DRAFT

NATIONAL ACTION PLAN:

PRIORITIES FOR MANAGING FRESHWATER RESOURCES IN A CHANGING CLIMATE

INTERAGENCY CLIMATE CHANGE ADAPTATION TASK FORCE

June 2, 2011

The Mississippi River at Lansing, Iowa - Photo by Stan Oleson
http://www.fotopedia.com/items/ehs1iuv5irde8-H-V_A5GxFPk

Disclaimer

This draft *National Action Plan* includes preliminary recommendations that may change as it is further developed. While this draft document reflects the Task Force's current thinking regarding climate change and water resources, the Task Force reserves the right to modify the recommendations included in the document, or act in a manner different from this document as appropriate. The actions and recommendations included in this draft *National Action Plan* are judged to be both a high priority today and achievable in the context of existing and foreseeable agency capacity. Over the next several months the Task Force agencies will be working to refine the proposals outlined in this draft and address public comments. This draft *National Action Plan* is not a final agency action subject to judicial review, nor is it considered a rule. Nothing in this draft plan is meant to, or in fact does, affect the substantive or legal rights of third parties or bind the federal agencies.

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Rio de Los Angeles State Park, Photo Courtesy of Ann Dove, National Park Service

Executive Summary

Freshwater resources are critical to the health of people, the environment, and the economy. Recent studies and assessments of climate change impacts, including the 2009 *Global Climate Change Impacts in the US* prepared by the U.S. Global Change Research Program, identify several major impacts of a changing climate on the Nation's freshwater resources. Expected increases in air temperatures will lead to warmer waters. Rainfall amounts are expected to decline in some areas and increase in others, while the proportion of precipitation that falls as snow decreases. Rainfall and storm events are expected to be more intense. Rising sea levels are expected to result in inundation of water infrastructure, such as water treatment facilities, and degradation of coastal groundwater resources.

These impacts of a changing climate pose significant challenges for freshwater resource managers. Assuring adequate water supply will be more difficult. New problems arise for water managers working to protect human life, health, and property. Changing water resources conditions will also make protecting the quality of freshwater resources, habitats, and aquatic life more complex.

> "Of all the potential threats posed by climatic variability and change, those associated with water resources are arguably the most consequential for both society and the environment"
>
> *Water – the Nation's Fundamental Climate Issue: A White Paper on the U.S. Geological Survey Role and Capabilities*; U.S. Department of the Interior, U.S. Geological Survey; Circular 1347; 2010

In October of 2010, the Interagency Climate Change Adaptation Task Force published a *Progress Report* describing Federal agency actions needed to better prepare the Nation to respond to the impacts of a changing climate. The Task Force recommended in the *Progress Report* that the Water Resources and Climate Change Adaptation Workgroup supporting the Task Force develop a national action plan to identify steps that Federal agencies can take to improve management of freshwater resources in a changing climate.

This *National Action Plan* synthesizes the latest science on climate risks to freshwater resources and establishes the following national goal:

> *Government agencies and citizens collaboratively manage freshwater resources in response to a changing climate in order to assure adequate water supplies, to protect human life, health and property, and to protect water quality and aquatic ecosystems.*

To accomplish this goal, the *Plan* makes six major recommendations that are described briefly below. Specific actions in support of these recommendations are summarized in Table 1; more detailed information is provided in Section IV and Appendix C.

RECOMMENDATIONS

1. **Establish a Planning Process to Adapt Water Resources Management to a Changing Climate:** This *National Action Plan* is an initial step to respond to the challenges to freshwater resources posed by a changing climate. The recommendations and actions in this *Plan*, however, will need to be evaluated and updated regularly over time. In addition, a more formal organizational framework is needed to link Federal agencies with State, tribal and local governments and with other interested parties.

2. **Improve Water Resources and Climate Change Information for Decision-Making:** Current decision-making tools and policies for water resources management rely on historical water data to estimate future variations in water availability and quality. In a changing climate, however, water data used in decision-making tools needs to be complete and current. In addition, new insights from predictive models need to be applied to key decisions.

3. **Strengthen Assessment of Vulnerability of Water Resources to Climate Change:** Climate change impacts—including extreme weather events, sea level rise, shifting precipitation and runoff patterns, among others—are expected to significantly affect operations of water resources facilities. To effectively reduce climate change risks, water resource managers need improved tools to assess the climate change vulnerabilities in their systems that are tailored to the specific type of facility and most critical management decision.

4. **Expand Water Use Efficiency:** Climate change will further challenge water resources that are already under stress because of growing populations, contamination, and demands to meet diverse human and ecosystem needs. Making more efficient use of water can extend the availability of current supplies, reduce competition among sectors, save energy, and reduce the cost of water system operations.

5. **Support Integrated Water Resources Management:** Management of the risks from a changing climate should not occur in isolation and needs to be integrated with efforts to address other freshwater resources management challenges. As models and methods for integrated water resources management are developed across the country, challenges posed by a changing climate need to be incorporated.

6. **Support Training and Outreach to Build Response Capability:** Today, the workforce that manages water resources programs at all levels of government and in the private sector needs information and tools to recognize the implications of a changing climate or to make complex climate change adaptation decisions related to freshwater resources.

The Task Force recognizes that managing the risks to freshwater resources posed by a changing climate is a complex and multi-faceted undertaking for which many recommendations and actions might be appropriate. This *National Action Plan* presents the recommendations and actions that are judged to be both a high priority today and achievable in the context of existing and foreseeable agency capacity. As described in more detail in Section IV, this document is an initial step in planning for climate change risks to freshwater resources that is expected to be evaluated, revised, and expanded in the years ahead.

Finally, this *Plan* is part of a larger set of climate change adaptation activities.

- **National Climate Assessment:** The 2009 national climate assessment, published by the U.S. Global Change Research Program, includes an assessment of climate change impacts on water resources. The information published in that assessment provides the scientific foundation for this *Plan.* National assessments are required by law every four years and the next assessment in 2013 will provide new information about impacts, opportunities, and vulnerability as well as a basis for evaluating effectiveness of adaptation actions and determining next steps.

- **Agency Climate Change Adaptation Planning:** The 2010 *Progress Report* of the Climate Change Adaptation Task Force recommended that agencies integrate adaptation into their ongoing planning to ensure that resources are invested wisely and that Federal operations, policies and programs remain effective in a changing climate. Implementing instructions for this work were recently issued by the Council on Environmental Quality. This *National Action Plan* for freshwater resources will inform and guide development of water resources related elements of Agency adaptation planning.

- **Other "Crosscutting Strategies":** In addition to calling for this freshwater action plan, the *Progress Report* recommended the development of a national strategy to build the resilience of coastal, ocean and Great Lakes ecosystems to climate change and ocean acidification and the development of a national climate adaptation strategy focused on fish, wildlife and plants. Each of these three "crosscutting strategies" has common elements and development of these plans is being closely coordinated. For example, the strategy addressing fish, wildlife and plants, now being developed under the leadership of the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, is addressing climate adaptation needs on an ecosystem basis (e.g.; forests, grasslands, freshwater ecosystems) and will speak to actions for freshwater ecosystem adaptation in greater detail.

Table 1: Summary of Recommendations and Supporting Actions

Recommendation 1: Establish a Planning Process
Action 1: Establish a planning process
Action 2: Establish an organizational framework
Recommendation 2: Improve Water Resources and Climate Data
Action 3: Strengthen data for understanding climate change impacts on water
Action 4: Create a program to align "hydroclimatic" statistics
Action 5: Implement surveillance system for tracking waterborne disease threats
Action 6: Provide information to identify areas likely to be inundated by sea level rise
Action 7: Expedite implementation of wetlands mapping standard
Recommendation 3: Strengthen Assessment of Vulnerability
Action 8: Publish long-term plan for Federal "downscaling" of climate model projections
Action 9: Develop a Federal internet portal
Action 10: Develop a pilot climate change/water vulnerability index
Action 11: Develop tools to build capacity for vulnerability assessments
Action 12: Assess vulnerability of National Forests and Grasslands
Action 13: Promote free and open access to water resources data
Recommendation 4: Improve Water Use Efficiency
Action 14: Develop nationally consistent metrics for water use efficiency
Action 15: Make water use efficiency an explicit consideration in the Principles and Standards for water resources projects and in the new NEPA guidance on climate change
Action 16: Enhance agency coordination and create a "toolbox" of key water efficiency practices
Recommendation 5: Support Integrated Water Resources Management
Action 17: Strengthen the role of river basin commissions in climate change adaptation
Action 18: Revise Federal water project planning standards to address climate change
Action 19: Working with States, review flood risk management and drought management planning and identify "best practices" to prepare for hydrologic extremes in a changing climate
Action 20: Develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies
Recommendation 6: Educate Water Resource Managers and Build Capacity
Action 21: Establish a core training program on climate change science
Action 22: Focus existing youth outreach programs on climate change and water issues
Action 23: Engage land grant colleges in climate change adaptation research
Action 24: Increase graduate level fellowships in water management and climate change

Introduction

This *National Action Plan* provides an overview of the challenges that a changing climate presents for the management of the Nation's water resources and recommends actions for Federal agencies to support water resource managers in understanding and reducing the risks of climate change.

This *Plan* was developed in response to a recommendation in the October 2010 *Progress Report* of the Interagency Climate Change and Adaptation Task Force (see http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation). It was developed for the Task Force by an interagency Water Resources and Climate Change Adaptation Workgroup made up of representatives from Federal agencies involved in water resources management. The Workgroup is co-chaired by the Department of Interior (DOI), the Environmental Protection Agency (EPA), and the Council on Environmental Quality (CEQ) (see Appendix A for Water Resources and Climate Change Adaptation Workgroup members).

During 2009 and 2010, the Workgroup held "listening sessions" with organizations outside the Federal government, reviewed scientific literature relating to the impacts of climate change on water resources, and reviewed existing efforts by Federal agencies involved in water resources management to adapt to a changing climate.

> "Given the breadth of climate change impacts and corresponding adaptation measures, certain key climate related issues will require a collaborative approach from the Federal government, such as water resource management…" (p. 34)
>
> *Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy;* October 2010

Drawing on this analysis, the Workgroup identified key concepts and specific actions to support adaptation of water resources management to a changing climate. Some of this initial work was included in the water resources section of the October 2010 *Progress Report* (see Appendix B).

This *National Action Plan* describes the major climate change risks to freshwater resources management and describes Federal agency activities to reduce these risks. A summary of comments and suggestions received from organizations and individuals during public listening sessions is provided in Appendix G.

Six recommendations to improve water resources management in a changing climate are presented in this *Plan.* For each of these recommendations, the *Plan* identifies specific actions that Federal agencies should consider to reduce climate risks to freshwater resources. A table summarizing recommendations and supporting actions is provided in Appendix C.

The October 2010 *Progress Report* of the Climate Change Adaptation Task Force also recommended the development of a national climate adaptation strategy focused on fish, wildlife and plants, and a national strategy to build the resilience of coastal, ocean, and Great Lakes ecosystems to climate change and ocean acidification. Each of these three "crosscutting strategies" share common elements and development of these plans is being closely coordinated.

I) Water Resources Management Challenges Posed by a Changing Climate

Water resources are managed by Federal, State, Tribal, and local governments with a wide range of objectives. Some of the key challenges that a changing climate poses for these efforts are described in this section.

A. Overview of Climate Change Impacts on Water Resources

To understand the challenges that water resources managers face in adapting to a changing climate, it is useful to understand some of the impacts that climate change may have on water resources. Some of the primary climate change risks for water resources are described below; more information is provided in Appendix D.

> "Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses."
>
> *Global Climate Change Impacts in the U.S., 2009*

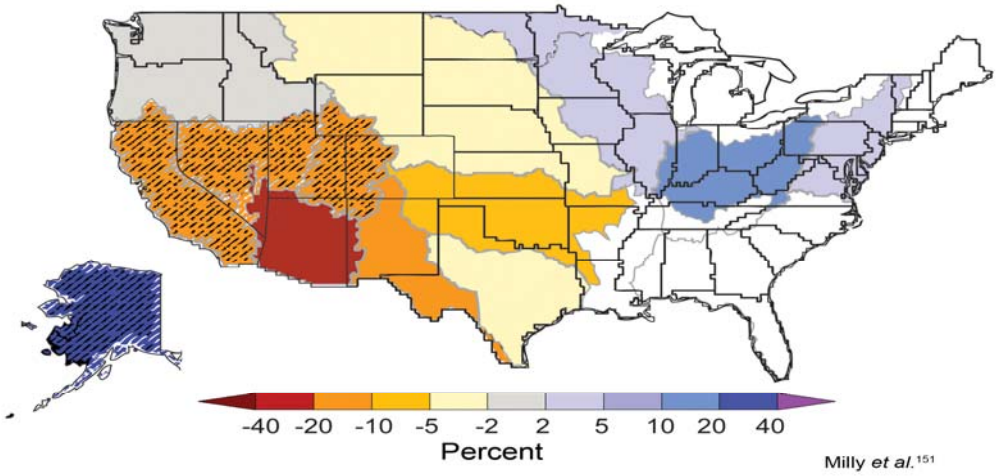
- **Air and Water Temperature Increases:** Warmer air and water temperatures will have significant impacts on water resources and aquatic habitats, including shifts in aquatic species distribution and population, increased concentrations of some pollutants, and increased eutrophication in some waterbodies. The U.S Global Change Research Program (USGCRP) concluded that "All climate models project that human-caused emissions of heat-trapping gases will cause further warming in the future…. global average temperature is projected to rise by 2 to 11.5°F by the end of this century (relative to the 1980-1999 time period) (Global Climate Change Impacts in the U.S., 2009 (GCCI), p. 24).

  More specifically, the USGCRP finds that "By the end of the century, the average U.S. temperature is projected to increase by approximately 7 to 11°F under the higher emissions scenario and by approximately 4 to 6.5°F under the lower emissions scenario" (ibid, p. 29). Climate models project regional variation of warming (e.g.; some models project that temperatures in parts of Alaska could increase by 10°C (18°F)). Water temperatures have been rising and increases have been observed in both saltwater and freshwater (ibid, p. 390; Kaushal, 2010, p. 5).

- **Changes in Amounts and Distribution of Rainfall and Snowfall:** As the climate warms, some areas will receive more precipitation while others will receive less, particularly in the U.S. West.

In addition, warmer temperatures will shift the form of precipitation from snow to rain and also result in earlier melting of snow packs. These changes are expected to lead to decreases in the size of snow packs and bring about earlier runoff in areas where seasonal cycles of runoff have historically been dominated by snow melt. These changes have already been documented in some areas of western North America (Knowles et al., 2006). This loss of snowpack storage is expected to result in a decrease in the amount of reliable water supply in areas where snow has been a major component of the hydrologic system.

Projected Changes in Annual Runoff: 2041-2060



Runoff, which accumulates as streamflow, is the amount of precipitation that is not evaporated, stored as snow pack or soil moisture, or filtered down to groundwater. Projected changes in median runoff for 2041-2060, relative to a 1901-1970 baseline, are mapped by water-resource region. Colors indicate percentage changes in runoff. Hatched areas indicate greater confidence due to strong agreement among model projections. White areas indicate divergence among model projections. Results are based on emissions in between the lower and higher emissions scenarios.[91]

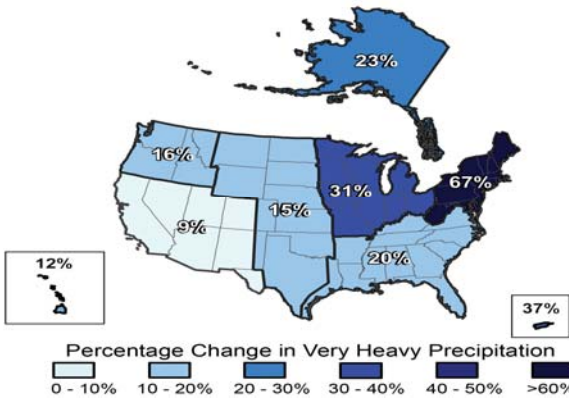
The USGCRP reported that "Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter and southern areas, particularly in the West, will become drier" (GCCI, 2009, p. 30).

USGCRP also indicated that "Over the last 50 years, there have been widespread temperature related reductions in snowpack in the West, with the largest reductions occurring in lower elevation mountains in the Northwest and California, where snowfall occurs at temperatures close to the freezing point. The Northeast has also experienced snowpack reductions during a similar period. Observations indicate a transition to more rain and less snow in both the West and Northeast in the last 50 years" (GCCI, 2009, p. 45). The IPCC also concluded that "Snow season length and snow depth are very likely to decrease in most of North America" (Christensen et al. 2007, p. 887).

- **Increased Intensity of Rainfall and Storms:** As the climate warms, the hydrologic system becomes more dynamic, rainfall occurs more often as a downpour, and the intensity of storms increases.

  The USGCRP reports that "The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places. (GCCI, 2009, p. 32) and that "Climate models project continued increases in the heaviest downpours during this century…. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase. The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now." (ibid).

Percentage Change in Very Heavy Precipitation



Percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1% of all daily events) from 1958 - 2007 for each region. (GCCI 2009)

The USGCRP also indicates that "As ocean temperatures continue to increase in the future, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming. Analyses of model simulations suggest that for each 1.8°F increase in tropical sea surface temperatures, core rainfall rates will increase by 6 to 18 percent and the surface wind speeds of the strongest hurricanes will increase by about 1 to 8 percent. Even without further coastal development, storm surge levels and hurricane damages are likely to increase because of increasing hurricane intensity coupled with sea-level rise, the latter being a virtually certain outcome of the warming global climate." (GCCI, 2009, p. 36).

- **Sea Level Rise:** Rising sea levels resulting from a warming climate are likely to cause a complex set of interrelated impacts on coastal freshwater aquifers and the threat of inundation to water-related infrastructure (e.g.; sewage treatment plants).

  The USGCRP indicates that "After at least 2,000 years of little change, sea level rose by roughly 8 inches over the past century. Satellite data available over the past 15 years show sea level rising at a rate roughly double the rate observed over the past century." (GCCI, 2009, p. 18). The report also states "…assuming historical

geological forces continue, a 2-foot rise in global sea level (which is within the range of recent estimates) by the end of this century would result in a relative sea-level rise of 2.3 feet at New York City, 2.9 feet at Hampton Roads, Virginia, 3.5 feet at Galveston, Texas, and 1 foot at Neah Bay in Washington state." (GCCI, 2009, p. 37).

Recent observations confirm that trend; a 2011 study shows that the melting of the Antarctic and Greenland ice sheets is accelerating (Rignot, et al. 2011, p. 4). The researchers found that if these accelerating rates continue, global sea level rise could be as much as 1 foot within the next 40 years (NASA, 2011).

Infrastructure at Risk from Sea Level Rise
(From *Global Climate Change Impacts in the United States Report 2009)*

- **Indirect Impacts:** It is likely that climate change mitigation actions will lead to adoption of low carbon fuel and energy technologies. Some of these technologies may have indirect impacts on water resources. For example, production of biofuels can result in increased competition for water supplies.

B. Climate Change Challenges for Water Resources Managers

The impacts of a changing climate are expected to pose significant challenges for water resources managers in three major areas:

- assuring adequate water supplies;
- protecting human life, health, and property; and
- protecting the quality of freshwater resources.

These challenges for water resources managers are interconnected in many ways and are not presented here in any particular order.

Some of the key elements of these major challenges are summarized below. More detailed information describing these risks and impacts, and explaining connections between these impacts and the scientific findings described above, is provided in Appendix E.

1) **Assuring Adequate Water Supplies:** Assuring adequate supplies of freshwater, including surface water and groundwater needed to support key sectors, including:

   - municipal drinking water supplies;
   - navigation, recreation, and tourism;
   - agriculture;
   - energy development, production, and generation;
   - industry; and
   - aquatic ecosystems and ecosystem services.

   The reliability of water supplies for these sectors is in question as a result of anticipated reductions in precipitation in some regions of the country as well as earlier runoff of snowmelt. Other examples of climate change related factors influencing reliability of water supplies include increases in forest fire damage to watersheds that are sources of supply, and impairment of freshwater supplies from saltwater intrusion resulting from sea level rise.

2) **Protecting Human Life, Health, and Property:** Protecting human life, health, and property at increased risk from the impacts of a warmer climate on freshwater resources, including risks associated with:

   - increased water-borne and vector-borne disease;
   - increased difficulty in treating drinking water depending on specific geographic needs;
   - increased flooding in some areas as the hydrologic system becomes more variable;
   - disruptions of power, water, sewer, and emergency services as a result of more extreme rainfall and storm events; and
   - increased drought and wildfires in some areas.

   > "Some of the most important societal and ecological impacts anticipated in this region [i.e. North America] stem from changes in surface and groundwater hydrology."
   >
   > *Climate Change and Water*; IPCC Technical Paper VI; 2008

   These increased risks to life, health, and property can be traced to changes in freshwater resource conditions that result from a changing climate, including a linkage between heavy precipitation and disease outbreaks, changes in rainfall levels and

watershed resilience that make floods more severe, and increases in extreme weather events that disrupt power, water and emergency services.

3) **Protecting the Quality of Freshwater Resources:** Protecting the quality of freshwater resources throughout the country, including:

- the quality of surface water;
- the quality of groundwater;
- the health of fisheries and aquatic habitat; and
- wetlands needed for sustainable aquatic ecosystems.

Examples of the connections between changing climatic conditions and the quality of freshwater include more challenging water treatment as a result of higher concentrations of contaminants in receiving waters and more variable streamflows, more difficult management of stormwater due to more intense rainfall patterns, and changes in aquatic systems characteristics allowing invasive species to become more widely established.

Photo courtesy of the National Oceanic and Atmospheric Administration

II) Current Federal Water Resources Agency Activities to Manage Climate Change Risks

The Water Resources and Climate Change Adaptation Workgroup reviewed the broad range of activities underway throughout the Federal government, within individual Agencies as well as in cooperative interagency projects (see Appendix F). While not exhaustive, this review illustrates the breadth and depth of ongoing activities to address climate change impacts on water resources.

Based on this review of agency activities, the Workgroup came to the following conclusions:

- **Agencies are taking significant steps to reduce climate risks to freshwater resources:** Federal agencies are making significant efforts to respond to the three major challenges that a changing climate poses for water resources identified in Section I.

- **Cooperative efforts for climate change adaptation of freshwater resources management are valuable:** Federal agencies have initiated interagency projects to address the impacts of a changing climate on water resources. These projects are making valuable contributions to understanding and responding to a changing climate. For example, the Department of the Interior (DOI) has begun to establish eight regional Climate Science Centers (CSCs) and is creating twenty-one Landscape Conservation Cooperatives (LCCs). In addition, Federal agencies have been working closely with the governments of Mexico and Canada through existing institutional arrangements to ensure that climate adaptation planning is included in management of shared waters.

- **Existing efforts to reduce climate risks to freshwater resources are not sufficient:** Despite significant work to date, (e.g.; DOI's LCCs and CSCs, National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Science Assessments (RISA), Army Corps of Engineers guidance on accounting for sea level rise, and EPA and Forest Service planning for climate change) agency adaptation actions now underway are not sufficient to address the extensive and complex challenges that water managers face from a changing climate.

- **A national forum to coordinate efforts to reduce climate change risks to freshwater resources is lacking:** Although cases of valuable interagency cooperative actions exist (e.g.; the Climate Change and Water Working Group (CCAWWG), the DOI/Department of Commerce (DOC) Memorandum of Understanding on climate change, and the Floodplain Management Task Force), there does not presently exist a national forum for fostering communication and

coordination for climate change and water resources adaptation-related work among the full range of relevant Federal agencies.

- **A strategic approach for Federal agency action to reduce risks to freshwater from climate change is needed:** Both the agency specific projects and the cooperative projects described in Appendix F were developed in the absence of an overall, interagency strategy for prioritizing the actions Federal agencies could undertake to address water resources and climate change challenges that are the most timely and effective. Some important emerging examples of efforts that can form the foundation for the development of an interagency approach include the Landscape Conservation Cooperatives and the Climate Change and Water Working Group.

- **Better coordination with State and local adaptation efforts is needed:** Initial efforts by Federal agencies to establish strong working relationships with States on common challenges, such as the Western States Federal Agency Support Team (WestFAST), show promise. In addition, the development by DOI of CSCs and LCCs is expected to strengthen intergovernmental coordination on a wide range of climate change adaptation challenges, including challenges to water resources management.

Photo courtesy of the National Oceanic and Atmospheric Administration

III) Public Comments at Listening Sessions

The Water Resources and Climate Change Adaptation Workgroup convened a series of six listening sessions with organizations knowledgeable about the impacts of a changing climate on freshwater resources. The listening sessions provided a forum for interested parties to voice their views on water resources and risks posed by climate change early in the Workgroup's process. Each session brought useful insights to the table and the broad themes that emerged are summarized below and described in greater detail in Appendix G. Note, however, that these themes and recommendations are those of the individual listening session participants and may not reflect the conclusions of the Workgroup.

Listening Sessions

The Workgroup conducted listening sessions with a range of stakeholders:

- energy and industrial organizations;
- State, Tribal, local governments;
- water utility organizations;
- environmental and coastal organizations;
- agriculture and transportation organizations; and
- public health organizations.

Listening session participants expressed concern about the impacts of climate change on:

- water supply and demand;
- the interplay between water and energy;
- water infrastructure, both as financial investments at risk as well as their role in protecting public health and safety;
- protection of water quality and natural ecosystems;
- coastal communities, coastal ecosystems, and ocean environments
- the livelihood and traditions of native peoples.

In its deliberations following the listening sessions, the Workgroup identified four general themes in participants' views on how to best address these concerns:

- facilitate long-range planning;
- assure adequate supplies for diverse water uses;
- integrate and update Federal water agency programs; and
- support local adaptation.

The Workgroup also heard from representatives of Tribal nations that indigenous people are subject to a range of challenges related to a changing climate. There are 565 federally recognized American Indian tribes and Alaska Native Villages and hundreds of other Native communities in the U.S. Many of these communities have observed climate-related changes that are already underway, including the melting of permafrost in Alaska, the shifting ranges of important species of plants and trees, changing migration patterns of elk and fish, and the drying of lakes and rivers. Listening session participants stressed that these effects are not

simply "changes" to be adapted to – they represent a fundamental crisis of survival for communities' livelihoods and cultures. Because federally recognized tribes and villages are sovereign governments with unique land and natural resources, adapting to climate change also poses challenges for the political, economic, and cultural resiliency of Tribal nations.

Photo courtesy of the U.S. Fish and Wildlife Service

IV) Reducing Climate Change Risks to Freshwater Resources

This *National Action Plan* establishes a goal for managing freshwater resources in a changing climate, identifies six key recommendations to achieve the goal, and describes twenty-four specific supporting actions that Federal agencies should take to implement the recommendations over the next several years.

Based on input from listening sessions and consideration of scientific and Federal program information, the Task Force is adopting the following goal for managing freshwater resources in a changing climate:

> ***Government agencies and citizens collaboratively manage freshwater resources in response to a changing climate in order to assure adequate water supplies, to protect human life, health and property, and to protect water quality and aquatic ecosystems.***

Specific recommendations supporting this goal are:

1. **Establish a Planning Process to Adapt Water Resources Management to a Changing Climate** (including continuing interagency coordination and expanding outreach to, and collaboration with, State, Tribal, and local governments and other stakeholders);
2. **Improve Water Resources and Climate Change Information for Decision-Making** (including observational data, predictive models, measures of progress, and regular updates of analysis);
3. **Strengthen Assessment of Vulnerability of Water Resources to Climate Change** (including effective communication of data and development of risk assessment tools at multiple scales);
4. **Expand Water Use Efficiency** (including opportunities to develop water efficient technologies and promote greater efficiency of water use and reuse)**;**
5. **Support Integrated Water Resources Management** (including methods to promote resilience of water resources as the climate and environment changes); and
6. **Support Training and Outreach to Build Response Capability** (including identification of practices to "mainstream" climate change adaptation into existing programs).

Specific supporting actions that Federal agencies should take to accomplish each recommendation are described below. For each supporting action, information concerning the lead Federal agency for that action, the implementation status of the action (i.e., ready for implementation now or requiring further development in the next several years), and a link to related goals and recommendations in the October *Progress Report* are provided in an adjoining text box. A table summarizing recommendations and supporting actions is provided in Appendix C. It is important to note that the proposal of an action in this report and the

association of an action with a "lead agency" do not commit an agency to provide or seek funding for the action or to make related policy or program changes.

Implementation actions related to some of the six key recommendations are already underway. For example, the October 2010 *Progress Report,* highlighted the need to address water resource data issues and support more efficient use of water. Federal agencies are now working on these efforts. In the area of water data and information, Federal agencies have developed a report to Congress identifying a range of needed actions as required by Section 9506 of the Omnibus Public Lands Act.

Finally, the Task Force recognizes that managing the risks to freshwater resources posed by a changing climate is a complex and multi-faceted undertaking for which many recommendations and actions might be appropriate. This *National Action Plan* presents the recommendations and actions that are judged to be both a high priority today and achievable in the context of existing and foreseeable agency capacity. As described below, this document is an initial step in planning for climate change risks to freshwater resources and is expected to be evaluated, revised, and expanded in the years ahead.

RECOMMENDATION #1: Establish a planning process to adapt water resources management to a changing climate.

A consistent theme at listening sessions and in discussions with Federal agency water resources program managers is the need for a clearly defined planning process and organizational framework for addressing water resources and climate change issues.

Some of the key attributes of an effective planning process and organizational framework identified in these discussions include:

- **Involve State, Tribal, and Local Governments:** An organizational framework for water resources adaptation to climate change needs to provide a material role for States, Tribes, and local governments and support collaboration with the governments of Canada and Mexico.

- **Prioritize the Major Challenges Climate Change Poses for Water Resources:** An organizational framework should support a planning process that is capable of setting priorities among the full range of Federal water resources challenges posed by climate change and should support agencies at different governmental levels in making informed choices about where to focus attention. Priority setting should also be linked to Federal budgets and funding decisions.

- **Consider Implications of Adapting to Impacts of Climate Change on Resources Other than Water:** Governments will increasingly be planning to manage the risks from the impacts of climate change on a range of resources other than water resources (e.g.; energy, human health, soil resources, agriculture, forestry, fisheries, ecosystem, non-water infrastructure). It is important that climate change adaptation be coordinated across these topics including plans to reduce greenhouse gas emissions. To date, emissions reduction (i.e.; mitigation) planning has largely overshadowed planning for managing the risks of a changing climate. Many of the practices that reduce greenhouse gases (e.g.; bioenergy, seeking access to natural gas reserves, sequestering carbon geologically or through land management or wetland protection practices) have potentially significant implications (both positive and negative) for water resources.

- **Consider Other Water Resources Challenges:** An organizational framework should account for the other significant challenges to sustainable water resources management that exist apart from climate change. Some of the major challenges include: depletion of aquifers in many regions of the nation and saltwater intrusion into aquifers in coastal areas; nutrient enrichment of rivers, lakes, reservoirs, and estuaries; aging infrastructure for storing and delivering water to users, for treating waste water, for navigation, and for flood protection; emerging contaminants in groundwater and surface water that threaten human health and aquatic species; and the need for water to support the protection and restoration of aquatic ecosystems.

- **Build on Existing Institutional Mechanisms:** Existing organizational structures for coordination among water resource management agencies, the research community, and with public organizations involved in water resource management can play an important role in adapting water resources management to a changing climate. In addition, existing institutional capability for addressing climate change adaptation issues at a regional level (i.e.; RISAs, CSCs and LCCs) should be actively engaged in addressing water resource issues. The research community needs clear guidance on the information that is needed by decision makers and planners to address adaptation challenges. Water resources managers need to have up-to-date and useable summaries and decision support tools to apply to their operational needs.

Supporting Actions

The following specific actions support this recommendation.

1. **Establish a planning process with the capability to identify priority adaptation actions and promote their implementation.** The development of this *Plan* is an important step in building the capability to manage freshwater resources in a changing climate. The *Plan*, however, will need to be revised over time as conditions change and as information on the effectiveness of the *Plan* becomes available. For this process to be successful, a timeline of key planning and evaluation actions is needed.

Lead Agency: Workgroup co-chairs (DOI/EPA/CEQ)

Implementation Status: Now, with phase in over coming years

Link to *Progress Report*: Goal 3; Develop water/climate action plan; page 36/37

A key mechanism for understanding changing impacts of climate on water resources over time is the assessment prepared by the U.S. Global Change Research Program. This comprehensive assessment of climate change impacts was last completed in 2009 and includes a section on water resources. Required by law every four years, the next assessment is planned for completion in 2013 (see box below).

Given the four year revision cycle for the national assessment, an appropriate time to revise the freshwater adaptation plan is two years after publication of the assessment (i.e.: 2011 and 2015). This schedule allows for development of plan revisions based on full consideration of the most recent assessments.

A related consideration is that the "crosscutting strategies" related to coasts, oceans and the Great Lakes and to fish, wildlife, and plants have elements in common with freshwater resources and these planning efforts need to be closely coordinated.

An important element of the water resources and climate change planning process is sustained evaluation of implementation actions and of the overall success of water resources and climate change adaptation efforts.

This process should include:

Water Resources and Climate Change Planning Timeline

2009 National Climate Assessment

2011 Freshwater Action Plan I and Coastal/Ocean Strategy

2012 Annual Freshwater Progress Report; Fish/Wildlife/Plants Strategy

2013 National Climate Assessment

2014 Independent Freshwater Evaluation

2015 Freshwater Action Plan II

- development of evaluation measures to track progress in improving adaptation of water resources to a changing climate, including both process measures of program performance (e.g.; timely development of plans or other actions) and outcome measures addressing overall success in supporting effective adaptation of water resources to climate change (e.g.; as reflected in a periodic survey of water resource managers to request a self-assessment of adaptation progress);
- publication of annual reports describing the progress being made toward overall goals in narrative terms and reporting on progress under each of the management measures; and

- an evaluation in the third year of each four-year planning cycle by an independent organization, such as the National Academy of Science or the National Academy of Public Administration, that provides an objective evaluation of the overall response of water resource managers to risks from a changing climate.

2. **Establish an organizational framework to promote effective management of water resources in a changing climate.** An effective organizational framework to promote water resources adaptation to climate change includes four elements:

Lead Agencies: Workgroup Chairs (EPA/DOI/CEQ)

Implementation Status: Now

Link to *Progress Report*: Goal 3; Develop water/climate action plan; page 35/36

- Federal agency coordination;
- linkage to science and research;
- engagement in different regions of the country with State, local and Tribal governments; and
- participation of stakeholders and the public.

The existing interagency Water Resources and Climate Change Adaptation Workgroup should be charged with continuing to support the national interagency Climate Change Adaptation Task Force in matters relating to freshwater resources. Section 16 of the Executive Order on Federal leadership on environmental, energy and economic performance (i.e.: EO 13514) directs Federal agencies to "participate actively" in the work of the Task Force. Key objectives of the Workgroup should be to:

- foster Federal agency coordination at the national level on program management issues related to domestic freshwater and climate change, including oversight and coordination of existing water and climate activities;
- facilitate good coordination among Federal water resource management agencies as they develop water related elements of Agency-specific climate change adaptation plans called for in the October *Progress Report*;
- manage development of plans and reports, including this *National Action Plan* for freshwater resources and the report to Congress on water data and information for climate change;
- cooperate with State, tribal, and local governments and organizations interested in water and climate change issues, including groups such as the Western Governors' Association and the Water Utility Climate Alliance, and other key organizations;
- coordinate with groups developing climate change action plans related to coastal, ocean, and the Great Lakes issues and to fish, wildlife and plant issues;
- oversee implementation of the recommendations and actions described in this *National Action Plan*; and

- work toward regional coordination of climate science and services being implemented in response to a recommendation for this effort in the October 2010 Progress Report of the Climate Change Adaptation Task Force.

To assure effective coordination on science and research issues related to water resources and climate change, the existing Subcommittee on Water Availability and Quality (SWAQ), a subcommittee of the Committee on Environmental and Natural Resources and Sustainability (CENRS), should be charged with defining climate change and water research needs and identifying scientific issues. The SWAQ has made important contributions to scientific understanding of water resource issues and disseminating water resources research across Federal agencies. Adding climate change issues to the SWAQ's water resources research coordination charge will help integrate climate change research needs into the larger water research agenda. The SWAQ and the Water Resources and Climate Change Adaptation Workgroup should actively cooperate and meet on a regular basis.

> "Climatologists…speak in a convincing manner about the changes that are taking place. On the other hand, hydrologists are skeptical that, after reviewing the data they have gathered, there is sufficient evidence of change in river flow characteristics. The gap between these two opinions does not seem to be narrowing."
>
> Gerald Galloway; University of Maryland; 2010

In addition, at present, there is no forum for climate modelers and managers of water data systems to resolve issues and differing interpretations in order to provide better clarity for end-users of information. Several Federal agencies presently fund the Water and Science Technology Board (WSTB) of the National Academies' National Research Council (NRC) to support a "standing committee" on issues related to hydrology. The US Global Change Research Program has also recently contracted with the NRC to provide a "one-stop shop" for guidance on global change research. This new institutional structure will ensure appropriate linkage across the various committees of the NRC, including the WSTB's committees. The Federal agencies should continue to work with the NRC to ensure that the WSTB committee on hydrology is coordinated with the global change committee and others, as appropriate. They should pay particular attention to facilitating communication among water observational data managers and climate model experts to help resolve methodological differences and better tailor observational data to calibrate and verify model results.

A third element of a water and climate change adaptation organizational structure is effective engagement with Federal, State and local governments at the regional level. Climate change impacts, especially water resources related impacts, vary across the country. Several Federal agencies have established regional entities addressing climate

change, including the Department of Interior Landscape Conservation Cooperatives and the National Oceanic and Atmospheric Administration Regional Integrated Science Assessments (RISAs). The Interagency Climate Change Task Force has also called for the creation of Regional consortia to address climate adaptation needs of each region. Federal agency water resources program managers should participate in these regional collaborations and reach out to stakeholders at the regional level. As these collaborations develop over the coming years, it may be appropriate to have regional representatives on the national Workgroup.

> Water managers should take the initiative to clearly communicate their needs for applied science to the climate research community, and must seek opportunities to guide hydroclimatic research in directions that will support real world problem-solving.
>
> Western Governors' Association; 2008

Finally, it is essential that stakeholder organizations and the public are able to provide input as adaptation actions for climate change and water resources are planned and implemented. The Advisory Committee on Water Information (ACWI) is an existing public advisory group chartered under the Federal Advisory Committee Act (FACA) to advise the Federal government on water issues. The Committee is managed by the Department of the Interior and advises a range of Federal agencies on water matters. ACWI includes a range of stakeholders with interests in water management, including States, Tribes, and other water related interest groups (see www.doi.acwi.gov). ACWI operates through an extensive subcommittee structure but does not currently have a subcommittee addressing issues relating to climate change. ACWI should consider options for how best to engage climate change and water issues, including establishing a new subgroup to help Federal agencies seek input and guidance from stakeholders and the public on climate and water issues or amending the charter and membership of an existing subgroup as needed to serve this purpose.

RECOMMENDATION # 2: Improve Water Resources and Climate Change Information for Decision-Making

Every day, all across the Nation, decisions are being made about water. These decisions involve:

- supplying water for public drinking water systems, irrigation, electricity generation and transportation fuels production, or industrial activities;
- collecting and treating drinking water, wastewater and stormwater; developing new or alternative sources of water;
- protecting or restoring water bodies, aquatic habitats, and aquifers; or

- protecting citizens and infrastructure from the consequences of impaired water quality, too much water (flooding), or too little water (droughts).

> "In a non-stationary world, continuity of observations is crucial."
>
> Milly, et al, 2008

These water resources decisions, and the data systems needed to support them, are summarized in the Table in Appendix H. Analytic approaches currently exist for every one of these types of decisions. However, most of the current decision-making approaches rely on historic data to estimate future variations in water availability and quality.

Many decisions are based on hydro-climatic characteristics such as the mean flow of a river, the 50-year 1-hour rainfall intensity, the 7 day-10 year low flow, the "100-year" flood, or the mean August water temperature. These are estimated based on conditions of the past, but form the basis for design, investment, and water allocation decisions that can have long-range (50-100 years) implications. Similarly, traditional methods for water system design and operation assume that what will happen hydrologically in the coming days, weeks, months, and years, can be estimated in a probabilistic sense from what we know of the current state of the watershed and records of past experience.

In response to the requirements of section 9506 of the Omnibus Public Lands Act, an interagency group worked over the past year to prepare a report on the technical challenges related to water data and information needed to support adaptation to climate change. Key next steps in the report have informed the supporting actions described below and include:

- strengthen observational data systems;
- prioritize observations for understanding water supply availability;
- step up the pace of systematic reanalysis of existing observational data to bring statistics used for design and planning purposes up to date with current conditions;
- strengthen links between water observational data and climate models;
- provide water datasets to an interagency climate data portal;
- make strengthening of water data a priority in the *National Action Plan* for freshwater resources; and
- strengthen Federal agency coordination to improve data quality and accessibility.

Supporting Actions

Key actions to support this recommendation include:

3. **Strengthen data for understanding climate change impacts on water.** The Federal government should implement a multi-agency effort, led by the Department of Interior, to build a national Water Census describing the changing availability, quality, location, and uses of water resources. This information will be organized on a watershed basis

and will be readily available to water managers and the public. The Water Census will contain:

Lead Agency: DOI

Implementation Status: Now

Link to *Progress Report*: Goal 3; Strengthen water/climate data; pages 35/36

- water use information (withdrawals, return flows, and consumptive use for all major water use sectors with special data collection efforts designed to track changing water use patterns relevant to public water systems, agriculture, energy, industry, ecosystem services, and nonpotable demands);
- water quantity and availability information including analysis of changes in storage (groundwater) and flow (rivers);
- analysis of changes in water quality that are critical to its use (temperature, sediment, nutrients, pathogens, salinity, waterborne contaminants) and;
- identification of alternative water sources that may become available through technology advances including reuse, green infrastructure, conservation, desalination, aquifer storage and recovery.

4. **Create a formal program to align "hydroclimatic" statistics with today's climate and anticipate future changes.** This work should include evaluation of data as needed to provide water resources managers and engineers engaged in infrastructure planning, management decisions, ecosystem protection, and flood hazard mitigation with the interpretative "hydrostatistics" that they need to make good decisions as hydrological conditions change over time. Hydroclimatic statistics related to floods (e.g.; 100 year flood), intense rainfall (e.g.; 50-year 6-hour rainfall), streamflows (e.g.; 7Q10), and water temperature (e.g.; mean August water temperature) are central to water infrastructure planning, ecosystem protection, and flood hazard mitigation.

Lead Agency: DOI

Implementation Status: Now

Link to *Progress Report*: Goal 3; Strengthen water/climate data; pages 35/36

This program should include:

- systematic nationwide updates of statistical analyses;
- research to evaluate changes in hydroclimatic conditions at several temporal and spatial scales;
- updating analytical approaches to incorporate climate change;
- assuring the continuity and

"There is no consistent formal procedure across agencies for certifying a new method or making a new product official."

Decision Support Experiments and Evaluations Using Seasonal-to-Interannual Forecasts and Observational Data: A Focus on Water Resources; U.S. Climate Change Science Program, Synthesis and Assessment Product 5.3; 2008

stability of the long-term data collection programs on which these statistics depend; and

- consideration of a process for endorsement or certification of updated methods and data.

5. **Implement an active, reliable surveillance system for tracking waterborne disease and public health threats relevant to climate change**. The surveillance system should provide for centralized coordination of public health information with water exposure pathways including surveillance of:

Lead Agency: CDC

Implementation Status: Further development

Link to *Progress Report*: Goal 3; Build public health surveillance systems; page 38

- endemic disease and outbreaks associated with exposure to waterborne pathogens; and
- diseases associated with waterborne contaminant exposures (chemicals and their byproducts, toxins released by algae and cyanobacteria, etc.).

Data on waterborne disease will provide a basis for developing national profiles of current and emerging diseases that are relevant to climate change, identifying climate-sensitive disease pathways, predicting factors that trigger public-health threats, and developing control and monitoring strategies that are protective of public health.

6. **Provide coastal states and communities with essential information to identify areas likely to be inundated by sea level rise.** Coastal communities need reliable maps of areas likely to be inundated by rising sea levels due to climate change in order to protect water-related infrastructure facilities (e.g.; sewage treatment plants, drinking water treatment facilities, and power plants) as well as other uses such as managing natural habitat and resources. Development of these maps will require that the Federal Government provide nationally consistent information concerning coastal topography (i.e. LIDAR data), coastal land subsidence, and expected storm surges. Federal Agencies need to develop a strategy for providing these maps and relevant guidance in specific areas on clear schedules.

Lead Agency: NOAA

Implementation Status: Further development

Link to *Progress Report:* Goal 3; Develop action plan for coastal and ocean adaptation to climate change; pages 42/43

This coordinated activity should:

- increase the availability of high resolution elevation data in coastal areas;
- provide regionally specific projections of relative sea level changes;

- provide tools for assessing storm surge risks in coordination with changing sea levels and storm frequencies and intensities; and
- assure that all maps and other geospatial information are provided in the consistent format of the National Geospatial Reference System.

7. **Establish an interagency effort to expedite implementation of the newly developed wetlands mapping standard.** Wetlands play a critical role in supporting resilience of watersheds and water resources to a changing climate. As temperatures warm, some wetlands will disappear and others may be created. Understanding the changes in location, size and functions of wetlands will require accurate maps. Federal Agencies are now implementing a newly developed wetland mapping standard, but this process is underfunded and will not be completed for many years at current funding levels. This recommendation calls for an interagency effort to complete this work across the country on a significantly expedited schedule.

Lead Agency: DOI

Implementation Status: Now

Link to *Progress Report*: Goal 3; Strengthen water/climate data; pages 35/36

RECOMMENDATION # 3: Strengthen Assessment of Vulnerability of Water Resources to Climate Change

Extreme weather events, sea level rise, shifting precipitation and runoff patterns, temperature changes, and resulting changes in water quality and availability all have potentially significant implications for the operations of water sector utilities. To adapt to climate change, water resource managers must first determine the degrees of risk and vulnerability in their systems. In order to maintain consistency with other approved Federal guidelines and documents, the team adopted the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability from its fourth assessment:

> *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, the sensitivity and adaptive capacity of that system*.

Risk can simply be defined as: *Exposure to the chance of injury or loss; a hazard or dangerous choice.* Risk assessment can be defined as:

> *Risk assessment characterizes the nature and magnitude of risks to a physical system from stressors that may be present in the environment. It represents the determination of quantitative or qualitative value of risk related to a concrete situation and a*

recognized threat (also called hazard). Risk managers use this information to help them decide how to protect a system from stressors.

Risk assessments can generally be conducted two different ways – utilizing a top-down approach or utilizing a bottom-up approach. A top-down risk assessment utilizes global circulation models and other globally and nationally derived data and scenarios and applies them to regions by downscaling. A bottom-up risk assessment utilizes regional and local knowledge, data, and information to determine the risk of an area to identified hazards.

Federal agencies have made substantial investments in the development of climate change assessment tools related to water resources. Some examples include:

- Environmental Protection Agency (EPA) work to modify existing risk assessment methodologies (e.g.; natural disaster and terrorism) for drinking water and wastewater utility owners and operators to consider climate change impacts, including the Climate Resilience Evaluation and Awareness Tool (CREAT) (see Appendix I);
- The July 30, 2010 Memorandum of Understanding between the Department of Commerce and the Department of Interior to establish a framework to enable better decisions and policies relating to understanding climate change, assessing vulnerability, and improving science, data, and technical assistance;
- National Oceanic and Atmospheric Administration's (NOAA) work to expand regional drought early warning information system pilot projects under the National Integrated Drought Information System (NIDIS);
- NOAA Vulnerability Assessment Techniques and Applications (VATA) for coastal communities and the joint training on vulnerability assessment of fish and wildlife and other natural resources for managers (see Appendix I); and
- US Army Corps of Engineers' (ACE) Dam Safety Action Classification tool (see Appendix I).

Supporting Actions

The following actions support this recommendation.

8. **Publish a long-term plan for Federal "downscaling" of modeled projections of changes in water resource conditions:** A barrier to expanded use of climate change vulnerability assessment tools is the limitations of modeled projections of long-term changes in water resource conditions expected as a result of warmer temperatures. Although these projections are available at

Lead Agency: NOAA

Implementation Status: Further development

Link to *Progress Report*: Goal 2; Build science translation capacity; page 32

large scales, there is a need to "downscale" the model outputs so that they are more relevant to the facilities for which assessments are being conducted. Federal agencies are in the process of developing "downscaled" modeled outputs but many decision-makers are not aware of these plans. Federal agencies should publish and make more widely available plans and schedules for improvements to models projecting changes in water conditions as a result of climate change and evaluate the performance of various downscaling approaches.

9. **Develop a Federal internet portal to provide current, relevant, and high quality information on water resources and climate change.** This portal will support water resource management decisions like climate vulnerability assessments. Currently, core water data and hydrostatistics are not readily available to water resource managers at a single site. The portal should also offer data applications and tools for assessing vulnerability of programs or facilities to climate change. Activities such as the National Integrated Drought Information System (NIDIS) have demonstrated the value of a single Federal government portal. A prototype portal should be developed for one group of decision-makers and expanded upon successful development and evaluation. This work should be coordinated with the National Climate Assessment, which is currently working on an interagency climate portal that could support this action. In addition, the portal should be linked to NOAA's climate portal and take advantage of the extensive efforts to gather non-federal sources of water data through the Hydrologic Information System (HIS) developed by the Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI).

   Lead Agency: NOAA

   Implementation Status: Further development

   Link to *Progress Report:* Goal 3; Develop online data and information; page 33

   Agencies should provide information to the portal using data standards and mechanisms that have been agreed upon nationally and internationally. An example is leveraging GEO standards for data interchange and interoperability. This includes archiving climate-related information in netCDF format and using OGC-compliant web services for delivery of the information.

10. **Develop a pilot climate change vulnerability index for a major category of water facilities and use pilot findings to support vulnerability assessments by other facility categories**. An index of vulnerability should be developed for a major category of water facilities (e.g.: sewage treatment facilities or water supply or flood control dams) to demonstrate an

    Lead Agency: NOAA/DOI

    Implementation Status: Further development

    Link to *Progress Report*: Goal 2; Build science translation capacity; page 32

approach to assessing the relative risk of climate change impacts to facilities. The results of an index assessment can be used to set priorities for implementation of climate adaptation responses. This pilot index for a single category of facility should serve as a proof of concept for developing vulnerability indices to support assessments by a range of other water facilities and sectors. This work should be conducted in coordination with complementary vulnerability assessment activities, such as those identified in the MOU between DOI and DOC/NOAA, and EPA's Climate Ready Water Utilities efforts to support the water sector.

Lead Agency: EPA

Implementation Status: Now

Link to *Progress Report*: Goal 2; Build science translation capacity; page 32

11. Continue development of tools and approaches that build capacity for water-related institutions to conduct vulnerability assessments and implement appropriate responses. EPA has successfully developed the Climate Ready Estuaries Program and is in the process of developing a Climate Ready Water Utilities program. Both programs provide climate assessment tools tailored to the needs of a particular water institution or program and have the potential to promote effective climate impact assessments and to establish public recognition of climate adaptation efforts. Similar approaches could be adapted by other Federal agencies and could be applied to irrigation districts, power plants, ports, and dams and reservoirs. Vulnerability assessments can also be used to identify those aquatic species and habitats most likely to be in need of conservation actions as a result of climate change.

12. Assess vulnerability of watersheds and aquatic systems in National Forests and Grasslands. The U.S. Department of Agriculture's (USDA) Forest Service is implementing assessments of the condition of forested watersheds in each of the agency regions. These condition assessments will be expanded into assessments of the vulnerability of watersheds and aquatic systems to climate and non-climate stresses in multiple future scenarios. The watershed vulnerability assessments will be integrated with assessments of the vulnerability of terrestrial resources, social, and economic attributes and used to guide adaptation strategies in forest planning.

Lead Agency: USDA Forest Service

Implementation Status: Now

Link to *Progress Report*: Goal 2; Build science translation capacity;

13. **Promote free and open access to authoritative climate change science and water resources data.** Data and information should be available freely and openly in formats that fit decision maker needs. Current law (15 U.S.C. §1534) mandates cost recovery for access to certain science data for most users outside of the Federal and state governments. To enhance the use of authoritative Federal climate science information and data for all decision makers, Congress should be encouraged to eliminate mandatory cost recovery for this information. This recommendation would likely require changing the fee access structure in current law.

Lead Agency: NOAA

Implementation Status: Further development

Link to *Progress Report*: Goal 2; Build science translation capacity; page 32

RECOMMENDATION # 4: Expand Water Use Efficiency

Water resources in the United States, already under stress because of growing population, contamination, demand to meet ecosystem needs, and drought, will be further challenged by climate change. Making more efficient use of water can extend the availability of current supplies, reduce competition among sectors, save energy, reduce the cost of water system operations through reduced water use, protect the environment, and prepare for increased climate driven variability in the hydrologic cycle.

Water use efficiency has several aspects which encompass:

- Efficiency – using as little water as needed to do the job;
- Conservation – using fewer drops
- Productivity – getting more output per drop, and
- Substitution – using alternative sources as a means to match the quality of water with the intended use.

There are currently a number of programs across the Federal agencies that have a focus on water use efficiency. The types of programs include research and development, regulatory/policy development, technical assistance/training, funding, voluntary/incentive programs, and public education/outreach. However, there are several significant Federal efforts underway – some of which are just beginning – that deserve special attention and continued support. These include the DOI WaterSMART initiative, the U.S. Geological Survey (USGS) Water Census, EPA's WaterSense program, the USDA Natural Resources Conservation Service's (NRCS) Agricultural Water Enhancement Program, DOE research development and demonstration (RD&D) on water efficient-clean energy practices, and a Federally-requested assessment by the National Academy of Sciences of water reuse as an alternative water supply.

There are also activities to advance water use efficiency being carried out by other entities, including states, local governments and affiliated agencies, green building programs, and non-governmental organizations.

The Workgroup considered the following barriers as it developed recommendations.

- **Information:** End users do not have sufficient information on their water use to compare their usage rates to those of others and to recognize the benefits of improved water use efficiency.
- **Pricing and incentives**: Because water is often undervalued and underpriced, there is little incentive to use water more efficiently.
- **Coordination**: Improved coordination on water use management issues across Federal agencies and within agencies is needed to improve efficiency gains.
- **Planning**: There is inadequate consideration of water use efficiency when making water supply management, land use, and energy development decisions.
- **Education**: There is a general lack of public awareness and education on the benefits of water and how to use it more efficiently.
- **Development and adoption of water efficient technology and practices:** There is inadequate effort to advance research, development, and adoption of cost-effective technology and approaches that could improve water use efficiency or facilitate use of alternative sources.

Although the Federal government has a direct role in making water management decisions where it controls water resources, its role is largely limited to serving as a source of information, providing guidance, conducting research and development, and supplying funding to incentivize actions. The recommendations that follow reflect that general role for the US government.

Supporting Actions

The following actions support this recommendation.

14. **Develop nationally consistent metrics for water use efficiency in key sectors and report water efficiency information in nationally consistent formats**. To be able to make sound decisions on improving efficiency, it is important to understand how water is used. The USGS has published national scale summaries of water use every five years since 1950 and the Energy Information Agency (EIA) collects data annually on water withdrawals, consumption, discharge, and water sources directly from power plants. The most recent USGS report indicates that thermoelectric

Lead Agency: EPA/USDA/DOE

Implementation Status: Now

Link to *Progress Report*: Goal 3; Improve water use efficiency to reduce climate change impacts; page 36

power, irrigation, and public supply were the largest water users by volume – making up 91% of the total water diverted for use in the country. Improvements in water use efficiency will require implementation of actions that reduce both water withdrawal and consumptive water use (water withdrawn from a source for any use and not returned).

A fundamental principle is: "You can't manage what you don't measure." Although publicly-supplied water is metered in more locations than is irrigation water, there are still significant improvements that can be made in all sectors to understand use. Further, nationally consistent metrics for key sectors expressing water withdrawal and use on a per capita, per acre, or per kilowatt basis should be developed. These metrics would provide decision makers and the public with information on relative water efficiency and the potential for efficiency improvements that would have cost savings and environmental benefits. It is important that this type of effort be undertaken in cooperation with States, producers, landowners, and others and based on voluntary incentives rather than mandatory reporting.

15. **Consider making water use efficiency an explicit consideration in the Principles and Standards for water resources projects and in the new NEPA guidance on climate change.** The Council on Environmental Quality is working with other Federal agencies to review and revise the 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. This effort is intended to ensure that Federal water resources planning will both improve the economic well-being of the Nation and protect and restore the environment. The proposed Principles and Requirements have been published for public review and comment and additional comments were received from the National Academy of Sciences in December 2010. A final, revised "Principles and Requirements" document is expected to be approved in mid-2011. As improvements are made to the Principles and Requirements, options for improving water use efficiency should be an explicit consideration.

Lead Agency: CEQ

Implementation Status: Now

Link to *Progress Report*: Goal 3; Improve water use efficiency to reduce climate change impacts; page 36

In a related effort, CEQ has proposed guidance for improved implementation of the National Environmental Policy Act (NEPA). On February 18, 2010, CEQ proposed guidance for consideration of the effects of climate change and greenhouse gas emissions. Although the draft guidance does not specifically address water projects, many major water resources projects, or projects that rely on water (e.g.; energy facilities) would be covered by the approaches described in the draft guidance. The draft guidance speaks to consideration of greenhouse gas impacts of projects, including analysis of alternatives to mitigate climate impacts. The draft guidance also describes how climate changes should be addressed in identification of "reasonably foreseeable

future conditions" and comparing the incremental effects of alternatives. Opportunities for agencies to recognize the potential for water use efficiency to result in energy conservation and greenhouse gas reductions should be considered as the draft guidance is finalized. The final guidance on considering Greenhouse Gas Emissions and Climate Change in the NEPA process is expected to be approved by the end of 2011.

16. **Enhance coordination among Federal water efficiency programs and improve program effectiveness, including creating a "toolbox" of key practices.** Several existing Federal programs now make important contributions to water use efficiency. These programs should be maintained and, where possible, expanded. However, because programs currently operate independently, they may be missing opportunities to share best practices and approaches, particularly in specific geographic areas that are under water stressed conditions. The DOI WaterSMART Clearinghouse is an example of a valuable mechanism that will facilitate information sharing for water conservation-related government grants, funding, and programs.

    Lead Agency: DOI/EPA/DOE

    Implementation Status: Now

    Link to *Progress Report*: Goal 3; Improve water use efficiency to reduce climate change impacts; page 36

    Additionally, agencies should enhance coordination and information exchange with Federal research, development, and demonstration (RD&D) planning efforts to highlight key technology and data gaps and identify priority RD&D needs. Agencies also should establish a formal coordination mechanism and a cross-agency "toolbox" that includes key practices, such as pricing signals. In addition, the Federal government should promote institutional commitment to water conservation and reuse by making annual awards for proven efforts and calling out innovative practices or approaches that have the potential to result in significant water conservation or reuse if adopted widely.

RECOMMENDATION #5: Support Integrated Water Resources Management

The Intergovernmental Panel on Climate Change (IPCC) states that integrated water resources management (IWRM) should be the "instrument to explore adaptation measures to climate change." According to the Global Water Partnership, IWRM "promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

Climate change will increase the stress on water resources and this will require more collaboration among federal agencies and Federal, State, Tribal and, local governments, stakeholders, and countries with which the US shares transboundary waters. Climate change is just one of the stressors affecting water resources. Changes in water demand and alterations in

the watershed are also key stressors. Managing the risks from a changing climate cannot occur in isolation from other major stressors and effective water resources management requires integration of response to all stressors and a commitment to adaptive management.

> "…there will have to be a paradigm shift" from the deterministic view embodied in the "Principles and Guidelines" (WRC; 1973, 1983), based on a view of relatively stationary climate, to a much more flexible set of multi-objective evaluation principles and procedures that more appropriately account for the full range of social, environmental, and regional economic dimensions of water infrastructure under a wide range of uncertain climate scenarios."
>
> Eugene Stakhiv; Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management Proceedings, 2010.

Planning is always conducted under conditions of uncertainty. Water agencies should seek solutions that encompass a range of potential future conditions. Adaptive management may be the most effective way of dealing with future climate impacts. Adaptive management requires sustained, coordinated monitoring and ongoing analysis of data in order to incorporate the most effective structural and operational adjustments in response to observed system changes. Adaptive management also requires institutions and funding to re-evaluate project and program performance and to revise decisions based on the most recent information.

Supporting Actions

Actions to support integrated water resources management are described below.

17. **Work with States and river basin commissions to provide the financial and technical assistance needed to establish or substantially strengthen up to three river basin commissions to incorporate IWRM into their planning and programs, paying particular attention to climate change adaptation issues.** The Water Resources Planning Act of 1965 authorizes river basin water commissions to provide for coordination of water resources management on a large watershed scale. The establishment of river basin management authorities or commissions is considered one of the essential components of a successful IWRM strategy.

    Lead Agency: ACE

    Implementation Status: Further development

    Link to *Progress Report*: Goal 5; Build strong partnerships with State and local government; page 50

    In their 2006 report on "Interstate Water Solutions for the New Millennium," the Interstate Council on Water Policy (ICWP) noted "a strong state/federal partnership is

necessary to enhance the efficiency and capacity of integrated water resource management efforts."

> "To foster IWRM, an appropriate role for the Federal government may be that of integrator. Many participants in this initiative extolled the supporting role of the interstate organizations as vanguards in furthering integrated approaches and outcomes. The fragmentation of governance mechanisms at all government levels hinders government ability to support state's water resources planning…".
>
> *National Report: Responding to National Water Resources Challenges*; US Army Corps of Engineers; 2010

As an initial first step in expanding or strengthening river basin commissions, Federal agencies should work with States and river basin commissions to provide the financial and technical assistance needed to establish or strengthen river basin commissions to conduct a range of water resources planning functions. Priority should be given to proposals to address climate change adaptation challenges such as coordinated management of water supply and energy production, planning for limited water availability, and coordination to protect the health of large aquatic ecosystems stressed by climate change, including downstream coastal areas.

18. **Revise Federal water project planning standards to address climate change.** Planning "principles" articulated in the draft revised "Principles and Requirements" document (described above) include new emphasis on addressing risk and uncertainty, including the effects of climate change on future development. The final, revised "Principles and Requirements" document is expected to be approved in mid-2011. Federal agencies should continue this effort and give priority to maintaining recognition of the importance of accounting for future climate change in Federal water resources planning and applying adaptive management principles to this work.

Lead Agency: CEQ

Implementation Status: Now

Link to *Progress Report*: Goal 3; Improve water resource management; page 36

19. **Working with States, review flood risk management and drought management planning to identify "best practices" to prepare for hydrologic extremes in a changing climate.** With the potential for more extreme hydrologic conditions as a result of climate change, effective planning for the management of flood and drought

Lead Agency: ACE

Implementation Status: Further development

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risk is a strategic national concern because of the potential for cascading economic and public safety impacts where adequate planning has not occurred.

Flood and drought management and preparedness are the leading edge of a practical adaptation strategy as part of IWRM. Flood and drought management have often been characterized by reactive response activities after a flood or while a drought is occurring. More efforts and resources should be directed at proactive preparedness to reduce vulnerability to floods and droughts. This work needs to recognize that the frequency and magnitude of future floods and droughts is likely to increase and that the historical record is no longer a reliable predictor of future conditions.

In addition, State, Tribal, and local governments play an important role in flood and drought preparedness and mitigation. Land use decisions, which are a determinant of vulnerability, are primarily a function of these governments. Federal programs need to be better integrated with State, Tribal, and local programs and Federal investment should shift from crisis response toward an integrated and proactive risk management strategy. In some States, "Silver Jacket" interagency teams provide well-trained and proactive Federal-state-local efforts at the state and local scale to coordinate a comprehensive flood risk management program.

As a first step in strengthening coordination among Federal, State, Tribal, and local agencies on drought and flood issues, Federal agencies should work closely with States to review flood and drought planning activities. Key goals of this effort should be to identify "best practices" that can be shared with others, including the degree of coordination between flood and drought management, cooperative efforts with Federal agencies (e.g.; Sliver Jackets), the extent to which new information concerning hydrologic variations is reflected in plans, and innovative or especially useful planning or coordination mechanisms.

20. Develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies. A planning strategy for climate change is to promote mid-course corrections in response to new information. As noted above, adaptive management is a key element of IWRM. According to the National Research Council, "Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood" (NRC, 2004). Federal agencies should develop benchmarks for incorporating adaptive management into their planning and operations and should allocate a portion of project funds for monitoring for adaptive management.

Lead Agency: ACE

Implementation Status: Now

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RECOMMENDATION #6: Support Training and Outreach to Build Response Capability

In communities across America, solutions to climate-driven water challenges will often come from local experts equipped with the right mix of local knowledge, technical expertise, resources and tools, and understanding of climate change impacts and adaptation measures. Today, the workforce that manages water resources programs at all levels of government and in the private sector is generally not well prepared to recognize the implications of a changing climate or to make complex risk management decisions.

Capacity building and education are inextricably connected. Human capacity in the context of climate adaptation – the ability to understand, adapt, and innovate in the face of a changing climate – will be built through educational and developmental activities at all levels, from traditional education to professional development, outreach, and informal learning.

The current water and science education paradigm does not prepare citizens (students, workforce, etc.) to understand, interpret, and address the water challenges posed by a changing climate. Until now, instruction has commonly been based on a model that assumes that information leads to knowledge and knowledge leads to engagement – including types of action that will be needed to adapt to a changing climate. Unfortunately, the vast majority of citizens, employees, and decision-makers have limited engagement in addressing water issues.

To help water managers and others understand and appreciate the value of water as a shared resource that is increasingly stressed in a changing climate, a new paradigm for climate-water education is needed that values cross-disciplinary education, instruction and training. Programs should focus on holistic solutions (i.e., cross-cutting solutions for agriculture, energy, environment, and communities) for water resource management in response to a changing climate. Education must come from a host of sources and through a variety of mechanisms including traditional, non-traditional, and informal learning. In addition, programs must be tailored to audience needs as reflected by age, geography, and varying cultural backgrounds.

Supporting Actions

The following specific actions are proposed to support this recommendation.

21. **Establish a core training program related to climate change science for local, Tribal, State, and Federal water resources managers.** Federal, State, Tribal, and local water resources managers need basic information and guidance on a range of issues associated with climate-related data, models, analytic approaches, and local and

Lead Agencies: USBR/ACE/ NOAA

Implementation Status: Now

Link to *Progress Report*: Goal 3; Build resilience to climate change in communities; page 39

regional interpretation of climate change impacts and adaptation options.

Federal agencies should collaborate to develop and provide a core, cross-disciplinary training program that would provide State, Tribal, and local managers (as well as other natural resource, land, and wildlife managers) with a solid foundation in climate change information and issues. Training should be conducted in different regions of the country and provide easy access to web-based curriculum, perhaps in cooperation with "continuing education" requirements of various professional groups, such as water and wastewater treatment operators).

22. **Focus existing youth outreach programs on climate change and water issues.** Federal agencies should make climate change and water resources a key element of existing youth outreach programs, like the USDA 4H program and Project WET (Water Education for Teachers), and expand Federal agency environmental education programs to target climate and water resources.

Lead Agency: USDA

Implementation Status: Now

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23. **Engage Water Resources Research Institutes at land grant colleges and tribal colleges in applied climate change adaptation research and capacity building through annual climate change grant awards.** Investing in the existing Water Resources Research Institutes has the double benefit of generating relevant research in states throughout the country and of engaging graduate students in issues related to climate change and water. Graduate students with research experience in these areas will then be available to move into Federal staff positions or positions with other water resource management agencies at the State, Tribal and local level. This work should be done in partnership with local institutions and utilities.

Lead Agency: DOI

Implementation Status: Further development

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24. **Increase Graduate Level Fellowships in Water Management and Climate Change** Support fellowships for graduate students with an interest in climate change and water research or management issues that include an avenue to Federal employment. Federal agencies could look to trained graduate students as a recruitment mechanism to meet long term staffing needs related to

Lead Agency: NOAA

Implementation Status: Further development

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water resources research and management. The existing John A. Knauss Fellowships in Marine Policy should be considered as a model.

Conclusion

A changing climate will have important consequences for the Nation's freshwater resources. Today, the community of water resource managers is increasingly informed about climate impacts and engaged in defining response actions. Federal agencies with water resources management responsibility have become increasingly engaged in understanding climate impacts and developing response actions. This *National Action Plan* is an initial effort to provide a common foundation of useful information and to describe priority response actions for Federal agencies. Information on climate impacts on freshwater resources will improve in the coming years. And, understanding of the contributions of various response actions described in this *Plan* will contribute to improved and more effective response actions. More important, however, for the long term success of this effort is for the broader community of water resources managers to continue to engage and address the challenges of a changing climate.

"Hoover Dam", Photo courtesy of Christian Mehlführer,
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APPENDIX A:
Water Resources and Climate Change Adaptation Workgroup Members

Matthew Larsen (co-chair)	U.S. Geological Survey
Mike Shapiro (co-chair)	Environmental Protection Agency
Jeff Peterson (co-chair)	Council on Environmental Quality
Rolf Olsen	Army Corps of Engineers
Janet Cushing	Army Corps of Engineers
Karl Wirkus	Bureau of Reclamation
Curt Brown	Bureau of Reclamation
Dave Raff	Bureau of Reclamation
Rob Blake	Centers for Disease Control and Prevention
Joan Brunkard	Centers for Disease Control and Prevention
Cathleen Kelly	Council on Environmental Quality
Judsen Bruzgul	Council on Environmental Quality
Christopher Carlson	Department of Agriculture – Forest Service
Noel Gollehon	Department of Agriculture
Allan Hoffman	Department of Energy
Craig Zamuda	Department of Energy
Maria Placht	Department of State
Matt Robinson	Department of State
Karen Metchis	Environmental Protection Agency
Bradley Doorn	National Aeronautics and Space Administration
Nancy Beller-Simms	National Oceanic and Atmospheric Administration
Michael Brewer	National Oceanic and Atmospheric Administration

Priority Action Topic Team Chairs

Water Data Team	Robert Hirsch: US Geological Survey
Vulnerability/Risk Team	Michael Brewer; National Oceanic and Atmospheric Administration
Water Efficiency	Veronica Blette; Environmental Protection Agency
Integrated Water Resources Management	Rolf Olsen, Army Corps of Engineers
Education and Outreach	Joan Brunkard; Centers for Disease Control and Prevention

APPENDIX B:
Text of Water Resources Section of the *Progress Report of the Interagency Climate Change Adaptation Task Force (pages 35-37)*

(Note: the Water Resource Workgroup referred to below is the same group as the Water Resources and Climate Change Adaptation Workgroup referred to in this *Plan*.)

Recommended Action: Improve water resource management in a changing climate
A changing climate is expected to have major consequences for the Nation's water resources. On average, water temperatures are predicted to increase. Rainfall amounts will decline in some areas and increase in other areas.[15,16] The proportion of precipitation that falls as snow will decrease; and rainfall and storm events will become more intense. In the case of coastal and ocean waters, the impacts of climate change include rising sea levels, more saline estuarine waters, and more acidic ocean waters.[17,18]

These impacts are already posing significant challenges for water resources management in several major areas: assuring adequate water supply (e.g.; for drinking water, agriculture, irrigation, energy, etc.); protecting human life, health, and property; and protecting the quality of freshwater resources.

The Task Force's Water Resource Workgroup has identified the following actions to improve water resource management in a changing climate:

Strengthen data and information systems for understanding climate change impacts on water.

DOI is leading an interagency effort to build a national system that will describe the changing availability, quality, location, and uses of water resources. This information system should be organized by watershed and made available to water managers and the public.
The effort should include evaluation of these water data as needed to provide water resource managers and engineers engaged in infrastructure planning, water management decisions, ecosystem protection, and flood hazard mitigation with the interpretative "hydrostatistics" that are needed to make good decisions as hydrological conditions change over time. Examples of these statistics include precipitation frequency estimates, probable maximum precipitation estimates, and streamflow estimates for multiple time scales.

Actions needed to strengthen data and information systems for water in response to a changing climate will be described in more detail in a Report to Congress in March 2011, as required under Section 9506 of the Omnibus Public Lands Act.

> *"We farm a ground that my grandfathers had farmed. This is not just a job or even a career – this is a legacy, a life.… And just one year could wipe all of that out. So we take these [climate change adaptation] policies and these issues very seriously."*
>
> – Wayne Hurst, Vice President, National Wheat Growers Association at the Denver public outreach meeting

Improve water-use efficiency to reduce climate change impacts.

Increasing water-use efficiency helps to extend the availability of current supplies, save energy, reduce the cost of water system operations, maintenance, and replacement, protect the environment, and prepare for increased climate-driven variability in the hydrologic cycle. Key steps to improve water-use efficiency may include:

- Establishing nationally consistent metrics of water-use efficiency for municipal water systems,energy producers, irrigation suppliers, and other users of water, and defining a mechanism to make these data transparent and readily available to decision makers and the public;
- Revising existing Federal guidelines related to environmental assessments required under both the National Environmental Policy Act and the "Principles and Standards" that guide Federal water resource projects to more clearly address opportunities for water-use efficiency and water reuse;
- Identifying and sharing examples of excellence in improving water-use efficiency, and developing and deploying innovative and cost-effective water-efficient technologies in key water use sectors (e.g.; drinking water, agriculture, irrigation, energy) and regions of the country as a means to facilitate wider adoption of practices.

Develop a national action plan to strengthen climate change adaptation for freshwater resources.

A national action plan should be developed to ensure an effective, well-coordinated, and sustained approach to adapting the Nation's freshwater resources to a changing climate. The existing Task Force Water Resources Workgroup should lead the development of this adaptation plan. The Workgroup should engage a diverse range of stakeholders in this effort through the existing DOI *Advisory Committee on Water Information* and work with regional coordination partnerships wherever available. The Workgroup should also coordinate with existing interagency organizations, such as the National Science and Technology Council's *Subcommittee on Water Availability and Quality* and the *Climate Change and Water Working Group*, on issues related to water science and research. In addition to developing the

action plan for freshwater resources, the Workgroup should oversee related activities including the development of the Report to Congress on water resources data and information needs related to climate change and expanded efforts to improve water use efficiency described above.

The freshwater action plan should be coordinated with the National Ocean Council's efforts for coastal and ocean water resources as described in the *Final Recommendations of the Interagency Ocean Policy Task Force*, where appropriate.

15 *Global Climate Change Impacts in the United States*, Karl, Thomas R., Melillo, Jerry M., Peterson, Thomas C., (2009).
16 *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Parry, M.L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., et. al.,
contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 2007 (2007).
17 *Global Climate Change Impacts in the United States*, Karl, Thomas R., Melillo, Jerry M., Peterson, Thomas C., (2009).
18 *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Parry, M.L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., et. al., contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 2007 (2007).

APPENDIX C:
Table of Recommendations and Supporting Actions

Recommendation, and Supporting Action	Lead Agency	Implementation (Now/Further Development)	Link to Task Force Progress Report
Recommendation 1: Establish a Planning Process			
Supporting Action 1: Establish a planning process with the capability to identify priority adaptation actions and promote their implementation	Water Workgroup Co-chairs	Now	Pages 36/37
Supporting Action 2: Establish an organizational framework to promote effective management of water resources in a changing climate	Water Workgroup Co-chairs	Now	Pages 35/36
Recommendation 2: Improve Water Resources and Climate Data for Decision-Making			
Supporting Action 3: Strengthen data for understanding climate change impacts on water	DOI	Now	Pages 35/36
Supporting Action 4: Create a program to align "hydroclimatic" statistics with today's climate and anticipate future changes	DOI	Now	Pages 35/36
Supporting Action 5: Implement surveillance system for tracking waterborne disease/health threats relevant to climate change	CDC	Further Development	Page 38
Supporting Action 6: Provide coastal states/communities with information to identify areas likely to be inundated by sea level rise	NOAA	Further Development	Pages 42/43

Supporting Action 7: Establish interagency effort to expedite implementation of the newly developed wetlands mapping standard	DOI	Now	Pages 35/36
Recommendation 3: Strengthen Assessment of Vulnerability			
Supporting Action 8: Publish long-term plan for Federal "downscaling" of modeled projections of changes in water resources	NOAA	Further Development	Page 32
Supporting Action 9: Develop a Federal internet portal to provide information on water resources and climate change	NOAA	Further Development	Page 33
Supporting Action 10: Develop a pilot climate change vulnerability index for a major category of water facilities	NOAA/DOI	Further Development	Page 32
Supporting Action 11: Continue development of tools and approaches that build capacity for water institutions to conduct vulnerability assessments and implement appropriate responses	EPA	Now	Page 32
Supporting Action 12: Assess vulnerability of watersheds and aquatic systems on National Forests and Grasslands	USDA/Forest Service	Now	Page 32
Supporting Action 13: Promote free and open access to authoritative climate change science and water resources data	NOAA	Further Development	Page 32
Recommendation 4: Improve Water Use Efficiency			
Supporting Action 14: Develop nationally consistent metrics for water use efficiency in key sectors	EPA/USDA/DOE	Now	Page 36
Supporting Action 15: Consider making water use efficiency an explicit consideration in the Principles and Standards for water resources projects and in the new NEPA guidance on climate change	CEQ	Now	Page 36

Supporting Action 16: Enhance coordination among current Federal water efficiency programs and create a "toolbox" of key practices	DOI/EPA/DOE	Now	Page 36
Recommendation 5: Support Integrated Water Resources Management			
Supporting Action 17: Work with States and river basin commissions to provide the financial and technical assistance needed to establish or substantially strengthen up to three river basin commissions to incorporate IWRM into their planning and programs, paying particular attention to climate change adaptation issues	ACE	Further Development	Page 50
Supporting Action 18: Revise Federal water project planning standards to address climate change	CEQ	Now	Page 36
Supporting Action 19: Working with States, review flood risk management and drought management planning to identify "best practices" to prepare for hydrologic extremes in a changing climate	ACE	Further Development	Page 50
Supporting Action 20: Develop benchmarks for incorporating adaptive management into water project designs, operational procedures, and planning strategies	ACE	Now	Page 35
Recommendation 6: Support Training and Outreach to Build Response Capability			
Supporting Action 21: Establish a core training program on climate change science for local, Tribal, and State water resources managers	USBR and NOAA	Now	Page 39
Supporting Action 22: Focus existing youth outreach programs on climate change and water issues	USDA	Now	Page 39

Supporting Action 23: Engage Water Resources Research Institutes at land grant colleges in climate change adaptation research	DOI	Further Development	Page 39
Supporting Action 24: Increase graduate level fellowships in water management and climate change	NOAA	Further Development	Page 39

APPENDIX D:
Supplemental Information:
Impacts of Climate Change on Water Resources

Supplemental information describing the expected impacts of climate change on freshwater resources is provided below. Much of this scientific information is drawn from the 2009 assessment of climate change impacts, titled *Global Climate Change Impacts in the U.S.,* published by the U.S. Global Change Research Program (USGCRP). The USGCRP has a mandate under the Global Change Research Act to prepare a report to the President and Congress every four years that evaluates, integrates, and interprets the findings of the global change research by the Federal government. Some additional information from other scientific studies is also provided.

In general, the USCRP concludes that:

- "Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses.
- Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between).
- Precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer.
- In areas where snowpack dominates, the timing of runoff will continue to shift to earlier in the spring and flows will be lower in late summer.
- Surface water quality and groundwater quantity will be affected by a changing climate.
- Climate change will place additional burdens on already stressed water systems.
- The past century is no longer a reasonable guide to the future for water management" (GCCI, 2009, p. 41).

A. Air and Water Temperature Increases

Air temperatures have warmed in recent years and warming trends are projected to continue globally and in North America. These warmer air temperatures will result in warmer waters and significant impacts on water resources.

Background

According to data from NOAA (2007) and NASA (2006), since the mid 1970s, the average surface temperature has warmed about 1°F (about 0.6°C). The Earth's surface is currently warming at a rate of about 0.32ºF (about 0.18°C) per decade or 3.2°F (about 1.8°C) per century. The five warmest years over the last century have been: 2005, 1998, 2002, 2003, and 2006 and the top 10 warmest years have occurred since 1990.

Looking ahead, the average surface temperature of the Earth is likely to increase by between 2 to 11.5°F (1.1 to 6.4°C) by the end of the 21st century, relative to 1980-1990, with a best estimate of 3.2 to 7.2°F (1.8 to 4.0°C) (EPA 2007c, IPCC 2007a).

More specifically, the USGCRP finds that "By the end of the century, the average U.S. temperature is projected to increase by approximately 7 to 11°F under the higher emissions scenario and by approximately 4 to 6.5°F under the lower emissions scenario" (Global Climate Change Impacts in the U.S., 2009, p. 29). Climate models project regional variation of warming (e.g.; some models project that temperatures in parts of Alaska could increase by 10°C (18°F)). Water temperatures have been rising and increases have been observed in both salt and freshwater (ibid, p. 390; Kaushal, 2010, p. 5).

Water temperatures have also been rising and increases have been observed in both salt and freshwater. The IPCC reported recently that "There is compelling evidence that the heat content of the World Ocean has increased since 1955. In the North Atlantic, the warming is penetrating deeper than in the Pacific, Indian and Southern Oceans…" (Bindoff et al. 2007, p. 420). Ocean surface temperatures are predicted to increase over the next hundred years (IPCC 2007a, p. 72).

In the case of freshwater, the USGCRP found "Increased air temperatures lead to higher water temperatures, which have already been detected in many streams, especially during low-flow periods. (GCCI, 2009, p. 46). Inland water temperature projections indicate that "simulated future surface and bottom water temperatures of lakes, reservoirs, rivers, and estuaries throughout North America consistently increase from 2 to 7°C [3.6 to 12.6°F] … with summer surface temperatures exceeding 30°C [86°F] in Midwestern and southern lakes and reservoirs" (Field et al. 2007, p. 629).

Impacts on Water Resources

The most significant impact of warmer air on water resources is warmer water. Some impacts of warmer water temperatures are:

- "In lakes and reservoirs, higher water temperatures lead to longer periods of summer stratification (when surface and bottom waters do not mix). Dissolved

oxygen is reduced in lakes, reservoirs, and rivers at higher temperatures" (GCCI, 2009, p. 46).

- a shift in aquatic species distribution and population (Field et al. 2007, p. 631);
- "higher stream temperatures affect fish access, survival and spawning (e.g. west coast salmon) (Field et al. 2007, p. 629);
- increased concentrations of some pollutants (e.g.; simulations in the Bay of Quinte in Lake Ontario indicated that 5.4 to 7.2° F (3 to 4°C) warmer water temperatures contribute 77 to 98 percent increases in summer phosphorus concentrations (ibid., p. 629);
- "[h]igher surface water temperatures will promote algal blooms and increase the bacteria and fungi content", which "… may lead to a bad odor and taste in chlorinated drinking water and the occurrence of toxins" (Kundzewicz et al. 2007, p. 188); and
- "Because warmer waters support more production of algae, many lakes may become more eutrophic due to increased temperature alone, even if nutrient supply from the watershed remains unchanged" (U.S. CCSP 2008, p. 142).

Other important impacts of warmer air temperatures on water resources include:

- "actual evaporation over open water is projected to increase, e.g. over much of the ocean and lakes, with the spatial variations tending to relate to spatial variations in surface warming" (IPCC 2008, p. 29); and
- warmer air leads to diminishing snow pack and increasing evaporation, which affects the seasonal availability of water (Field et al. 2007, p. 619).

Some aquatic organisms are particularly sensitive to temperature. For example, the breeding cycle of many amphibians is closely related to temperature and moisture, and reproductive failure can occur when breeding phenology—periodic biological phenomena correlated with climate—and pond-drying conditions are misaligned (Field et al. 2007, p. 630).

Additionally, "[c]old-water fisheries will likely be negatively affected by climate change; warm-water fisheries will generally gain; and the results for cool-water fisheries will be mixed, with gains in the northern and losses in the southern portions of ranges" (Field et al. 2007, p. 631). Although temperature increases may favor warm-water fishes, such as smallmouth bass, "changes in water supply and flow regimes seem likely to have negative effects" on these fishes (ibid., p. 632).

The USGCRP concluded that "Studies suggest that about one-third of the current habitat for the Northwest's salmon and other coldwater fish will no longer be suitable for them by the end of this century as key temperature thresholds are exceeded. Because climate change impacts on their habitat are projected to be negative, climate change is expected to hamper efforts to restore depleted salmon populations." (GCCI, 2009, p. 137)

B. Rainfall/Snowfall Levels and Distribution

As the climate warms, some areas will receive more precipitation while others receive less, particularly in the West. In addition, warmer temperatures will shift the form of precipitation from snow to rain and also result in earlier melting of snow pack. These changes are expected to result in decreases in the size of snow packs and bring about earlier runoff in areas where runoff has historically been dominated by snow melt. This loss of snowpack storage is expected to result in a decrease in size of reliable water supply in areas where snow has been a major component of the hydrologic system.

Background

According to the IPCC, an increase in the average global temperature is very likely to lead to changes in precipitation and atmospheric moisture because of changes in atmospheric circulation and increases in evaporation and water vapor (EPA 2007e). The effects of increases in temperature "alter the hydrological cycle, especially characteristics of precipitation (amount, frequency, intensity, duration, type) and extremes" (Trenberth et al. 2007, p. 254).

The IPCC has concluded that: "Increases in the amount of precipitation are very likely in the high latitudes, while decreases are likely in most subtropical land regions…continuing observed patterns in recent trends" (IPCC 2007a, p. 16). These precipitation trends are expected to continue. The IPCC reported that "Annual mean precipitation is very likely to increase in Canada and the northeast USA, and likely to decrease in the southwest USA" (Christensen et al. 2007, p. 887).

The USGCRP reported that "Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier (GCCI, 2009, p. 30). The USGCRP also found that "During the last century, consistent increases in precipitation have been found in the Midwest and Northeast along with increased runoff. Climate models consistently project that the East will experience increased runoff, while there will be substantial declines in the interior West, especially the Southwest. Projections for runoff in California and other parts of the West also show reductions, although less than in the interior West. In short, wet areas are projected to get wetter and dry areas drier" (GCCI, 2009, p. 45).

Increases in temperature can affect the amount and duration of snow cover which, in turn, can affect timing of streamflow and impact groundwater recharge. Glaciers are expected to continue retreating, and many small glaciers may disappear entirely (EPA 2007i).

The IPCC Technical Paper on *Climate Change and Water* indicates that "...warming would lead to changes in the seasonality of river flows where much winter precipitation currently falls as snow, with spring flows decreasing because of the reduced or earlier

snowmelt, and winter flows increasing. This has been found in … western, central and eastern North America" (IPCC 2008, p. 30). It further states that "[p]rojected warming in the western mountains by the mid-21st century is very likely to cause large decreases in snowpack, earlier snowmelt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows" (ibid., p. 130). The IPCC also concluded that "Snow season length and snow depth are very likely to decrease in most of North America…" (Christensen et al. 2007, p. 887).

Finally, USGCRP concluded "Observations indicate a transition to more rain and less snow in both the West and Northeast in the last 50 years. Runoff in snowmelt-dominated areas is occurring up to 20 days earlier in the West, and up to 14 days earlier in the Northeast. Future projections for most snowmelt-dominated basins in the West consistently indicate earlier spring runoff, in some cases up to 60 days earlier. For the Northeast, projections indicate spring runoff will advance by up to 14 days" (GCCI, 2009, p. 46).

Impacts on Water Resources

Changing precipitation patterns are expected to have numerous impacts on water resources including water supply, water quality, and the health of aquatic systems.

In general, in areas where precipitation increases sufficiently, net water supplies may increase while in other areas where precipitation decreases, net water supplies may decrease (EPA 2007i). In some areas, decreases in precipitation will reduce water supply at the same time that warmer temperatures are resulting in decreased snowpack and reduced runoff from snowpacks in summer months.

USGCRP found that "Water-quality changes during the last century were probably due to causes other than climate change, primarily changes in pollutants" (GCCI, 2009, p. 46). However, "The negative effects of water pollution, including sediments, nitrogen from agriculture, disease pathogens, pesticides, herbicides, salt, and thermal pollution, will be amplified by observed and projected increases in precipitation intensity and longer periods when streamflows are low.…Heavy downpours lead to increased sediment in runoff and outbreaks of waterborne diseases. Increases in pollution carried to lakes, estuaries, and the coastal ocean, especially when coupled with increased temperature, can result in blooms of harmful algae and bacteria. However, pollution has the potential of being diluted in regions that experience increased streamflow" (GCCI, 2009, p. 46).

Other reported impacts of changing precipitation patterns include:

- "…water-borne diseases and degraded water quality are very likely to increase with more heavy precipitation" (IPCC 2008, p. 103);
- potential increases in heavy precipitation, with expanding impervious surfaces, could increase urban flood risks and create additional design challenges and costs for stormwater management" (Field et al. 2007, p. 633);

- flooding can affect water quality, as large volumes of water can transport contaminants into waterbodies and also overload storm and wastewater systems (EPA 2007h).
- "… increased occurrence of low flows will lead to decreased contaminant dilution capacity, and thus higher pollutant concentrations, including pathogens. In areas with overall decreased runoff (e.g.; in many semi-arid areas), water quality deterioration will be even worse" (IPCC 2008, p. 43).
- "a wide range of species and biomes could be affected by the projected changes in rainfall, soil moisture, surface water levels, and stream flow in North America during the coming decades. The lowering of lake and pond water levels, for example, can lead to reproductive failure in amphibians and fish" (ibid., p. 104);
- "some of the greatest potential impacts of climate change on estuaries may result from changes in physical mixing characteristics caused by changes in freshwater runoff....Changes in river discharges into shallow near-shore marine environments will lead to changes in turbidity, salinity, stratification, and nutrient availability" (ibid., p. 58);
- "greater rainfall variability is likely to compromise wetlands through shifts in the timing, duration and depth of water levels" (ibid., p. 128).

It is important to note that there are benefits to increased precipitation (e.g.; increased drinking water supply) and of decreased precipitation (e.g.; reduced frequency of flooding).

C. Rainfall and Storm Intensity

As the climate warms, the hydrologic system becomes more dynamic. Rainfall occurs more often as a downpour and the intensity of storms increases. A more dynamic hydrologic system will have significant consequences for water resources.

Background

The IPCC reports that "the frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor" (IPCC 2007a, p. 8).

The USGCRP reports that in the U.S. "The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places" (GCCI, 2009, p. 32). "Climate models project continued increases in the heaviest downpours during this century…. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase. The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now" (ibid).

The USGCRP indicates that "As ocean temperatures continue to increase in the future, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming. Analyses of model simulations suggest that for each 1.8°F increase in tropical sea surface temperatures, core rainfall rates will increase by 6 to 18 percent and the surface wind speeds of the strongest hurricanes will increase by about 1 to 8 percent. Even without further coastal development, storm surge levels and hurricane damages are likely to increase because of increasing hurricane intensity coupled with sea-level rise, the latter being a virtually certain outcome of the warming global climate." (GCCI, 2009, p. 36).

The USGCRP also found that "The destructive energy of Atlantic hurricanes has increased in recent decades. The intensity of these storms is likely to increase in this century. In the eastern Pacific, the strongest hurricanes have become stronger since the 1980s, even while the total number of storms has decreased. …Cold-season storm tracks are shifting northward and the strongest storms are likely to become stronger and more frequent" (GCCI, 2009, p. 27).

The IPCC indicates that "it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures" (IPCC 2007a, p. 15).

Impacts on Water Resources

The primary impact of increasing storm intensity on water resources is coastal and inland flooding, complicated in the case of coastal storms by storm surges, and degradation of water quality as a result of both flooding and overloading of water treatment infrastructure. Some specific impacts of increased rainfall and storm intensity are:

- "Observed and projected increases in a variety of extreme events will have significant impacts… More intense rainstorms, which have been observed and projected, can lead to rivers flooding… (GCCI, 2009, p. 58);
- "water infrastructure malfunctioning during floods" (Kundzewicz et al. 2007, p. 189);
- "Drainage systems will be overloaded more frequently and severely, causing backups and street flooding. Areas where flooding is already common will face more frequent and severe problems" (GCCI, 2009, p. 64);
- water quality changes may be observed in the future as a result of "overloading the capacity of water and wastewater treatment plants during extreme rainfall" (ibid., p. 189);
- adverse effects in surface and groundwater quality and contamination of water supply (IPCC 2007b, p. 18);
- "water-borne diseases will rise with increases in extreme rainfall" (Kundzewicz et al. 2007, p. 189); and

- "all studies on soil erosion have suggested that increased rainfall amounts and intensities will lead to greater rates of erosion unless protection measures are taken" (ibid., p. 189);
- "More intense storms, especially when coupled with sea-level rise, will result in far-reaching and damaging storm surges (GCCI, 2009, p. 63);
- "Facilities on land at ports and harbors will be vulnerable to short term flooding from heavy downpours, interrupting shipping service. Changes in silt and debris buildup resulting from extreme precipitation events will affect channel depth, increasing dredging costs. The need to expand stormwater treatment facilities, which can be a significant expense for container and other terminals with large impermeable surfaces, will increase" (GCCI, 2009, p. 65).

D. Sea Level Rise

Rising sea levels resulting from a warming climate have the potential to cause a complex set of interrelated impacts on the health of coastal aquatic ecosystems as well as to pose a major threat of inundation to coastal infrastructure, including water infrastructure facilities, such as sewage treatment plants, and drinking water systems relying on groundwater supplies affected by salt water intrusion. It is important to note that impacts of inundation can be the result of the combined effect of sea level rise and storm surges associated with more intense storms.

Background

The USGCRP indicates that "After at least 2,000 years of little change, sea level rose by roughly 8 inches over the past century. Satellite data available over the past 15 years show sea level rising at a rate roughly double the rate observed over the past century" (GCCI, 2008, p. 18).

IPCC forecasts global average sea level rise of between 8 inches and 2 feet (0.18 and 0.59 m) by the end of the 21st century (2090 to 2099) relative to the years 1980 to 1999 under a range of scenarios (IPCC 2007a, p. 13). In five of the six modeling scenarios, "… the average rate of sea level rise during the 21st century is very likely to exceed the 1961–2003 average rate (.7 ± .2 inches, or 1.8 ± 0.5 mm/yr)" (IPCC 2008, p. 28; IPCC 2007a, p. 13).

These estimates assume that ice flow from Greenland and Antarctica will continue at the same rates as observed from 1993 to 2003. The IPCC cautioned that these rates could increase or decrease in the future. For example, if ice flow were to increase linearly, in step with global average temperature, the upper range of projected sea level rise by the year 2100 would be 19.2 to 31.6 inches (48 to 79 cm or 0.48 to 0.79 m). However, current understanding of ice sheet dynamics is too limited to estimate such changes or to provide an upper limit to the amount by which sea level is likely to rise over this century (IPCC 2007a, p. 13-14; EPA 2007g).

The USGCRP observed that "… the IPCC could not quantify the contributions to sea-level rise due to changes in ice sheet dynamics….More recent research has attempted to quantify the potential contribution to sea-level rise from the accelerated flow of ice sheets to the sea or to estimate future sea level based on its observed relationship to temperature. The resulting estimates exceed those of the IPCC, and the average estimates under higher emissions scenarios are for sea-level rise between 3 and 4 feet by the end of this century. An important question that is often asked is, what is the upper bound of sea-level rise expected over this century? Few analyses have focused on this question. There is some evidence to suggest that it would be virtually impossible to have a rise of sea level higher than about 6.5 feet by the end of this century "(GCCI, 2009, p. 25).

Recent observations confirm this trend; a 2011 study shows that the melting of the Antarctic and Greenland ice sheets is accelerating (Rignot, et al. 2011, p. 4). The researchers found that if these accelerating rates continue, global sea level rise could be as much as 1 foot within the next 40 years (NASA, 2011).

Current model projections indicate substantial variability in future sea level rise between different locations. Some locations could experience sea level rise higher than the global average projections, while others could have a fall in sea level (EPA 2007g). In the United States, sea level has been rising 0.08 to 0.12 inches (2.0 to 3.0 mm) per year along most of the U.S. Atlantic and Gulf coasts (EPA 2007f). The rate of sea level rise varies from about 0.36 inches per year (10 mm per year) along the Louisiana Coast (due to land sinking), to a drop of a few inches per decade in parts of Alaska (because land is rising) (ibid.).

The USGCRP indicates that "…assuming historical geological forces continue, a 2-foot rise in global sea level (which is within the range of recent estimates) by the end of this century would result in a relative sea-level rise of 2.3 feet at New York City, 2.9 feet at Hampton Roads, Virginia, 3.5 feet at Galveston, Texas, and 1 foot at Neah Bay in Washington state." (GCCI, 2009, p. 37).

Impacts on Water Resources

The primary impact of sea level rise on water resources is the gradual inundation of natural systems and human infrastructure in coastal and estuarine areas. Inundation impacts include:

- wetland displacement and loss (Burkett et al. 2001, p. 348);
- accelerated coastal erosion (ibid., p. 345);
- water quality modifications as a result of stormwater drainage operation and sewage disposal disturbances in coastal areas (Kundzewicz et al. 2007, p. 189); and
- increases in the vulnerability of coastal areas to flooding during storms (EPA 2007l);

- "Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding, especially along the Atlantic and Gulf Coasts, Pacific Islands, and parts of Alaska. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected" (GCCI, 2009, p. 12); and
- "In some areas, waterway systems will become part of open water as barrier islands disappear" (GCCI, 2009, p. 63).

Water resources impacts of sea level rise other than inundation include:

- "sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination" (GCCI, 2009, p. 47);
- as sea level rise causes salt fronts to migrate upstream in coastal rivers, water intakes may draw in salty water during dry periods (EPA 2007l); and
- salinity increases in estuaries can harm aquatic plants and animals that do not tolerate high salinity (EPA 2007l).

E. Indirect Impacts

Likely responses to climate change include development of alternative methods of energy production that reduce emissions of greenhouse gases, such as the production of "biofuels," expanded use of renewables, and low or zero carbon emitting energy technologies. Responses may also include investment in sequestration of carbon produced by conventional energy generation in geologic formations and through forestry and agricultural practices or wetland protection and restoration. All of these activities have implications for water resources.

Background

"Biomass energy is primarily used for industrial process heating, with substantially increasing use for transportation fuels and additional use for electricity generation" (U.S. CCSP 2007, p. 64). "Liquid fuel production from biomass is highly visible as a key renewable alternative to imported oil. Current U.S. production is based largely on corn for ethanol and, to a lesser extent, soybeans for biodiesel" (ibid., p. 69). Next generation biofuels will rely on cellulosic feedstocks and production of oil substitutes by algae.

"Carbon capture and storage in underground geological formations is a new technology with the potential to make an important contribution to mitigation by 2030. Technical, economic, and regulatory developments will affect the actual contribution" (IPCC 2007c, p. 13). Other types of carbon sequestration include injection of carbon into deep seabed regions of the ocean, as well as storage in biological forms (e.g.; forests and agricultural practices).

"Implementing important mitigation options such as afforestation, deployment of a broad range of renewable electric technologies (photovoltaics, concentrating solar power,

wind, biomass power and fuels, geothermal, ocean, hydropower) may have positive and negative impacts on freshwater resources, depending on site-specific situations. Therefore, site-specific joint evaluation and optimization of (the effectiveness of) mitigation measures and water-related impacts are needed" (IPCC 2008, p. 130).

Impacts on Water Resources

Some examples of the implications of these energy production and carbon management practices for water resources are described below.

- "There is a high likelihood that water shortages and warmer water temperatures will limit power plant electricity production in many regions. Future water constraints on electricity production in thermal power plants are projected for Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington state by 2025. (GCCI, 2009, p. 56).
- "Sustainable biomass production and use imply the resolution of issues relating to competition for land and food, water resources, biodiversity, and socio-economic impact" (Barker et al. 2007, p. 621).
- "[L]arge-scale biofuel production raises questions on several issues including fertilizer and pesticide requirements, nutrient cycling, water use for irrigation of the feedstock, energy balance, biodiversity impacts, hydrology and erosion, conflicts with food production, and the level of financial subsidies required" (IPCC 2008, p. 66).
- "Groundwater can be affected both by CO_2 leaking directly into an aquifer and by brines that enter the aquifer as a result of being displaced by CO_2 during the injection process" (IPCC 2005, p. 31). Geologic carbon sequestration could result in increases from 50% to as much as 90% in the amount of water used per KWH of energy produced as compared to today's conventional coal-fired power plants.
- "Stopping or slowing deforestation and forest degradation (loss of carbon density) and sustainable forest management may significantly contribute to avoided emissions, conserve water resources and prevent flooding, reduce run-off, control erosion, reduce river siltation, and protect fisheries and investments in hydroelectric power facilities; and at the same time, preserve biodiversity" (Nabuurs et al. 2007, p. 574).
- Coastal wetlands and mangroves have a major capacity for carbon sequestration and storage. Current studies suggest they store 2-4 times more carbon than tropical forests by area. When they are damaged or destroyed, carbon is released over time, and when they are restored, they offer not only carbon uptake but also water quality and ecological benefits. (Murray et al. 2010, p. 3).

APPENDIX E:
Supplemental Information:
Challenges a Changing Climate Poses for Water Resources Managers

Members of the Water Resources and Climate Change Adaptation Workgroup considered the scientific information concerning the consequences of a changing climate for freshwater resources described in Appendix D as well as input from listening sessions. Drawing on this information, the Workgroup members used their best professional judgment to identify the most significant impacts and risks of a changing climate for water managers. This listing of impacts and risks is intended to provide examples of impacts that Workgroup members recognize as possible and that were considered in the process of identifying recommendations and supporting actions. This information does not represent an exhaustive list of water resources impacts and risks related to climate change. The Workgroup members identified impacts of a changing climate for water resources in three major areas:

- assuring adequate water supply;
- protecting human life, health, and property; and
- protecting quality of freshwater resources.

1) Assuring Adequate Water Supplies

Climate change is expected to reduce supplies of surface water and groundwater in parts of the country, especially the Southwest. The causes of reduced water availability include reduced precipitation and warmer water and air temperatures that increase rates of evaporation and reduce the winter snowpack while moving spring runoff periods forward in the year and reducing stream flows later in the year. Reduced water availability poses challenges for water resource managers in several key areas:

- municipal drinking water supplies;
- agriculture;
- energy development, production, and generation;
- navigation, recreation, and tourism; and
- meeting the needs of aquatic ecosystems.

Although reduced water availability makes water management in each of these sectors more challenging, it is important to note that the cumulative effect of reduced water supplies will heighten competition among sectors and make water allocation decisions more contentious.

It is important to note that some areas of the country, such as the upper Midwest and northeastern states, are expected to experience increased precipitation. This increased rainfall can lead to challenges such flooding (see challenge #2 below). Some areas of the Midwest, however, may experience limited water supplies as a result of increased evaporation from the Great Lakes and declines in water levels.

Municipal Drinking Water Supplies

Municipal water utilities need to assure that they have adequate supplies of water to meet current and projected future needs. To assure adequate supply, utilities need to develop the capacity to make long-range plans that implement a mix of adaptive strategies including:

- develop useful information about localized changes in rainfall and snowmelt over both short and long time scales;
- design and install systems to retain water within utility management areas (e.g.; expanded wetlands, artificial recharge of ground water, reservoir construction, capture of rain water from roofs and paved surfaces and storage for later use);
- reduce water use by utility customers through water conservation programs employing strategies based on education, price incentives, and regulation;
- invest in infrastructure to diversify the sources of water available to water providers (interconnection of watersheds, conjunctive use of surface and ground water), enter into agreements to share resources among utilities, increasing the resilience of all water supplies;
- allow market mechanisms (such as water rights transfers and water banking) to encourage movement of water supplies from lower valued uses to higher valued uses with proper consideration of protecting environmental values;
- encourage the work of river basin commissions and similar organizations to create agreements that will provide for effective management of scarce water resources during times of drought, thereby protecting water uses that are crucial to local economies, public health, and ecological integrity; and
- encourage water conservation through the development of conservation strategies and the development and adoption of technologies to assist in lowering water use across all uses.

In addition to limited water supplies, municipal water utilities face a range of other challenges resulting from climate change described elsewhere in this section, including impairment of freshwater by salt water intrusion resulting from sea level rise, service disruption due to flooding and sea level rise, and more complex water treatment requirements as a result of increased pollution in surface and groundwater.

Agriculture

The changes to the hydrologic system resulting from climate change are likely to impact agriculture in several key ways:

- Irrigated agriculture will need to become more efficient in areas of the country where less precipitation is available and the competition for uses of available water among municipal, industrial, and agricultural uses and for ecosystem services become more intense.
- Non-irrigated agricultural enterprises may need to shift to crops that require less water in areas where rainfall declines
- Agricultural production may need to shift from areas with less rainfall or diminished supplies of water for irrigation, to areas with greater rainfall.
- Increasing acres may require the adoption of supplemental irrigation as a production response to stabilize crop yield and quality given an increase in the variability of precipitation.
- Agricultural enterprises in areas receiving reduced precipitation and/or increased temperatures will need to anticipate consequences of reduced soil moisture and the resulting potential for increases rates of soil loss due to wind erosion and other factors. Increased salination of soil will result from the combination of higher air temperature, higher evapotranspiration, and decreased precipitation.
- Additional drainage systems may be needed in areas where precipitation is expected to increase or to manage more extreme rainfall events.

Energy Development, Production, and Generation

Water is essential to several key forms of energy production and reduced availability and higher temperatures of water have the potential to pose significant problems for these facilities.

- Predicting rainfall and runoff at various time scales are key elements in management of hydroelectric dams and predicted declines in rainfall and associated runoff may result in declines in power production.
- Coal, natural gas, nuclear, geothermal and concentrated solar powered steam electric power plants rely on withdrawal and consumption of large amounts of water from lakes, rivers and oceans. Declines in freshwater availability or inundation of facilities drawing from freshwater or marine sources due to sea level rise pose risks for these facilities.
- Increased air and surface-water temperature will require greater volumes of water to achieve cooling needs.
- Emerging low carbon energy technologies such as carbon capture and storage may result in increased water demand.

- Biofuels production and refining use large amounts of water and often draw water from underground sources that also serve municipal and agricultural users.
- Conventional geothermal and concentrated solar thermal power systems use large amounts of water comparable to fossil- or nuclear-fueled power systems that may not be available in many of the arid regions where these plants are contemplated for development.
- Alternative fuels production (e.g.; biofuels, shale gas, oil shale, tar sand, coal-to-liquids, hydrogen) will also require large quantities of water if widely deployed in the future.

Navigation, Recreation, and Tourism

Climate change poses several threats to the reliability of navigation and to recreation and tourism.

- Coastal ports face problems associated with inundation of facilities as a result of sea level rise and the need to plan for the combined impacts of rising sea levels and more severe storms and storm surges.
- Disruptions to inland navigation may increase if there is an increase in the frequency and/or duration of very high and very low river flows.
- Increased runoff of sediment from more intense storms will increase sediment loads to channels and harbors, causing increased costs of dredging.
- The Great Lakes face special problems associated with increased evaporation and predicted reductions in the size and depth of the lakes. Some Great Lakes channels and ports, such as Toledo, Ohio may require significantly increased dredging. If lake levels decline by as much a three feet, as some models predict, use of the Lakes by ocean going vessels may become more difficult and alternative means of shipping may need to be developed.
- Reduced water supply will also limit recreational activities as water levels in reservoirs like Lake Mead decline.

Meeting Needs of Aquatic Ecosystems

Changes to the hydrologic system resulting from climate change are likely to impact fish and wildlife in several key ways:

- Warmer temperatures may accelerate the evaporation of water bodies in prime waterfowl breeding habitat, particularly in the prairie pothole region of this Nation. The loss of these breeding areas would greatly reduce the population of waterfowl and other species dependent on those habitats.
- Precipitation changes and reduced water availability will impact several life history stages of freshwater fish as well as invertebrates such as freshwater mussels.

Particular stages of life history are especially sensitive to the timing and volume of water flows, such as the timing of migration for diadromous species, fish egg survival, and food web connections that are driven by water flows.

- Aquatic ecosystems have adapted to natural hydrologic variability, but reservoirs were built to reduce flood and low-flow impacts. Recent reservoir management is trying to provide flows to replicate natural variability, but these environmental flows are another competing use of water supply. There may be increased competition for limited water supply in a warmer climate.
- The reduction of water in lakes impacts not only fish and waterfowl, but may result in changes in the aquatic vegetative communities upon which fish and wildlife rely for food. Consistently low stream flows or lake volumes may contribute to the growth and spread of invasive aquatic plants.
- Reduction of water availability in certain parts of the Nation will reduce overall levels of soil moisture, alter the communities of organisms that soil supports, and alter grassland and forest community structure. This in turn, will result in the loss of food availability for upland species.

2. Protecting Human Life, Health, and Property

Human life, human health, and property are at increased risk as a result of the impacts of a warmer climate on water resources including:

- increased water-borne disease;
- increased difficulty in treating drinking water;
- increased flooding as the hydrologic system becomes more variable;
- disruptions of energy, water, sewer, and emergency services as a result of more extreme rainfall and storm events; and
- increased drought and wildfires in some areas.

Water-Borne Disease

Heavy precipitation events have been statistically linked to an increased incidence of waterborne disease outbreaks in the United States. An analysis of waterborne outbreaks occurring during 1948–1994 found that 68% of outbreaks were preceded by precipitation events above the 80th percentile (Curriero *et al.*, 2001). A similar study in England and Wales found that waterborne disease outbreaks were preceded by both low cumulative rainfall and heavy precipitation events, suggesting that projections for both extremes—drought and increased intensity of precipitation events—may increase incidence of waterborne disease and outbreaks (Nichols *et al.*, 2009). The anticipated increase in the risk for waterborne disease with climate change will require improved surveillance systems and prevention efforts at local, state, and national levels. Water quality issues associated with climate change are also likely to have

multiple public health impacts including an increase in algal blooms and potential shifts in the microbial ecology of freshwater and coastal systems.

Municipal Drinking Water Treatment Systems, Wastewater Treatment Systems, and Stormwater Management Systems

Managing the Nation's infrastructure that provides for safe and clean water for human health and environmental protection will become increasingly challenging as a result of climate change. Systems are already under stress due to population and land use change, age, and socio-economic factors, and climate change will exacerbate investment, planning, and design issues. Warming water temperatures, increased variability and intensity of rainfall, lower water body flows, sea level rise, and increases in erosion and sedimentation will challenge water systems. Examples of actions that may be needed depending on specific geographic conditions include:

- wastewater and drinking water utilities will need to reduce water use through a range of practices, including incentives and pricing;
- the changing hydrological system will require system engineers and planners to develop methods to improve the ability of existing infrastructure to manage precipitation amounts that exceed the design capacity of that infrastructure, and to adopt practices for new systems that factor in increasing 'nonstationary' variability;
- planners and engineers will need to work together to improve coastal and inland infrastructure protection and resilience against flooding and storm damage.
- wastewater collection and treatment systems will need to address increased pollutant concentrations resulting from warmer water temperatures and decreased flows, as well as increased stormwater runoff;
- drinking water treatment systems will need to address changes in microbial and chemical makeup, including increased levels of total organic content that will require use of greater amounts of chlorine-based disinfectants that can lead to larger amounts of byproducts in drinking water that pose a risk to public health;
- planners and engineers will need to adopt non-structural approaches to managing stormwater, including 'green infrastructure' methods that work with the natural environment to mitigate stormwater flow as well as wetland preservation to enhance natural flow management;
- new contaminants arising from development of new energy or water reuse methods will need to be evaluated, and where needed, treated (e.g.; practices to store water in underground aquifers could have the potential to cause chemical reactions that release contaminants in drinking water sources that will need to be accounted for in treatment systems and hydraulic fracturing to obtain additional natural gas stores could have impacts on groundwater); and
- drinking water and wastewater system managers will need to alter emergency plans to incorporate threats from natural hazards, including climate change induced risk from increased flooding or damage from storm surges.

Flooding

As the intensity and frequency of heavy precipitation changes, we can expect there to be changes in flood risk in many areas. Some of the challenges in this area include:

- planning for long-term system operations and evaluations of flood risk will require the development of new tools and approaches as uncertainty increases;
- large floods, defined relative to past experiences, may become more frequent and/or be more severe under future climate conditions (IPCC 2007b);
- planning for long-term system operations and evaluations of flood risk will require new tools and approaches as uncertainty increases;
- estimates of flood risk and flood-control operating rules may need to be based on an expanded record of flood hydrology data and should consider potential impacts of land use change and changes in river channel and floodplain configurations;
- changing climate and changing land use and land cover can result in increased rates of erosion and sediment deposition. This can have impacts on aquatic and riparian habitats, river channel characteristics, and a loss of water storage in downstream reservoirs needed for water supply and flood control purposes; and
- aging and poorly maintained levee infrastructure, combined with the growth of residential, commercial, and industrial development in flood plains (with or without levees), has substantially increased flood risk on a national level. This will be exacerbated in some areas as climate changes.

Disruptions of Power, Water, and Emergency Services

The anticipated increase in uncertainty with respect to the frequency and magnitude of floods and droughts, fires associated with droughts, and extreme weather events such as intense rainfall and hurricanes will potentially cause major disruptions to energy supply and water and sewage services (e.g.; large water main breaks requiring community-wide boil water advisories). This will require strengthening resilience and the workforce of local environmental, public health, and energy and water utility agencies to respond and manage a wider range of water-resources challenges. We are likely to see:

- more intense and prolonged droughts that will require tradeoffs among water users that are likely to lead to litigation between local, State, Tribal, and Federal parties that will affect how shortages are managed;
- more intense and prolonged droughts will episodically diminish inflow to surface water reservoirs used for hydroelectric power, as well as limit water supplies necessary for operation of thermoelectric power plants and other forms of electrical generation, particularly during peak electricity demand associated with heat waves;

- more intense and prolonged floods will stress and disrupt public water treatment systems, storm runoff management, and the maintenance of water-quality standards for endangered or threatened species;
- more intense and prolonged floods will increase management challenges for operators of reservoirs used for water supply and flood control; and
- increased conflicts between users of surface and groundwater will occur in montane areas where seasonal snowpack and spring snowmelt recharge groundwater aquifers and surface water fills downstream reservoirs along rivers draining mountain fronts that are used for power generation.

Wildfires

Forests and grasslands contain vital biodiversity that provide essential services to the American public. Healthy forests and grasslands are needed to provide:

- most of the water used for drinking, agriculture and industry;
- fiber for paper, lumber, and other wood products;
- clean air;
- livestock feed;
- recreation opportunities;
- habitat for plants and animals; and
- sources of renewable energy feedstock.

Climate change is one of the greatest challenges to the sustainable management of public and private forests and grasslands and the vital services they provide.
Changes in regional temperatures, precipitation, weather extremes, severe drought, and earlier snowmelt can result in increased pest infestations, increased risk of wildfires, and eventual destruction of these vital ecosystems. If adaptation is not successful, the most likely (and initial) impact to manifest itself is the increased risk of wildfire frequency and severity. Under this scenario, we will likely see:

- increases in the number of acres burned;
- increases in smoke and particulate matter generated (i.e., short term air quality);
- loss of public and private property (loss of recreational opportunities, homes, etc.);
- loss of plant and animal habitat; and
- increased sedimentation of reservoirs.

The longer term effects will impact:

- water quantity and quality:
- wood product and renewable energy feedstocks; and
- long-term air quality due to loss of forest generated oxygen.

3. Protecting Quality of Freshwater Resources

Climate change threatens the quality of the Nation's freshwater resources, including:

- the quality of surface water;
- the quality of groundwater;
- the health of fisheries and aquatic habitat; and
- wetlands needed for sustainable aquatic ecosystems.

Surface Water

Climate change will have significant effects on programs designed to protect the Nation's water quality. Examples of effects, depending on geographic conditions, include:

- sewage treatment facilities, which will need to address issues related to both less precipitation (e.g.; discharges to receiving waters with lower flows) and more precipitation (e.g.; infiltration and combined sewer overflows);
- sewage treatment facilities need to plan for inundation as a result of increased flooding and sea level rise;
- more intense rainfall will make management of stormwater discharges more difficult;
- changing rainfall, snowmelt, and streamflow conditions will result in increased pollution from nonpoint sources;
- water quality standards may be more difficult to achieve and maintain;
- as waters warm, more waters are likely to be impaired, resulting in the need for increasing investments in pollution control; and
- water treatment plants will need to be adaptable to changes in the amount and quality of available streamflow.

Groundwater

Climate change may have significant effects on groundwater quality, though effects are difficult to quantify due to the complexity of groundwater systems. These effects could mean locally-severe impacts on water supplies, groundwater dependent ecosystems, and property. Some of the potential changes include:

- an increased demand for groundwater as an alternative to surface-water supplies with increased pumping resulting in degraded water quality, increase pumping costs, and land subsidence;
- changes in groundwater recharge rates and in base flows to streams that will result in long-term changes in groundwater storage;
- mobilization of contaminants due to higher water tables, affecting public groundwater supplies or discharge to surface water;

- intrusion of seawater in coastal aquifers as a result of either increased pumping and/or sea level rise; and
- rising water tables may affect public infrastructure such as sewer lines and subways, as well as basements and septic systems.

Fish, Shellfish, and Aquatic Habitats

As waters become warmer, the aquatic life they now support will be replaced by other species better adapted to the warmer water (i.e., cold water fish will be replaced by warm water fish). This process, however, will occur at an uneven pace disrupting aquatic system health and allowing non-indigenous and/or invasive species to become established. In the long-term (i.e. 50 years), warmer water and changing flows may result in significant deterioration of aquatic ecosystem health and habitat in some areas. A related consideration is the need to address the potential for increased ocean acidification to make marine corals less viable and to harm the calcium structures of marine life that form the foundation of the ocean food web. Loss of key ocean prey species has the potential to cause marine fisheries and endangered species impacts as serious as the loss and degradation of coastal and river habitat, including impacts on migratory species that may live in marine, estuarine, and freshwater (e.g.; salmon). Meeting or exceeding water quality standards is becoming an essential adaptation tool by reducing water quality stressors and increasing ecosystem resilience to climate change threats. Sea level rise and increased storm surge inundation and associated wetland losses will be an accelerating threat to fish, shellfish, and aquatic life in coastal environments, and as a result, shoreline protection strategies that maintain or restore coastal habitats are needed for sustainability of these ecosystems and the services they provide.

Wetlands

As the climate warms and the hydrologic cycle changes, new wetlands will develop in some parts of the country while wetlands move or disappear in other parts of the country. The Fish and Wildlife Service maintains maps of wetlands in the National Wetlands Inventory and it is increasingly important to establish baselines for wetlands' locations, size, and conditions. EPA and the Army Corps of Engineers jointly implement the Section 404 program to protect wetlands. USDA resource conservation programs and practices support the maintenance and restoration of wetlands. Wetlands will help mitigate some of the harmful impacts of climate change because they:

- help filter out pollutants generated by more intense stormwater runoff;
- retain water and help reduce the degree of flooding resulting from storm events;
- provide a buffer for coastal areas from more severe storms and help reduce the impacts of storm surges; and
- provide spawning and nursery services for aquatic life that is under stress as a result of climate change.

All these benefits are enhanced by the protection and restoration of existing wetlands and programs to establish new wetlands. Finally, wetlands may also have benefits for sequestering carbon. Financial and other incentives for carbon sequestration applied to wetlands have the potential to both reduce carbon in the atmosphere and to provide water quality and flood control services.

APPENDIX F:
Summary of Federal Water Resource Agency Adaptation to Climate Change Activities

Selected Interagency Efforts

Project	*Scope of Work*	*Agencies involved*	*Activities and Adaptation Assets*	*Adaptation Programmatic Needs and Opportunities*
Climate Science Centers	DOI has begun to establish eight regional Climate Science Centers (CSCs) that will synthesize existing climate change impact data and management strategies, help resource managers put them into action on the ground, and engage the public through education	DOI and other agencies	CSCs are being developed in coordination with other federal agencies, local and state partners, and the public.	CSCs will coordinate with RISAs and anticipate using model results and projections produced by RISA-supported scientists.
Landscape Conservation Cooperatives	As part of its strategy to address climate change at the local and regional level, the DOI is creating twenty-one Landscape Conservation Cooperatives (LCCs).	DOI and other agencies	The LCCs are to coordinate landscape-level strategies for conserving public lands, wildlife, water and other natural resources. Some of the LCC products and services will include computer models, projections of species' ranges with climate change, assessments of species' and landscapes' vulnerability to climate change and maps showing potential wildlife movement corridors as climate change forces migration. Each of the LCCs is created for a specific landscape type, with boundaries that cross both state lines and international borders.	LCCs are to collaborate with academia, other Federal agencies, local and state partners, and the public and will coordinate with CSCs and RISAs in their regions.

National Integrated Drought Information System (NIDIS)	The goal of NIDIS is to improve the nation's capacity to proactively manage drought-related risks, by providing those affected with the best available information and tools to assess the potential impacts of drought, and to better prepare for and mitigate the effects of drought.	NOAA (DOC), USDA, DOE, USACE, EPA, DOI (USGS, USBR), DOT, FERC, FCA, IRS, USITC, NASA, NSF, SBA	U.S. Drought Portal is an interactive system to: provide early warning about emerging and anticipated droughts ; assimilate and quality control data about droughts and models; provide information about risk and impact of droughts to different agencies and stakeholders; provide information about past droughts for comparison and to understand current conditions; explain how to plan for and manage the impacts of droughts; provide a forum for different stakeholders to discuss drought-related issues	- Develop leadership and networks to implement an integrated drought monitoring and forecasting system at federal, State, and local levels. - Foster and support a research focusing on risk assessment, forecasting, and management. - Create a drought "early warning system" to provide accurate, timely, and integrated information. - Develop interactive systems, such as the Web Portal, as part of the early warning system. -Provide a framework for public awareness and education about droughts.
NOAA Regional Integrated Sciences and Assessment (RISAs)	The RISA program supports research that addresses complex climate sensitive issues of concern to decision-makers and policy planners at a regional level.	NOAA and other agencies	RISA research team members work closely with natural resource managers and land planners, nongovernmental organizations and the private sector within each region to advance new research on how climate variability and change will impact the environment, economy, and society, and develop innovative ways to integrate climate information into decision-making.	Research topics include fisheries, water, wildfire, agriculture, public health and coastal restoration. Team members are primarily based at universities though some of the team members are based at government research facilities, non-profit organizations or private sector entities.
Climate Change and Water Working Group (CCAWWG)	Joint effort by principal water resources management agencies and the earth science data collection agencies of the U.S. government	USGS, NOAA, USBR, USACE, EPA, FEMA	Produced *Climate Change and Water Resources Management: A Federal Perspective* with strategies to improve water management by tracking, anticipating, and responding to climate effects CCAWWG developing a comprehensive capability assessment and research plan that supports the common and complimentary needs of the Federal and non-Federal water management community.	- Work with Federal and non-Federal research programs to find ways for their programs to assist in implementing the research plan and to generate collaborative research efforts across members of the water management and scientific communities to close these gaps.

Western States Federal Agency Support Team (WESTFAST)	Provides support to Western States Water Council to implement the Western Governors Association report, "Water Needs and Strategies for a Sustainable Future: Next Steps."	USACE, EPA, USGS, USBR, NOAA, NRCS, USFS, USFWS, BLM, DOE	Coordination of Federal activities in the Western States to support multiple climate change adaptation activities.	- Continue and expand funding for data collection networks and activities necessary for monitoring, assessing, and predicting future water supplies. - Research for improving the predictive capabilities for climate change, and assessment and mitigation of its impacts.
Integrated Water Resources Science and Services (IWRSS)		NOAA, USACE, USGS	- Envisions a highly collaborative and integrative framework for providing a seamless suite of water resources information across scales ranging from small hillslopes to large watersheds, from droughts to floods, and from historical analyses to long-range predictions.	
Joint Climate Prediction Research Program	Development of climate system models more powerful than existing models.	DOE, USDA, NSF	High resolution models are being developed for predicting climate change and its resulting impacts at more localized scales and over shorter time periods than previously possible	- Program designed to generate models– significantly more powerful than existing models– that can help decision-makers develop adaptation strategies addressing climate change; -Efforts will provide improved capability with improved geographical and temporal resolution.
Border Region Cooperative Efforts	Individual and joint efforts by the United States, Mexico and Canada to assess, study and propose responses to the impact of climate change on water management on the border and within transboundary lakes and river basins	USGS, NOAA, USBR, EPA, USACE USIBWC, IJC	- Climate and water-related components of EPA's Border Environment Program (Border 2012) with Mexico - Flood Warning and Discharge Monitoring project undertaken by USGS in Nogales, Arizona/ Nogales, Sonora - IBWC and BOR joint cooperative efforts with Mexican counterparts in the Colorado River basin on behalf of water conservation, new sourcing, and environmental uses - New annex on Climate Change Impacts to be	- Enhance the focus of research and monitoring efforts on transboundary water/climate issues - Seek opportunities for consistent coordination and cooperation among Federal, state-level and academic research programs to generate the fullest possible collaboration among relevant water management and scientific communities - Increase binational collaboration on quantifying and understanding impacts of climate change in Great Lakes and the Colorado and Rio Grande river basins

			included in revised Great Lakes Water Quality Agreement (currently being renegotiated) - International Joint Commission's International Upper Great Lakes Study Board will examine potential climate change impacts on Lake Superior and Lake Huron and propose measures for adaptation.	- Coordinate adaptation strategies to reduce climate change risks to the Colorado and Rio Grande river basins and the Great Lakes, and increase resilience of respective aquatic ecosystems

Selected Agency Activities

Agency	*Scope of Water-Climate Work*	*Adaptation Activities*	*Potential Water Adaptation Assets*	*Adaptation Programmatic Needs and Opportunities*
DOE	-Ensure a reliable energy supply; -Meet the energy requirements for water use; -Manage water needs for energy production; and develop water-efficient environmentally - sustainable energy-related technologies.	- Assessed major water issues related to electrical generation and transportation fuels production, and the potential impact of climate change - Identified approaches that could reduce freshwater use in the energy sector including: (1) energy efficiency improvements in homes, buildings, industry and transportation; (2) use of non-traditional water sources including water reuse; and (3) optimizing energy production to reduce water intensity. - Produced "Energy Demands on Water Resources". -Participating Agency in multiple fora including: USGCRP; SWAQ, and WestFAST.	- Super-computing resources and modeling capabilities to assess potential climate change impacts on water resources and energy production. - National labs – research and technology development - Broad range of research and development activities at universities, at DOE National Laboratories, and in cooperative agreements with the private sector	- Improve regional/local scale forecasts of climate change - Conduct full assessment of risks and impacts of climate change on existing energy sector infrastructure - Develop technologies and practices for reducing and recovering from climate change impacts on water resources either requiring energy or used in energy production
USGS	Provide reliable, impartial and timely scientific information to understand the earth; serve as the primary	- Produced *Climate change and water resources management: A Federal perspective* with strategies to improve water management by tracking, anticipating, and responding to climate effects	- Robust monitoring network - Hydrologic expertise - Long-run datasets	- Develop paleoclimate information and stochastic modeling as useful tools for developing climate scenarios that include a wide range of potential hydroclimatic conditions

	Federal science agency for water resource information in the 21st century; provide science information to decision-makers	- Making long-term monitoring networks available to establish baselines, calibrate/validate models, and support and evaluate adaptation strategies - Producing stream flow forecasts with NOAA		- Adopt a System Projection paradigm (rather than a Stationary System paradigm) for adaptation planning - Improve groundwater monitoring - Coordinate with USGS-led interagency effort on water security
NOAA	Provide reliable, unbiased science products and services for citizens, planners, emergency managers, and other decision makers; produce climate and weather forecasts and severe storm warnings for the safety of life and property; conduct climate monitoring; manage fisheries and endangered speciesand their habitat; support coastal habitat restoration and marine commerce	- Leading efforts to improve the nation's response and adaptation to and mitigation of drought through the National Integrated Drought Information System (NIDIS) which serves as a model for climate services - Forecasting water-related climatic variables (ex. precipitation and soil moisture); stream flow and western snowpack (with USDA); - Updating precipitation duration/frequency atlases of recent decades of observations; - Maintaining mitigation and adaptation clearinghouses such as the Coastal Climate Adaptation which contain guides, plans, tools, and education materials - Participate in interagency USGCRP, which supports research on climate and associated global changes. - Providing authors and lead authors to the Intergovernmental Panel on Climate Change assessments - Providing authors and lead authors to the National Fish, Wildlife, and Plants Climate Adaptation Strategy (co-lead with the U.S. Fish and Wildlife Service and the state wildlife agencies)	- Extensive regional and local infrastructure for delivering climate information and mitigation/ adaptation support including National Weather Service Weather Forecast Offices, Regional Integrated Sciences and Assessment universities, Regional Climate Centers, Sea Grant, State Climatologists, etc. - Production of climate change scenarios - Delivery of coastal climate adaptation and mitigation information such as sea level rise and inundation through the Coastal Services Center and Sea Grant; consideration of climate change impacts when providing comments on other Federal agencies' proposed actions that could affect essential fish habitat	- Establish NOAA's National Climate Service - Strengthen weather and climate observations and monitoring at the regional and local levels (includes modernizing the Historical Climate Network and the Cooperative Observer Network) - Improve climate scenario models and short-term forecasts; build bridges between the two - Improve the downscaling of climate models and assessments - Fill need for increased financial resources; - Funding to complete updating of precipitation/duration/frequency atlases and to develop revised methods for engineering use for long-term infrastructure design.

			or endangered species	
USACE	Manage flood risk, navigation, hydropower, water supply, and infrastructure and practice environmental stewardship; provide emergency response; reduce damage of floods and mitigate impacts of drought	- Revised guidance on how to incorporate future sea-level change projections into life cycle of USACE projects	- National Flood Risk Management Program - Federal Interagency Floodplain Management Task Force (co-lead with FEMA) - Risk-informed decision making guidance and procedures	- Address key knowledge gaps - Monitor climate, hydrology, and ecosystems - Develop planning methods to account for climate uncertainty and facilitate adaptation
CDC	Serve as nation's lead public health agency to conduct and support research on health effects related to climate change; monitor, detect, and prevent waterborne disease in the US; provide technical assistance and funding to local, State, and territorial health departments; provide scientific data on climate-related health outcomes to decisions makers	- Maintaining a national database of all waterborne outbreaks reported in the US -Providing grants to states and cities to address and prepare for the health effects related to climate change as part of CDC's Climate Ready States and Cities Initiative. - Researching the water and public health impacts of climate change - Developing national guidance on the public health implications of drought	- Surveillance System and national database of all waterborne outbreaks reported in the US - CDC's Climate Ready States and Cities Initiative - National Environmental Public Health Tracking Network -Strong relationships with health departments at State and local levels to coordinate adaptation efforts and activities - Environmental Health Training for Emergency Response course to help local health departments prepare for natural disasters	-Develop and maintain robust surveillance systems for climate-sensitive diseases (e.g.; waterborne disease and mosquito-borne disease) so that long-term datasets are available for analysis and future planning - Increase investment in monitoring, detecting, and preventing waterborne disease at local, State, and national levels -Provide resources and training to local health departments to respond to climate-related public health emergencies (e.g.; floods, hurricanes, extreme weather events) -Strengthen climate change and health research, programmatic activities, and workforce at Federal, State, and local levels-
NASA	Study the Earth system from space as part of	- Producing downscaled climate models and assessing the uncertainty of these models	- Longest continuous record of the Earth's surface	- Respond to increased demand for data products, downscaled predictive models,

	the scientific discovery mission; create new space-based and related capabilities to advance scientific understanding and enhance civil space-based Earth observation; conduct water cycle research and application development	- Improved water models by increasing the access to earth observations - Collaborating with State, Tribal and local water managers - Engaging in US drought and disaster interagency and independent efforts - Water Cycle research program and Water Resources application program provides funding to researchers to integrate water impacts of climate change using models, aerial, and space observations	(Landsat) - Earth Observing System (EOS) with global data on the State of the atmosphere, land, and oceans - Earth science research and applied science to establish baselines, forecasts, and risk - Global Precipitation Mission with Japan Aerospace Exploration Agency and others	imagery, etc. - Initiate planned Soil Moisture Active-Passive (SMAP) to take direct measurements of soil moisture and freeze/thaw state to improve understanding of water cycles and forecasts for weather, flood, drought, and agricultural productivity - Manage risk of critical data and monitoring gaps due to aging space-based missions and lag-times for replacement

USDA	Ensure the sustainability of food and fiber production for consumption by the American public and export around the world; prepare for water related climate impacts that threaten US agriculture; proactively manage for watershed resilience and enhance the adaptability of forest ecosystems to protect those ecosystems' ability to provide clean water	- Partnering with research and development collaborators to advance understanding, quantification and prediction of climate change effects on agricultural and forest systems - Developing knowledge and tools to enhance the ability of conservation systems and practices to mitigate climate change effects - Developing and providing for outreach to internal and external stakeholders to assist in decision-making related to climate change on agricultural lands - Providing technical assistance to States, local governments and Tribes for natural resource studies and plans for watershed protection, flood prevention, irrigation, drainage, rural water supply, etc. - Creating and cultivating effective partnerships to promote collaborative actions across larger landscapes to increase awareness of the critical role of healthy forested watersheds	- Financial and technical assistance to farmers and ranchers who face natural resource threats, with priority given to water conservation or irrigation efficiency applications - Work with public and private partners to support entrepreneurial watershed management projects and to promote adaptive management	- Develop new methods, tools, and assessment protocols to evaluate the effectiveness of current and future conservation systems and practices for increasingly variable climatic conditions - Conduct additional research to identify or develop more drought resistant crops and trees, to gather information to support a better understanding of the interactions between climate and ecosystems to evaluate management options, and test solutions - Redesign our current water storage and management infrastructure - Revitalize programs such as the Small Watershed Program and build networks of small dams to manage water flow to respond to changes in water quantity and quality - Capture data to adequately describe current conditions and produce models to develop site specific planning thresholds to inform decision makers and the public on the scope of the impacts
Bureau of Reclam-ation	Assist in meeting the increasing water demands of the West; protect the environment; protect public's investment in water infrastructure	- Assessing changes in water flows on Federal lands - Assessing changing water needs as a result of climate impacts - Working to determine how flood events will change and impact Federal lands under a changing climate - WaterSMART Basin Study Program	- Paleoclimate information and stochastic data for expanding the range of hydrologic variability considered	- Access additional information on climate-water impacts through literature, projections, data, and planning scenarios - Improve the ability to assess social systems response to climate change - Establish practices for assessing operations and resource responses - Develop the ability to assess, characterize, and communicate uncertainties

EPA	Develop national programs, regulation, policies and technical guidance to protect the quality and integrity of the nation's drinking water, surface water, groundwater, and marine water resources	- Produced *2008 National Water Program Strategy: Response to Climate Change* and the subsequent *2010 NWP: Key Action Update)* to understand implications of climate change for clean water and drinking water programs and implemented 44 Key Actions throughout the base program, as well as in EPA Regions; currently updating strategy - Climate Ready Estuaries Program works with the National Estuaries Programs to develop and implement adaptation tools. - Climate Ready Water Utilities program works with the drinking water, wastewater and stormwater management utilities to develop and promote methods for understanding and reducing risk to climate change. - WaterSense water efficiency program partners with private sector to advance water efficient products and practices.- Participating Agency in USGCRP and lead author on several reports; -Active R&D program evaluating impacts and effects of environmental stressors on human health and the environment, including climate change; tests new technologies and practices, including for water infrastructure, nonpoint source controls, etc.	- State-Tribal Climate Change Council (STC3)involving governmental co-regulators to develop adaptation strategies - National Tribal Water Council facilitates working with Tribal government water professionals - Research capability to conduct studies on human health and the environment, and to develop and test adaptation methods for water infrastructure, watershed management, nonpoint source controls, and aquatic systems - Many stakeholder partnerships, including *Green Infrastructure* initiative; *Sourcewater Collaborative; Effective Utility Management* partnership; *WaterSense* and *Sustainable Infrastructure* program	- Baseline and monitoring data on shifting background parameters of water quality, water flow, temperature, and aquatic habitat to support climate-corrected policies and engineering design standards (e.g.; 7Q10 flow, 25-year 24-hour rainfall, 100-year storm, etc.) - Methods for projecting local hydrological shifts for long-term infrastructure planning, to prepare for increased risk of high flow and high velocity events due to intense storms as well as potential low flow periods - Technical assistance and guidance for States, Tribes, municipalities, watershed groups, - Guidance and decision tools, especially for small-to-medium sized drinking and waste water utilities - Definitions for most water efficient technologies (MET) for sector of expertise, e.g.; EPA for domestic water use; DOE for power plants; and USDA for agriculture.
FEMA		- Conducting a study on the impact of climate change on the National Flood Insurance Program (NFIP) - Revising FEMA's Coastal Construction Manual to include recommendations concerning coastal construction siting and		

		design within the context of potential climate change impacts - Studying the physics that drive natural hazard processes and severity to develop innovative measures for reducing damage resulting from such hazards - Studying mission and resource requirements associated with expanded operational demands due to climate change impacts		

APPENDIX G:
Notes from Listening Sessions

A. Facilitate Long-term Planning

The need for long-term planning was an important theme voiced by participants in several sessions. Long-term planning is made more complicated by uncertainty about the magnitude of effects on water resources, coupled with increased demand and competition for water resources. For capital-intensive water and energy infrastructure, projecting future trends raises long-term planning dilemmas, adding a new dimension to investment decisions.

- **Energy Infrastructure.** For energy infrastructure, the value of water and long-term reliability of supplies is an increasingly important consideration in siting and investment decisions. Development of cost-effective water- and energy-efficient technologies, as well as deployment strategies, will be required to reduce potential impacts. In addition, there may be a need to accelerate the timeframes to facilitate decision-making for water and energy in order to coordinate capital intensive infrastructure.

- **Water Infrastructure.** Aging water infrastructures – urban stormwater systems, wastewater treatment systems, and drinking water conveyance, treatment and distribution systems – are already under stress from a variety of demographic and socio-economic factors, and will be further stressed by changes to the hydrological system that lie outside their design capacities or operating conditions. This poses a problem for capital expenditure budgets. Failure to address these multiple stressors to infrastructure could put public health and safety at risk.

- **Water/Energy Nexus.** There is significant water usage in energy and fuel production. Furthermore, water extraction, transportation, treatment, and usage have significant energy costs. Integrated policies and analytical methods for calculating the energy-water costs of different activities could help optimize decision-making.

- **Public Health.** A range of public health challenges were raised in the context of the need for integrated cross-sector planning: expected increases in waterborne diseases, increased drought and flood cycles, increased need for emergency preparedness, increased threats to the quality of drinking water sources, land-use decisions and HIAs and water infrastructure. Public health considerations need to be incorporated into long-term planning around climate-water impacts.

B. Assure Adequate Supplies for Diverse Uses

A number of participants observed that assuring secure water supplies for a range of water uses – community water supplies, ecosystems, health, agriculture, energy, industry, transportation, and culture – is important.

- **Integrated planning.** Participants noted that coordination of water resource adaptation planning with other planning efforts will require integrated approaches that are multi-media, cross-sectoral, and watershed-based, and that take into account the 'triple bottom line' of economy, ecology, and social goals.

- **Water rights.** Some participants expressed concern that existing water rights systems and prior appropriation doctrines may not be conducive to sustainable resource use. However, the Workgroup notes that it is important to respect and give appropriate legal deference to existing water rights and state water appropriation systems. Further, trust responsibilities to protect the water rights of Tribes and treaty rights to aquatic resources will require effective coordination between Federal, State, Tribal and international governments.

- **Groundwater.** Groundwater resources are likely to be affected by both reduced recharge and increased demand. Protection of groundwater quality, as well as sustaining long term groundwater resources, will require careful coordination between surface water and groundwater planning and regulation.

- **Water reuse.** Water reuse will increasingly play an important role in increasing the availability of water for multiple sectors, but effective policies, practices and technologies will need to be developed to ensure that the health of the public is protected and cost effective options are available as strategies such as water reuse are undertaken in response to water scarcity.

- **Floodplains.** Management of floodplains is likely to become more problematic, demanding greater attention to landscape strategies that not only attenuate flow but also offer multiple ecosystem services, including sequestration of carbon, enrichment of soils, cleansing of water, and recharge of aquifers. Strategies to protect populations living in floodplains should be pursued (e.g.; early warning systems, zoning).

- **Vulnerable populations.** Tribal participants as well as public health professionals raised issues concerning vulnerable populations that already face challenges around health, safety, food security, housing, education and economy.

- **Tribes.** Ecosystem degradation and other effects of climate change have particularly dire consequences for Tribal communities that rely on natural resources for both subsistence and cultural lifeways, particularly for communities in remote areas inaccessible to centralized infrastructure such as treated drinking water, electricity, and grocery stores. Migration is not an adaptation option for Tribal communities that live on geographically defined land bases such as reservations. Special attention is needed to assist in planning for the health and safety of these populations.

C. Integrate and Update Federal Water Programs

A view expressed in several listening sessions is that the Federal government should view climate change as an opportunity to update programs, regulations, and policies, and should do so in a way that doesn't mask the value of water. In addition, participants recommended that Federal agency silos should be broken down and a systems approach should be adopted to ensure that Federal policies are not at cross-purposes. To avoid unintended adverse consequences, analyses should incorporate integrated objectives, including managing water, air, land, energy, food security, etc.

- **Develop cabinet-level oversight.** Because water adaptation is such a cross-cutting issue, listening session participants proposed frameworks for a Federal cabinet-level water manager to ensure Federal agency coordination and achievement of multi-agency and cross-sector objectives. The concept of a National Climate Service is appealing to many participants, but must be done in a way that builds capacity of local institutions and taps local expertise rather than a 'parachute in and leave' approach.

- **Provide leadership to develop science and technology, information and communication.** The Federal government can provide leadership to improve science and develop tools, guide energy-water technology development-deployment, coordinate adaptation experiments, build interoperability of data sets, and improve communication to locales. Research, water monitoring, climate modeling, and other scientific contributions are needed to support adaptation planning.

- **Sustain long-term monitoring of hydrologic data**. Participants strongly commented that there is a need for robust data-collection networks (e.g.; streamflow, groundwater levels, water quality and water use) to inform water resources decision making. These networks should be well-coordinated among Federal, State, and local entities, and supported by a strong Federal monitoring backbone.

- **Coordinate Federal agencies.** There is a need for improved coordination among Federal programs, as many State and local entities are already overwhelmed with their current workloads and confusion about which agency does what at the regional level.

D. Support Local Adaptation

Adaptation is largely a local issue, and water resource impacts and management vary from region-to-region. Participants in listening sessions observed that Federal policies should dovetail with, and complement, State, Tribal and local programs and policies, and should use regional approaches that address multiple issues.

- **Collaborate.** Based on examples cited of good working models currently in practice, effective governance models have some or all of the following characteristics: 1) adopt regional approaches that engage multiple entities across multiple issues; 2) work with existing institutions and organizations, such as river basin commissions, professional associations, and local educational institutions; 3) increase public education; 4) ensure leadership; 5) reach out for the best available science; 6) discuss alternative solutions; and 7) use lessons learned and best practices from local, and regional experience.

- **Build local capacity.** While a Federal-level water adaptation committee can provide leadership, effective implementation will require building upon and extending local knowledge and capacity. Collaboration should take advantage of existing institutions and organizations, such as river basin commissions, professional societies, Tribal colleges, and other on-the-ground organizations. The Federal government can play a role in providing grants to foster cross-sector collaboration and planning among local agencies in public health, emergency preparedness, and city planning.

- **Develop locally-relevant tools and information.** The Federal government should see that basin-specific planning and management tools are developed and that technical assistance to communities is provided. Further, research should be conducted at scales applicable to tribes and localities.

- **Best Practices and Lessons Learned.** Indigenous knowledge and long-held practices should be recognized and valued, and efforts to integrate Western-style science with traditional knowledge can yield important adaptation strategies that promote long-term sustainability. In addition, important insights can be gained from others that are addressing climate change challenges at local, regional, and international levels.

- **Educate the public.** Prospects for successful implementation of adaptation strategies will be improved if the public is educated on the need for adaptation and risk management, and the associated costs and benefits. Federal support for development of K-16 curricula to build understanding and awareness of climate change issues would also build local capacity for developing and implementing adaptation strategies. Community and Tribal colleges are examples of community institutions that can integrate science with local and traditional knowledge for developing and implementing sustainable adaptation strategies.

Appendix H:
Overview of Water Resource Management Decisions

Types of decisions	Who makes them	Examples of scientific information needed to support decisions
Investments in future water supply and water use infrastructure	Cities, farmers, energy companies, utilities municipal governments, federal agencies	• Streamflow and groundwater recharge • Water demand (by crops, or energy production system, or people)
Permits for discharge of wastewater or other pollutants and underground injection programs	EPA, State, and Tribal environmental agencies	• Low-flow characteristics of rivers (discharge, temperature, pollutant loadings) • Properties of underground sources of drinking water
Design of water and energy facilities near sea level (including water supplies; water storage and distribution systems; wastewater collection, reclamation and reuse; irrigators, power plants that rely on water; stormwater management)	Cities, farmers, industry, utilities, municipal, state, local, Federal, and Tribal governments	• Estimates of relative sea level rise and storm-surge hazard
Inland flood hazard mitigation	Property owners, municipal and Tribal governments, transportation planners and operators, insurance industry	• Flood frequency estimates
Design and rehabilitation of urban and rural drainage systems, including new "green" infrastructure	Municipal and Tribal governments, transportation authorities	• Estimates of the magnitude, frequency, and duration of extreme rainfall and small-stream flooding
Operation of water infrastructure (dams and diversions) at time scales from hours to years	Owners and operators of that infrastructure: including Federal, State, municipal, and Tribal agencies, and energy companies.	• Estimates of the probability and magnitude of extreme low flows and extreme flood flows and flood volumes, • Estimates of water demand, forecasts at multiple time scales of the amount of inflow • Estimates of the consequences of various flow scenarios on aquatic habitats

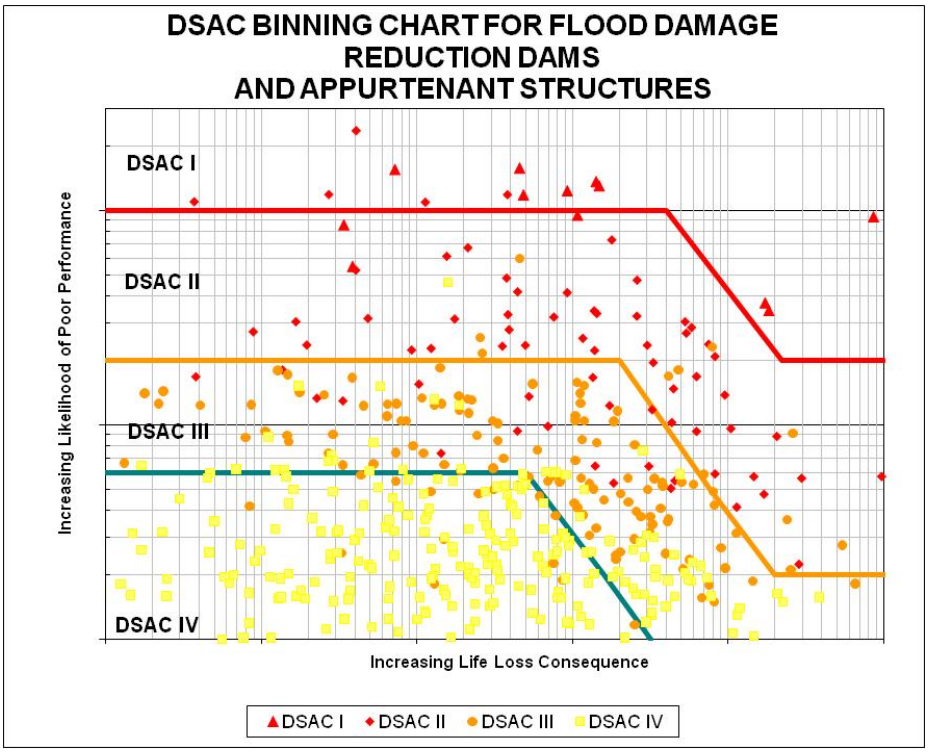
Protecting public health from waterborne disease	Public water supply utilities, public health officials, EPA and State and Tribal environmental agencies	• Reliable data on waterborne disease incidence in populations, • Estimates of the likely timing and location of water-borne pathogens and contaminants • Monitoring systems and interventions for mitigating their impact E
Protecting or restoring aquatic and riparian habitats	Many agencies at the Federal, State, Tribal, or local level	• Estimates of the likely streamflow at multiple times and scales, water temperature, water quality, and the variability and how those conditions will affect habitat and biological populations.

Appendix I:
Examples of Risk Assessment Tools

Example: USACE Dam Safety Action Classification (DSAC)

The USACE Dam Safety Action Classification (DSAC) is a method utilized by the USACE to manage dam safety risk. The program ensures that all dams and appurtenant structures are designed, constructed, and operated safely and effectively under all conditions, based on the dam safety program purposes, as adopted by the Interagency Committee on Dam Safety.

DSAC Categories:
Class I: Urgent and Compelling – Critically Near Failure OR Extremely High Risk
Class II: Urgent – Failure Initiation Foreseen OR Very High Risk
Class III: High Priority – Significantly Inadequate OR Moderate to High Risk
Class IV: Priority – Inadequate with Low Risk
Class V: Normal – Adequately Safe AND Residual Risk is Considered Tolerable



The graph above plots dams on the likelihood of failure of the structure and the potential loss of life as a result. Assessing vulnerability of aquatic ecosystems and water resources infrastructure such as wastewater facilities and dams, can utilize this comparison to prioritize projects. Consequences of failure can also be framed in terms of economic losses and environmental/ecosystem losses, among others, and presented on the x-axis. Limited resources can be focused on high priority projects using this matrix.

Example: NOAA Roadmap for Adapting to Coastal Risk

Community planning provides an opportunity to address hazards and climate change vulnerabilities, since residents and other stakeholders are already creating or updating policies and plans that will guide community development. Decisions are being made on land use, government services, community character, and natural resource protection. Hazards are connected to all these sectors and impact operations and budgets.

The NOAA Coastal Services Center developed the Roadmap for Adapting to Coastal Risk, which is a participatory process for assessing a community's vulnerability to hazards—and for incorporating relevant data and information about hazards and climate into ongoing local planning and decision-making.

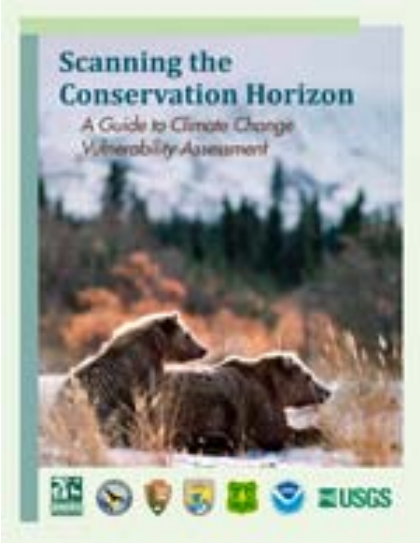
The Roadmap for Adapting to Coastal Risk approach emphasizes the importance of viewing community planning and development decisions through a hazards and climate lens. This means identifying how hazards and climate change can intensify existing issues, such as stormwater management and infrastructure maintenance. This participatory assessment process is designed to

- Engage key staff members and stakeholders in a comprehensive, yet rapid, assessment of local vulnerabilities;
- Use existing information resources to evaluate potential hazard and climate impacts;
- Collaborate across disciplines to better understand and plan for impacts; and
- Identify opportunities for improving resilience to current and future hazard risks.

A three-hour training introduces the "Roadmap" assessment methodology. Visit the Roadmap web site *www.csc.noaa.gov/roadmap* to learn more.

Example: Vulnerability Assessment Guide and Training (DOI, NOAA, and NWF)

New guidelines have been developed to help natural resources professionals understand how the changing climate is likely to affect fish and wildlife and the habitats on which they depend. Training for applying the guidelines is paramount to designing and carrying out effective adaptation strategies to counter the impacts of climate change. NOAA is contributing to work by the U.S. Department of the Interior and the National Wildlife Federation to train managers to develop and use vulnerability assessments as part of their broader adaptation planning efforts for freshwater, coastal, and inland ecosystems. Training workshops are being designed, based on the new document, *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*, developed jointly by the National Wildlife Federation, State and Federal agencies, and other partners.



Vulnerability assessments are a key step in adaptation planning by enabling managers to:

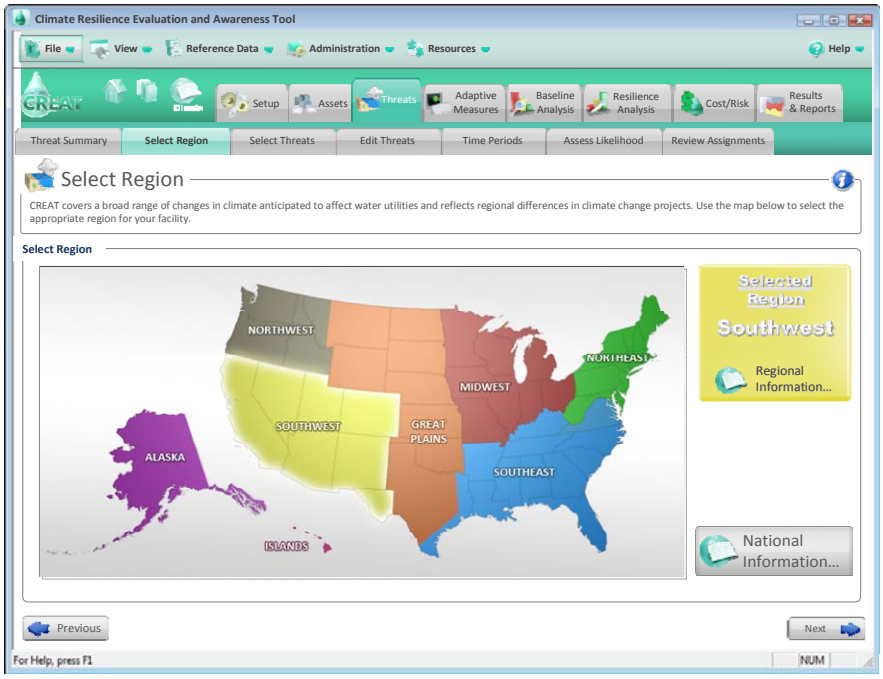
- Identify those species and habitats most likely to be in need of conservation actions as a result of climate change.
- Develop adaptation strategies tailored for managing species and habitats in greatest need.
- Foster collaboration at statewide and regional scales by providing a shared understanding of impacts and management options.
- Allow scarce resources for wildlife and habitat conservation to be allocated efficiently in the face of climate change.

Example: EPA Climate Resilience Evaluation and Awareness Tool

In response to actionable signals indicating localized climate impacts hold the potential to affect operational conditions, a drinking water or wastewater (water sector) utility would conduct a climate impacts risk (vulnerabilities, threats, and consequences) assessment looking at a broad range of potential systems implications. This focused engagement would include assessing the risk of a range of water sector system component responses to climate change-related watershed variation. A climate change risk assessment would be used to evaluate the overall risk of water systems to climate impacts.

Two alternative, though potentially complimentary, approaches to risk analysis have been articulated - “top-down” (quantitative scenario risk approach) and “bottom-up” (qualitative threshold risk assessment). The quantitative scenario risk approach seeks to employ “downscaled” outputs of general circulation climate models as inputs to localized hydrologic and other models to simulate a range of water sector system component responses to climate change-related watershed variation. Bottom-up approaches draw on the general findings of climate research, with utilities identifying system components potentially dependent on the status of key climate variables (e.g.; temperature and precipitation) resulting in a preliminary

risk assessment based on the professional judgment of experts who know the system and local watershed conditions. In response to risk assessment outputs, a water sector utility would develop strategies to address the identified risk, including expanded operating flexibility, expanded capacity, and development of alternative supply and treatment options.



As a result of the issues identified above, the U.S. Environmental Protection Agency has developed a PC-based Climate Resilience Evaluation and Awareness Tool (CREAT) for drinking water and wastewater utility owners and operators under its Climate Ready Water Utilities Program. The first version of CREAT is available for download at the Climate Ready Water Utilities Website (http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm). The second version of CREAT, which is currently under development, will incorporate the top-down as well as the bottom-up risk assessment approaches and will use the most current scientific understanding of climate change. The tool will assist water sector utility owners and operators in understanding potential climate change threats and in assessing the related risks at their individual utilities.

Individual utilities can analyze climate change as part of adaptation planning by using forecasts of future climate at a regional scale. However, the state of the art of climate modeling is evolving and is not fully understood. Model resolution is coarse and there is often substantial variability across climate models (mainly concerning precipitation projections). There is a critical need to conduct planning and make engineering and management decisions regardless of the considerable uncertainties about the timing, location and scale of future climate impacts. For most utilities, there is not an option to “wait and see” or take “no action.” Both the current stock of capital assets and any new investments will be affected by climate change, even if the

impacts cannot be precisely predicted. Thus, there is a need for an approach that can be used by utilities now to understand and evaluate potential adaptation measures.

CREAT allows water sector utility owners and operators to use known information about their utility, such as utility assets, to assist with identifying climate change threats, assessing potential consequences, and evaluating adaptation options. This approach allows users to help establish the thresholds at which climate change threats could result in asset or mission failure and to initiate adaptation planning despite the uncertainties. CREAT may also help organize and communicate climate-related activities to decision makers, stakeholders, and citizens. This may build confidence that the utility is being appropriately proactive, or alternately may serve to identify gaps or areas where additional funding may be needed.

Appendix J:
Selected Acronyms Related to Water Resources and Climate Change

Acronym	Definition
ACWI	Advisory Committee on Water Information
BLM	Bureau of Land Management
CCAWWG	Climate Change and Water Working Group
CENRS	Committee on Environment, Natural Resources and Sustainability (OSTP)
CEQ	White House Council on Environmental Quality
CDC	Centers for Disease Control and Prevention
CSC	Climate Science Centers
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science, Inc.
DOC	United States Department of Commerce
DOE	United States Department of Energy
DOI	United States Department of the Interior
DOT	United States Department of Transportation
EIA	Energy Information Agency
EPA	Environmental Protection Agency
FACA	Federal Advisory Committee Act
FCA	Farm Credit Administration
FERC	Federal Energy Regulation Commission
GCMs	Global Climate Models
HIS	Hydrologic Information System
IBWC	International Boundary and Water Commission
ICCATF	Interagency Climate Change Adaptation Task Force
ICWP	Interstate Council on Water Policy
IJC	International Joint Commission
IPCC	Intergovernmental Panel on Climate Change
IRS	Internal Revenue Service
IWRM	Integrated Water Resource Management
IWRSS	Integrated Water Resources Science and Services
LCC	Landscape Conservation Cooperative
NACC	National Assessment on Climate Change
NASA	National Aeronautics and Space Administration
NCDC	National Climate Data Center
NEP	National Estuary Program
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration

NPS	National Park Service
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWS	National Weather Service
NAWQA	National Water Quality Assessment Program
OSTP	Office of Science and Technology Policy
RISA	Regional Integrated Sciences and Assessments
SBA	Small Business Administration
SDWA	Safe Drinking Water Act
SWAQ	Subcommittee on Water Availability and Quality
TVA	Tennessee Valley Authority
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USGCRP	United States Global Change Research Program
USITC	United States International Trade Commission
VATA	Vulnerability Assessment Techniques and Applications
WRCCW	Water Resources and Climate Change Workgroup
WSTB	Water and Science Technology Board