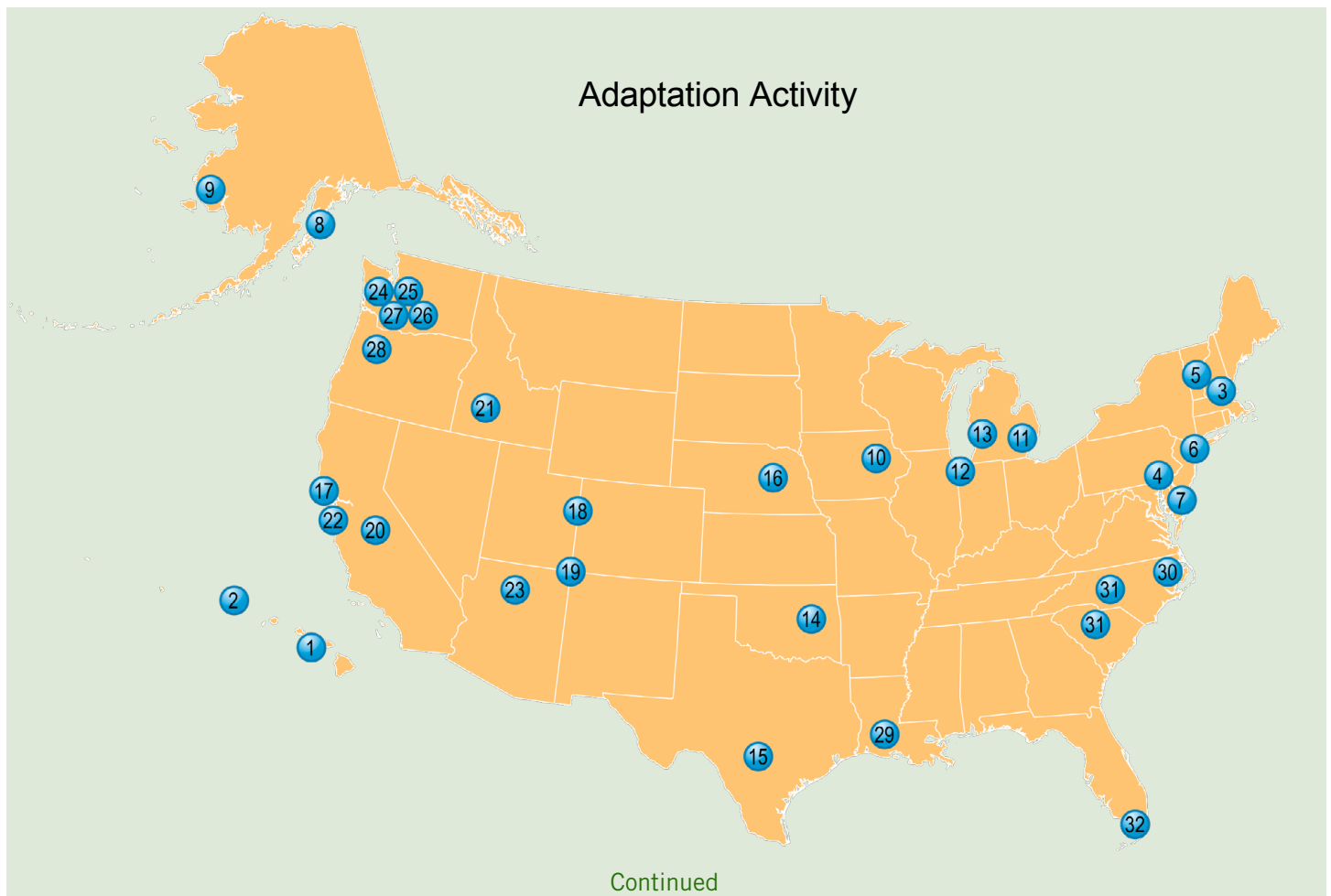


Figure 28.4. Adaptation Activity

1. The State of Hawai'i, Office of Planning, in cooperation with university, private, state, and federal scientists and others, has drafted a framework for climate change adaptation that identifies sectors affected by climate change, and outlines a process for coordinated statewide adaptation planning.¹²³
2. One of the priorities of the Hawai'i State Plan is preserving water sources through forest conservation, as indicated in their "Rain Follows The Forest" report.¹²⁴
3. New England Federal Partners is a multi-agency group formed to support the needs of the states, tribes, and communities of the New England Region and to facilitate and enable informed decision-making on issues pertaining to coastal and marine spatial planning, climate mitigation, and climate adaptation throughout the region.¹²⁵
4. Philadelphia is greening its combined sewer infrastructure to protect rivers, reduce greenhouse gas emissions, improve air quality, and enhance adaptation to a changing climate.¹²⁶
5. Keene, NH, developed a Comprehensive Master Plan that emphasizes fostering walkable, mixed-use neighborhoods by putting services, jobs, homes, arts and culture, and other community amenities within walking distance of each other. The plan also calls for sustainable site and building designs that use resources efficiently. These strategies were identified in the city's 2007 Adaptation Plan as ways to build resilience while reducing greenhouse gas emissions.¹²⁷
6. New York City has created a Green Infrastructure Plan and is committed to goals that include the construction of enough green infrastructure throughout the city to manage 10% of the runoff from impervious surfaces by 2030.¹²⁸
7. Lewes, DE, undertook an intensive stakeholder process to integrate climate change into the city's updated hazard mitigation plan.⁶²
8. Local governments and tribes throughout Alaska, such as those in Homer, are planting native vegetation and changing the coastal surface, moving inland or away from rivers, and building riprap walls, seawalls or groins, which are shore-protection structures built perpendicular to the shoreline (see also: Ch. 22:Alaska; Ch. 12: Indigenous Peoples).¹²⁹
9. Alaskan villages are physically being relocated because of climate impacts such as sea level rise and erosion; these include Newtok, Shishmaref, Kivalina, and dozens of other villages.¹³⁰
10. Cedar Falls, Iowa, passed legislation in 2009 that includes a new floodplain ordinance that expands zoning restrictions from the 100-year floodplain to the 500-year floodplain, because this expanded floodplain zone better reflects the flood risks experienced by the city during the 2008 floods.¹³¹
11. In January 2011, the Michigan Department of Community Health (MDCH) released the *Michigan Climate and Health Adaptation Plan*, which has a goal of "preparing the public health system in Michigan to address the public health consequences of climate change in a coordinated manner." In September 2010, MDCH received three years' funding to implement this plan as part of the Climate-Ready States and Cities Initiative of CDC.¹³²
12. Chicago was one of the first cities to officially integrate climate adaptation into a citywide climate adaptation plan. Since its release, a number of strategies have been implemented to help the city manage heat, protect forests, and enhance green design, such as their work on green roofs.⁶⁴
13. Grand Rapids, MI, recently released a sustainability plan that integrates future climate projections to ensure that the economic, environmental, and social strategies embraced are appropriate for today as well as the future.¹³³
14. Tulsa, OK, has a three-pronged approach to reducing flooding and managing stormwater: a) prevent new problems by looking ahead and avoiding future downstream problems from new development (for example, requiring on-site stormwater detention); b) correct existing problems and learn from disasters to reduce future disasters (for example, through watershed management and the acquisition and relocation of buildings in flood-prone areas); and c) act to enhance the safety, environment, and quality of life of the community through public awareness, an increase in stormwater quality, and emergency management.¹³⁴
15. Firewise Communities USA is a nationwide program of the National Fire Protection Association and is co-sponsored by USDA Forest Service, DOI, and the National Association of State Foresters. According to the Texas Forest Service, there are more than 20 recognized Texas Firewise Communities. The Texas Forest Service works closely with communities to help them to reach Firewise Community status and offers a variety of awareness, educational, informational, and capacity-building efforts, such as *Texas Wildscapes*, a program that assists in choosing less fire-friendly plants.¹³⁵

Continued

16. After the heavy rainfall events of 2004 that resulted in significant erosion on his farms, Dan Gillespie, a farmer with the Natural Resources Conservation Service in Norfolk, NE, began experimenting with adding cover crops to the no-till process. It worked so well in reducing erosion and increasing crop yields that he is now sharing his experience with other farmers. (<http://www.lenrd.org/projects-programs/>; <http://www.notill.org/>)¹³⁶
17. Point Reyes National Seashore is preparing for climate change by removing two dams that are barriers to water flow and fish migration. This change restores ecological continuity for anadromous fish (those that migrate from the sea to fresh water to spawn), creating a more resilient ecosystem.¹³⁷
18. Western Adaptation Alliance is a group of eleven cities in five states in the Intermountain West that share lessons learned in adaptation planning, develop strategic thinking that can be applied to specific community plans, and join together to generate funds to support capacity building, adaptation planning, and vulnerability assessment.¹³⁸
19. Navajo Nation used information on likely changes in future climate to help inform their drought contingency plan.¹³⁹
20. California Department of Health and the Natural Resources Defense Council collaborated to create the *Public Health Impacts of Climate Change in California: Community Vulnerability Assessment and Adaptation Strategies* report, which is being used to inform public health preparedness activities in the state.¹⁴⁰
21. State of Idaho successfully integrated climate adaptation into the state's Wildlife Management Plan. (<http://fishandgame.idaho.gov/public/wildlife/cwcs/>)⁸
22. The Rising Tides Competition was held in 2009 by the San Francisco Bay Conservation and Development Commission to elicit ideas for how the Bay could respond to sea level rise.¹⁴¹
23. Flagstaff, Arizona, created a resilience strategy and passed a resilience policy, as opposed to a formal adaptation plan, as a means to institutionalize adaptation efforts in city government operations.¹⁴²
24. The Olympic National Forest and Olympic National Park were sites of case studies looking at how to adapt management of federal lands to climate change. Sensitivity assessments, review of management activities and constraints, and adaptation workshops in the areas of hydrology and roads, fish, vegetation, and wildlife were all components of the case study process.¹⁴³
25. King County Flood Control District was reformed to merge multiple flood management zones into a single county entity for funding and policy oversight for projects and programs – partly in anticipation of increased stormwater flows due to climate change.¹⁴⁴
26. The Water Utilities Climate Alliance has been working with member water utilities to ensure that future weather and climate considerations are integrated into short- and long-term water management planning. (<http://www.wucaonline.org/html/>)⁹⁰
27. Seattle's RainWatch program uses an early warning precipitation forecasting tool to help inform decisions about issues such as drainage operations. (<http://www.atmos.washington.edu/SPU/>)¹⁹
28. City of Portland and Multnomah County created a Climate Action Plan that includes indicators to help them gauge progress in planning and implementing adaptation actions.¹⁴⁵
29. In 2010, the state of Louisiana launched a \$10 million program to assist communities that had been affected by Hurricanes Gustav and Ike in becoming more resilient to future environmental problems. Twenty-nine communities from around the state were awarded resiliency development funds. The Coastal Sustainability Studio at Louisiana State University started working in 2012 with all 29 funded communities, as well as many that did not receive funds, to develop peer-learning networks, develop best practices, build capacity to implement plans, and develop planning tools and a user-inspired and useful website to increase community resiliency in the state.¹⁴⁶
30. U.S. Fish and Wildlife Service and The Nature Conservancy are cooperating in a pilot adaptation project to address erosion and saltwater intrusion, among other issues, in the Alligator River Refuge. This project incorporates multiple agencies, native knowledge, community involvement, local economics, and technical precision.¹⁴⁷
31. North and South Carolina are actively working to revise their state wildlife strategies to include climate adaptation.⁸²
32. The Southeast Florida Climate Change Compact is a collaboration of the four southernmost counties in Florida (Monroe, Broward, Palm Springs, and Miami-Dade) focusing on enhancing regional resilience to climate change and reducing regional greenhouse gas emissions.⁶⁷

Section 3: Next Steps

Adaptation to climate change is in a nascent stage. The Federal Government is beginning to develop institutions and practices necessary to cope with climate change, including efforts such as regional climate centers within the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration (a division of the U.S. Department of Commerce), and the U.S. Department of the Interior. While the Federal Government provides financial assistance in federally-declared disasters, it is also enabling and facilitating early adaptation within states, regions, local communities, and the public and private sectors.¹¹ The approaches include working to limit current institutional constraints to effective adaptation, funding pilot projects, providing useful and usable adaptation information – including disseminating best practices and helping develop tools and techniques to evaluate successful adaptation.

Despite emerging efforts, the pace and extent of adaptation activities are not proportional to the risks to people, property, infrastructure, and ecosystems from climate change; important opportunities available during the normal course of planning and management of resources are also being overlooked. A number of state and local governments are engaging in adaptation planning, but most have not taken action to implement the plans.¹⁰⁷ Some companies in the private sector and numerous non-governmental organizations have also taken early action, particularly in capitalizing on the opportunities associated with facilitating adaptive actions. Actions and collaborations have occurred across all scales. At the same time, barriers to effective implementation continue to exist (see Section 2).

One of the overarching key areas of focus for global change research is enabling research and development to advance adaptation across scales, sectors, and disciplines. This includes social science research for overcoming the barriers identified in Section 2, such as strategies that foster coordination, better communication, and knowledge sharing amongst fragmented governing structures and stakeholders. Research on the kinds of information that users desire and how to deliver that information in contextually appropriate ways and research on

decision-making in light of uncertainty about climate change and other considerations will be equally important. In addition to these areas, emerging areas of emphasis include:

- **Costs and Benefits of Adaptation:** Methodologies to evaluate the relevant costs of adaptation options, as well as the costs of inaction, need to be developed.^{6,102}
- **A Compendium of Adaptation Practices:** A central and streamlined database of adaptation options implemented at different scales in space and time is needed. Information on the adaptation actions, how effective they were, what they cost, and how monitoring and evaluation were conducted should be part of the aggregated information.^{11,20,31}
- **Adaptation and Mitigation Interactions:** Research and analysis on the growing and competing demands for land, water, and energy and how mitigation actions could affect adaptation options, and vice versa.^{4,27,81,148}
- **Critical Adaptation Thresholds:** Research to identify critical thresholds beyond which social and/or ecological systems are unable to adapt to climate change. This should include analyzing historical and geological records to develop models of “breakpoints”.^{2,31,149}
- **Adaptation to Extreme Events:** Research on preparedness and response to extreme events such as droughts, floods, intense storms, and heat waves in order to protect people, ecosystems, and infrastructure. Increased attention must be paid to how extreme events and variability may change as climate change proceeds, and how that affects adaptation actions.^{11,150}

Effective adaptation will require ongoing, flexible, transparent, inclusive, and iterative decision-making processes, collaboration across scales of government and sectors, and the continual exchange of best practices and lessons learned. All stakeholders have a critical role to play in ensuring the preparedness of our society to extreme events and long-term changes in climate.

Section 4: Case Studies

Illustrative Case One: National Integrated Drought Information System

NIDIS (National Integrated Drought Information System), originally proposed by the Western Governors’ Association (WGA) and established by Congress in 2006,¹⁵¹ is a federally-created entity that improves the nation’s capacity to proactively manage drought-related risks across sectors, regions, and jurisdictions. It was created by Congress to “enable the Nation to move from a reactive to a more proactive approach to managing drought risks and impacts.” NIDIS has successfully brought together government partners

and research organizations to advance a warning system for drought-sensitive areas.

The creation of NIDIS involved many years of development and coordination among federal, state, local, regional, and tribal partners with the help of Governors’ associations and Senate and Congressional leaders. NIDIS provides: 1) drought early warning information systems with regional detail concerning onset and severity; 2) a web-based portal (www.drought.gov);

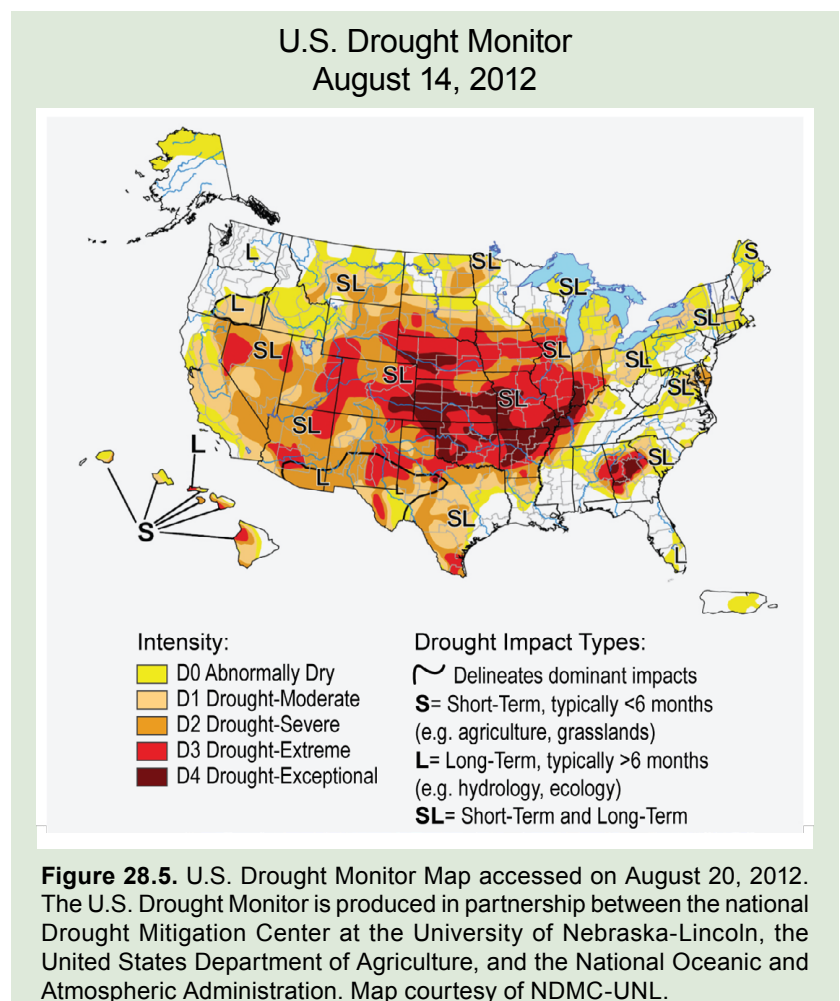
3) coordination of federal research in support of and use of these systems; and 4) leveraging of existing partnerships and of forecasting and assessment programs. NIDIS currently supports work on water supply and demand, wildfire risk assessment and management, and agriculture. Regional drought early warning system pilot projects have been established to illustrate the benefits of improved knowledge management, improved use of existing and new information products, and coordination and capacity development for early warning systems. These prototype systems are in the Upper Colorado Basin, the Apalachicola-Chattahoochee-Flint River Basin in the Southeast, the Four Corners region in the Southwest, and California. The NIDIS Outlook in the Upper Colorado Basin provides early warning information every week, for example, that is utilized by a variety of users from federal agencies, water resource management, and the recreation industry.

The Western Governors' Association, the U.S. Congress, and others have formally acknowledged that NIDIS provides a successful example of achieving effective federal-state partnerships by engaging both leadership and the public, and establishing an authoritative basis for integrating monitoring and research to support risk management. Some of NIDIS's keys to success include:

- **Usable Technology and Information for Decision Support:** The production of the U.S. Drought Monitor map, which integrates multiple indicators and indices from many data sources, was developed before NIDIS was established and has become a useful visual decision support tool for monitoring and characterizing drought onset, severity, and persistence. NIDIS has engaged regional and local experts in refining the regional details of this national product and in "ground truthing" maps via email discussions and webinars (Figure 28.5).
- **Financial Assistance:** Federal funding was allocated to NOAA specifically for NIDIS, but leveraged in kind by other agencies and partners.
- **Institutional/Partnerships:** Effective collaborations, partnerships, and coordination with NOAA, WGA, USDA, DOI, and USGS as well as local, regional, state, and tribal partners and with the National Drought Mitigation Center at the University of Nebraska, Lincoln, have led to multi-institutional "buy-in."
- **Institutional/Policy:** The NIDIS Act was oriented toward the improvement of coordination across federal agencies and with regional organizations, universities, and states. It focused on the application of technology, including the Internet, and on

impact assessments for decision support. A key aspect of NIDIS is the development of an ongoing regional outlook forum based on the above information to build awareness of the drought hazard and to embed information in planning and practice (in partnership with the National Drought Mitigation Center, the Regional Integrated Sciences and Assessments (RISA), and other research-based boundary organizations) to reduce risks and impacts associated with drought.

- **Leadership and Champions:** NIDIS supporters worked at all levels over more than two decades (1990s and 2000s) to establish the NIDIS Act, including political groups (WGA, Southern Governors' Association, National Governors Association, and U.S. Senators and Representatives), scientific leaders, and federal agencies (NOAA, USDA, DOI).
- **Risk Perceptions:** Whereas drought had been considered primarily a western issue in previous decades, drought is now regularly affecting the southern, southeastern, and north-eastern parts of the country and response strategies are needed. During the 2012 drought, more than 63% of the contiguous U.S. by the end of July was classified as experiencing moderate to exceptional drought, and more than 3,200 heat records were broken in June 2012 alone.¹⁵²



Illustrative Case Two: Adaptive Governance in the Colorado River Basin

The Colorado River supplies water and valuable ecosystem services to 33 million people and is vulnerable to climate change because of decreases in mountain snowpack and water availability, increased competition among water users, fires, drought, invasive species, and extended extreme heat events, among other threats.^{13,153} The 1922 Colorado River Compact, which allocates water among seven U.S. states and Mexico, was agreed upon in a particularly wet time period;¹⁵⁴ thus the river water is already over-allocated for current conditions. Given the likelihood of having less water because of climate change, resource managers and government leaders are increasingly recognizing that water must be managed with flexibility to respond to the projected impacts and the range of possible future climates (see Ch. 2: Our Changing Climate; Ch. 3: Water).^{13,155} Multiple actors across multiple disciplines, scales of governance (including tribal, local, state, and federal), non-governmental organizations, and the private sector are organizing and working together to address these concerns and the relationship between climate and other stresses in the basin.

The Western Governors' Association (WGA) spearheaded adaptation efforts to enable federal, state, tribal, local, and private sector partners to address a range of issues, including climate change.^{13,155,156} For example, the Western Federal

Agency Support Team (WestFAST), which was established in 2008, created a partnership between the Western States Water Council (WSWC) and 11 federal agencies with water management responsibilities in the western United States. The agencies created a work plan in 2011 to address three key areas: 1) climate change; 2) water availability, water use, and water reuse; and 3) water quality. To date they have produced the WestFAST Water-Climate Change Program Inventory, the Federal Agency Summary, and a Water Availability Studies Inventory (<http://www.westgov.org/wswc/WestFAST.htm>).

The WSWC and the USACE produced the Western States Watershed Study (WSWS), which demonstrated how federal agencies could work collaboratively with western states on planning activities.¹⁵⁷ In 2009, the WGA also adopted a policy resolution titled "Supporting the Integration of Climate Change Adaptation Science in the West" that created a Climate Adaptation Work Group composed of western state experts in air quality, forest management, water resources, and wildlife management. Other important adaptation actions were the SECURE Water Act in 2009, the Reclamation Colorado River Basin water supply and demand study, and the creation of NIDIS to support stakeholders in coping with drought.^{151,158}

Illustrative Case Three: Climate Change Adaptation in Forests

Northern Wisconsin's climate has warmed over the past 50 years, and windstorms, wildfires, insect outbreaks, and floods are projected to become more frequent in this century.¹⁶⁰ The resulting impacts on forests, combined with fragmented and complex forest ownership, create management challenges that extend across ownership boundaries, creating the need for a multi-stakeholder planning process.¹⁶¹

To address these concerns, the Northern Institute of Applied Climate Science, the USDA's Forest Service, and many other partners initiated the Climate Change Response Framework to incorporate scientific research on climate change impacts into on-the-ground management. Originally developed as a pilot project for all-lands conservation in northern Wisconsin, it has expanded to cover three ecological regions (Northwoods [Figure 28.6], Central Hardwoods, and Central Appalachians)

across eight states in the Midwest and Northeast. The Framework uses a collaborative and iterative approach to provide information and resources to forest owners and managers across a variety of private and public organizations. Several products were developed through the Framework in northern Wisconsin:

1. Vulnerability and mitigation assessments summarized the observed and projected changes in the northern Wisconsin climate, projected changes in forest composition and carbon stocks across a range of potential climates, and assessed related vulnerabilities of forest ecosystems in northern Wisconsin.¹⁶⁰
2. Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers¹⁶² was developed to help managers identify management tactics that facilitate adaptation. A "menu" of adaptation strategies and approaches for planning, implementing, and monitoring adaptation activities was synthesized into an adaptation workbook from a broad set of literature and refined based on feedback from regional scientists and managers.¹⁶³
3. A series of adaptation demonstrations was initiated to showcase ground-level implementation. The Framework and adaptation workbook provide a common process shared by diverse landowners and a formal network that supports



Figure 28.6. Northwoods Climate Change Response Framework Region (Figure Source: USDA Forest Service 2012¹⁵⁹).

cross-boundary discussion about different management objectives, ecosystems, and associated adaptation tactics.

From the beginning, the Framework has taken an adaptive management approach in its adaptation planning and projects. Lessons learned include:

- Define the purpose and scope of the Framework and its components early, but allow for refinement to take advantage of new opportunities.
- Begin projects with a synthesis of existing information to avoid duplicating efforts.
- Plan for the extra time necessary to implement true collaboration.
- Carefully match the skills, commitment, and capacity of people and organizations to project tasks.
- Maintain an atmosphere of trust, positivity, and sense of adventure, rather than dwelling on failures.

- Acknowledge and work with uncertainty, rather than submit to “uncertainty paralysis.”
- Recognize the necessity of effective communication among people with different goals, disciplinary backgrounds, vocabulary, and perspectives on uncertainty.
- Integrate the ecological and socioeconomic dimensions early by emphasizing the many ways that communities value and depend on forests.
- Use technology to increase efficiency of internal communication and collaboration, as well as outreach.

The Framework brings scientists and land managers together to assess the vulnerability of ecosystems based on scientific information and experience in order to plan adaptation actions that meet management goals. On-the-ground implementation has just begun, and an increased focus on demonstrations, monitoring, and evaluation will inform future adaptation efforts.

Illustrative Case Four: Transportation, Land Use, and Climate Change – Integrating Climate Adaptation and Mitigation in Cape Cod, Massachusetts

Cape Cod, Massachusetts, a region of scenic beauty and environmental significance, is currently affected by sea level rise, coastal erosion, and localized flooding – impacts that are likely to be exacerbated by climate change.^{164,165} To address these concerns and help meet the state’s greenhouse gas (GHG) reduction target (25% reduction based on 1990 levels by 2020), the U.S. Department of Transportation’s Volpe Center worked with federal, regional, state, and local stakeholders to integrate climate change into existing and future transportation, land-use, coastal zone, and hazard mitigation planning through an initiative called the Transportation, Land Use, and Climate Change Pilot Project.^{164,166}

The process was initiated through an expert elicitation held in mid-2010 to identify areas on Cape Cod that are or could potentially be vulnerable to sea level rise, flooding, and erosion. The Volpe Center then used a geographic information system (GIS) software tool to develop and evaluate a series of transportation and land-use scenarios for the Cape under future development projections.^{165,167} All scenarios were evaluated against a series of criteria that included: 1) reduction in vehicle miles traveled; 2) reduced heat-trapping gas emissions; 3) reduction in transportation energy use; 4) preservation of natural/existing ecosystems; 5) reduction in percentage of new population in areas identified as vulnerable to climate change impacts; and 6) increased regional accessibility to transportation.¹⁶⁴

Once the preliminary scenarios were developed, a workshop was convened in which community and transportation planners, environmental managers, and Cape Cod National Seashore stakeholders selected areas for development and transit improvements to accommodate new growth while meeting the goals of reduced heat-trapping gas emissions, increased resilience to climate change, and the conservation of natural systems.¹⁶⁵ Through interactive visualization tools, participants were able to see in real-time the impacts of their siting decisions, allowing them to evaluate synergies and potential tradeoffs of their choices and to highlight areas where conflict could or already does exist, such as increasing density of development in areas already or likely to be vulnerable to climate change.¹⁶⁸ As a result, the stakeholders developed a refined transportation and land-use scenario that will support the region’s long-range transportation planning as well as other local, regional, and state plans. This updated scenario identifies strategies that have climate adaptation and mitigation value, helping to ensure that the region simultaneously reduces its heat-trapping gas footprint while building resilience to existing and future changes in climate.^{164,165} The overall success of the pilot project stemmed from the intensive stakeholder interaction at each phase of the project (design, implementation, and evaluation).

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SUPPLEMENTAL MATERIAL

TRACEABLE ACCOUNTS

Process for Developing Key Messages

A central component of the process were bi-weekly technical discussions held from October 2011 to June 2012 via teleconference that focused on collaborative review and summary of all technical inputs relevant to adaptation (130+) as well as additional published literature, the iterative development of key messages, and the final drafting of the chapter. An in-person meeting was held in Washington, D.C., in June 2012. Meeting discussions were followed by expert deliberation of draft key messages by the authors and targeted consultation with additional experts by the lead author of each key message. Consensus was reached on all key messages and supporting text.

KEY MESSAGE #1 TRACEABLE ACCOUNT

Substantial adaptation planning is occurring in the public and private sectors and at all levels of government; however, few measures have been implemented and those that have appear to be incremental changes.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer-reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input.

Numerous peer-reviewed publications indicate that a growing number of sectors, governments at all scales, and private and non-governmental actors are starting to undertake adaptation activity.^{9,13} Much of this activity is focused on planning with little literature documenting implementation of activities.^{8,11,82} Supporting this statement is also plentiful literature that profiles barriers or constraints that are impeding the advancement of adaptation activity across sectors, scales, and regions.^{42,68}

Additional citations are used in the text of the chapter to substantiate this key message.

New information and remaining uncertainties

n/a

Assessment of confidence based on evidence

n/a

KEY MESSAGE #2 TRACEABLE ACCOUNT

Barriers to implementation of adaptation include limited funding, policy and legal impediments, and difficulty in anticipating climate-related changes at local scales.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input. A significant quantity of reviewed literature profiles barriers or constraints that are impeding the advancement of adaptation activity across sectors, scales, and regions.^{11,20,42,68}

Numerous peer-reviewed documents describe adaptation barriers (see Table 28.6). Moreover, additional citations are used in the text of the chapter to substantiate this key message.

New information and remaining uncertainties

n/a

Assessment of confidence based on evidence

n/a

KEY MESSAGE #3 TRACEABLE ACCOUNT

There is no “one-size fits all” adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer-reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input.

Literature submitted for this assessment, as well as additional literature reviewed by the author team, fully supports the concept that adaptations will ultimately need to be selected for their local applicability based on impacts, timing, political structure, finances, and other criteria.^{11,90} Similarities do exist in the types of adaptation being implemented, although nuanced differences do make most adaptation uniquely appropriate for the specific implementer. The selection of locally and context-appropriate adaptations is enhanced by iterative and collaborative processes in which stakeholders directly engage with decision-makers and information providers.^{11,20,28} While there are no “one-size fits all” adaptation strategies, evidence to date supports the message that the sharing of best practices and lessons learned are greatly aiding in adaptation progress across sectors, systems, and governance systems.^{82,86}

Additional citations are used in the text of the chapter to substantiate this key message.

NEW INFORMATION AND REMAINING UNCERTAINTIES

n/a

ASSESSMENT OF CONFIDENCE BASED ON EVIDENCE

n/a

KEY MESSAGE #4 TRACEABLE ACCOUNT

Climate change adaptation actions often fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be incorporated into existing decision-making processes.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer-reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input.

Literature submitted for this assessment, as well as additional literature reviewed by the author team, supports the message that a significant amount of activity that has climate adaptation value is initiated for reasons other than climate preparedness and/or has other co-benefits in addition to increasing preparedness to climate and weather impacts.^{11,20,82,86,116} In recognition of this and other factors, a movement has emerged encouraging the integration of climate change considerations into existing decision-making and planning processes (i.e., mainstreaming).^{5,11,40} The case studies discussed in the chapter amplify this point.

Additional citations are used in the text of the chapter to substantiate this key message.

New information and remaining uncertainties

n/a

Assessment of confidence based on evidence

n/a

KEY MESSAGE #5 TRACEABLE ACCOUNT

Vulnerability to climate change is exacerbated by other stresses such as pollution, habitat fragmentation, and poverty. Adaptation to multiple stresses requires assessment of the composite threats as well as tradeoffs amongst costs, benefits, and risks of available options.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer-reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input.

Climate change is only one of a multitude of stresses affecting social, environmental, and economic systems. Activity to date and literature profiling those activities support the need for climate adaptation activity to integrate the concerns of multiple stresses in decision-making and planning.^{16,17,32} As evidenced by activities to date, integrating multiple stresses into climate adaptation decision-making and vice versa will require the assessment of tradeoffs amongst costs, benefits, the risks of available options, and the potential value of outcomes.^{5,90,111}

Additional citations are used in the text of the chapter to substantiate this key message.

New information and remaining uncertainties

n/a

Assessment of confidence based on evidence

n/a

KEY MESSAGE #6 TRACEABLE ACCOUNT

The effectiveness of climate change adaptation has seldom been evaluated, because actions have only recently been initiated and comprehensive evaluation metrics do not yet exist.

Description of evidence base

The key message and supporting text summarize extensive evidence documented in the peer-reviewed literature as well as the more than 130 technical inputs received and reviewed as part of the Federal Register Notice solicitation for public input.

Numerous peer-reviewed publications indicate that no comprehensive adaptation evaluation metrics exist, meaning that no substantial body of literature or guidance materials

exist on how to thoroughly evaluate the success of adaptation activities.^{11,81,110} This is an emerging area of research. A challenge of creating adaptation evaluation metrics is the growing interest in mainstreaming; this means that separating out adaptation activities from other activities could prove difficult.

Additional citations are used in the text of the chapter to substantiate this key message.

New information and remaining uncertainties

n/a

Assessment of confidence based on evidence

n/a