

An aerial photograph of a large, dark blue reservoir nestled in a mountainous, forested region. The surrounding terrain is rugged and covered in dense green trees. The sky is a pale, clear blue. The text is overlaid on the upper portion of the image.

Looking Forward: Priorities for Managing Freshwater Resources in a Changing Climate

National Action Plan Update

Water Resources and Climate Change Workgroup

November 2016

Cover Photo: Naches River Basin, Washington. Climate change projections indicate a steady increase in temperature progressing through the 21st century, generally resulting in snowpack reductions, changes to the timing of snowmelt, altered stream flows, and reductions in soil moisture, all of which could affect water management, agriculture, recreation, hazard mitigation, and ecosystems across the nation. Despite some widespread similarities in climate change trends, climate change will affect specific water basins in the U.S. differently, based on the particular hydrologic and geologic conditions in that area.

Photo Credit: U.S. Geological Survey.

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EXECUTIVE SUMMARY

The *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (NAP)*¹ was published in 2011 as the product of the federal interagency Water Resources and Climate Change Workgroup (Workgroup). Since then, member agencies have worked together to make notable progress in advancing understanding of climate change impacts on water resources and developing information and new approaches to adapt to these changes. Meanwhile, the Nation has witnessed the effects of more intense storms, drought, and unseasonable weather that is causing significant damage to property and loss of life. Consequently, interest in building greater resilience to extreme weather phenomena and other impacts of a changing climate has grown among state, tribal, and local communities.

This report, titled *Looking Forward: Priorities for Managing Freshwater Resources in a Changing Climate*, updates the 2011 NAP. The participating federal agencies are reaffirming the importance of continuing to improve the Nation's ability to respond to the impacts of climate change on water resources. This document also affirms and implements the objectives of the October 2016 report published by the White House, *Opportunities to Enhance the Nation's Resilience to Climate Change*². The objectives of the "Opportunities Report" are to guide sustained and coordinated action among federal agencies to further climate resilience efforts and to empower communities to continue to work with federal agencies on shared resilience priorities. The *Opportunities Report* identifies three themes for priority action by federal agencies (see text box). This *Looking Forward* document is consistent with those themes, which are flagged for the reader in each of the following sections.

**Opportunities for Action:
Three Themes for Future Federal Action on
Climate Resilience**

1. Advancing and applying science-based information, technology and tools to address climate change risk;
2. Integrating climate resilience into federal agency missions, operations and culture; and
3. Supporting community efforts to enhance resilience.

-- *Opportunities to Enhance the Nation's Resilience to Climate Change, October 2016*

¹ *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate*, 2011, available at http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_national_action_plan.pdf.

² *Opportunities to Enhance the Nation's Resilience to Climate Change*, October 31, 2016, available at <https://www.whitehouse.gov/sites/default/files/finalresilienceopportunitiesreport.pdf>. See Appendix A for a table of the list of opportunities for future Federal action under each of the three themes identified in the *Opportunities Report*.

The actions described in this *Looking Forward* document also take into consideration the recommendations of the State, Local, and Tribal Leaders Task Force³, the Climate and Natural Resources Workgroup⁴, the Advisory Committee on Water Information,⁵ the Presidential Memorandum: Building National Capabilities for Long-Term Drought Resilience⁶, and public input in various forums. This document is not an inventory of the wide range of activity underway among water resources agencies throughout the federal government; rather, it focuses on addressing the highest priority actions that the Workgroup member agencies are planning to address in the next several years. General recommendations and specific actions are identified in three thematic areas.

Data and Research

Many different water resource managers and others throughout society rely largely on the federal government's data systems to collect and analyze information on hydro-meteorological conditions. Maintaining observational networks remains a challenging task and there is a recognized need to better understand how to both detect emerging trends attributable to climate change as well as how to incorporate the concept of nonstationarity into projections of future conditions. Meanwhile, the competing demands for use of water resources suggests that research into improving water use efficiencies could benefit not only water supply managers but also users such as the energy and agricultural sectors that rely on availability of supplies for production. The Workgroup suggests strategic actions addressing four key recommendations:

1. Sustain, expand, and collocate wherever possible existing monitoring networks and data collection on hydrologic and meteorological conditions and water demand.
2. Modernize statistical analyses of observational data sets so that climate changes that have already occurred are recognized in water resources decision-making.
3. Improve reliability and accessibility of water-related projections of future conditions.
4. Enhance water supply and reduce water use through innovative technologies.

Please see Appendix D: Summary of Strategic Actions and Lead Agencies for a tabulation of all strategic actions and lead Agencies.

³ *State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, Recommendations*, November, 2014. <https://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience/taskforce>.

⁴ *Priority Agenda*, 2014. Climate and Natural Resources Working Group.

⁵ *Next Steps for Managing Freshwater Resources in a Changing Climate*, April 10, 2014.

http://acwi.gov/climate_wkg/climate_water_recommendations_report_4_21_14_final_draft.pdf.

⁶ *Presidential Memorandum: Building National Capabilities for Long-Term Drought Resilience Memorandum for the Heads of Executive Departments and Agencies*, March 21, 2016, available at <https://www.whitehouse.gov/the-press-office/2016/03/21/presidential-memorandum-building-national-capabilities-long-term-drought>.

Planning and Decision Support

It has long been recognized that climate change impacts are unique to every locality and sector and that solutions are also necessarily unique. Managing the development of new information and tools and applying them to localized decisions necessitates close cooperation among researchers and practitioners. Many activities are underway to ‘downscale’ production, delivery, and application of information to more regional and local levels. Improving collaboration between agencies and regional and local decision makers and improving guidance on use of climate information is the focus of the following two recommendations and the associated strategic actions:

1. Advance regional coordination among federal water resource management agencies to support climate change adaptation and resilience efforts.
2. Develop guidance and provide assistance to communities and water resource managers on use of climate change information and tools for assessing vulnerability and building resilience.

Training and Outreach

Responding to the demand for access to information about projected impacts of climate change has resulted in an information explosion as federal agencies, local planners, nonprofit organizations, and the private sector have developed many different websites, models, guidebooks, and training resources, on ways to evaluate climate change vulnerability and to inform water resource decisions. Water resource decision-makers are now frustrated at the overwhelming amount of information. Decision-makers need to know how to readily find needed information and how to decide which tools best support specific decisions. The Workgroup, therefore, intends to undertake actions to support the following recommendations:

1. Increase involvement in the U.S. Climate Resilience Toolkit Water Resource Management Theme.
2. Sustain and enhance the Climate Change and Water Working Group’s Professional Development Series.
3. Engage State Water Resource Research Institutes on Building Climate Resilience.

Workgroup Management and Coordination

Finally, there are more than a dozen federal agencies involved in some aspect of water resources management, all of which are undertaking various efforts to incorporate climate change considerations into their programmatic missions. Given the inter-related nature of agencies’ respective programs, it is important that agencies continue to work together to leverage resources, find synergies, and develop consistency. To ensure ongoing coordination, the Workgroup intends to:

1. Ensure effective support for the Workgroup to maintain continuity of interagency collaboration and leadership on climate change adaptation among federal water resource agencies.
2. Expand collaboration and communication with partners and stakeholders.

The recommendations and strategic actions in this *Looking Forward* document are recognized as high priorities that need to be pursued in the coming years. As this work proceeds, however, new priorities are likely to emerge and the Workgroup will work to recognize new challenges and refocus efforts as needed.

Today, there's no greater threat to our planet than climate change.

-- President Barak Obama, Weekly Address, April 18, 2015



Photo courtesy of the Environmental Protection Agency

INTRODUCTION: PROGRESS AND CHALLENGES

Background and Goal of *National Action Plan*

The *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate (NAP)*⁷ was published in 2011 as the product of the interagency Water Resources and Climate Change Workgroup (the Workgroup). The *NAP* reflected federal agencies' commitment to develop a coordinated effort to tackle the challenges posed by climate change for water resources management. The 2011 report outlined six priority areas with 24 specific "Supporting Actions" that federal agencies engaged in water resources management would undertake to understand and address climate change challenges. The six priority areas were:

- 1) Establish a Planning Process;
- 2) Improve Information for Decision Making;
- 3) Strengthen Vulnerability Assessments;
- 4) Expand Water Use Efficiency;
- 5) Support Integrated Water Resources Management; and
- 6) Support Training and Outreach.

Working together, federal agencies have made notable progress in each of these six priority areas, as reflected in annual reports⁸ of the Workgroup. For example, some notable advances are:

- Creating a 40-member stakeholder advisory group on climate change and water resources as part of the Advisory Committee on Water Information (ACWI);
- Recognizing climate change in water planning principles⁹ and requirements;
- Expanding and upgrading reporting requirements for waterborne disease outbreaks expected to increase as water and air temperatures warm;
- Developing vulnerability assessment tools for water managers including tools for understanding climate vulnerability of water utilities, watersheds, and national forests;

The Water Resources and Climate Change Workgroup was established in 2009 by the Interagency Climate Change Adaptation Task Force, and continues to operate under the auspices of the 2013 President's Climate Action Plan and Executive Order 13653.

⁷ *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate*, 2011, available at http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_national_action_plan.pdf.

⁸ 2014 Highlights of Progress and 2015 Implementation Plan, http://acwi.gov/climate_wkg/nap-fy1415-version9_hwclean_final508c.pdf. And 2013 Highlights of Progress and 2014 Implementation Plan, http://acwi.gov/climate_wkg/NAP_2014_implementation_plan&2013_highlights_final3-24-14a.pdf.

Highlights of Progress: 2012, https://www.whitehouse.gov/sites/default/files/2012_progress_report.pdf

⁹ Updated Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies, December 2014. <https://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG>.

- Supporting water-use efficiency through expansion of EPA’s WaterSense program, the Department of Interior’s WaterSmart program, and related efforts¹⁰;
- Advancing pilot projects to demonstrate how integrated water resources management can address climate change impacts and challenges; and
- Developing training programs addressing climate change and water resources management challenges for federal government employees and others.

Implementing the NAP over the past several years has been coordinated with related efforts including the National Ocean Policy, the National Fish, Wildlife and Plants Climate Adaptation Strategy and the National Drought Resilience Partnership^{11,12}.

Another collaboration among federal agencies is the federal Climate Change and Water Working Group¹³ (CCAWWG), a technical forum to share expertise across federal science and water resource management agencies. Furthermore, federal agencies all have been implementing their own adaptation plans^{14,15} working with stakeholders to focus on mission-related water issues.

Meanwhile, as risks inherent in a changing climate were better understood, and as the Nation continued to witness impacts of a changing climate, the federal government developed new initiatives and activities to tackle the complex challenges posed by climate change. For example, under Executive Order 13653¹⁶, the President established the Climate and Natural Resources Working Group as well as the State, Local, and Tribal Leaders Task Force, each of which identified recommendations and priorities that provide context for this NAP update. In March 2016, the Presidential Memorandum on “Building National Capabilities for Long-Term Drought Resilience”¹⁷ institutionalized the National Drought Resilience Partnership¹⁸ and defined goals and actions related to drought resilience.

¹⁰ Bureau of Reclamation WaterSmart (Sustain and Manage America's Resources for Tomorrow) at: <http://www.usbr.gov/watersmart/>; and US EPA WaterSense Program at: <https://www3.epa.gov/watersense/>.

¹¹ Note: Climate change and water issues for aquatic habitat as well as for terrestrial habitat are more fully addressed in the *Fish, Wildlife & Plants Climate Adaptation Strategy*.

¹² For comprehensive information about the President’s climate change initiatives, including those addressing drought and flooding: <https://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience>

¹³ Climate Change and Water Working Group website: <http://www.ccawwg.us/>.

¹⁴ Federal Agency Adaptation Plans are available here: <http://www.performance.gov/node/3406/view?view=public#supporting-info>

¹⁵ In addition, the U.S. Army Corps of Engineers produced a crosswalk of water-related information contained in the 2014 adaptation plans, available at:

http://www.corpsclimate.us/docs/Comparison_of_2014_Adaptation_Plans_JUNE_2015.pdf

¹⁶ Executive Order 13653, available at: <https://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change>

¹⁷ Presidential Memorandum at <https://www.whitehouse.gov/the-press-office/2016/03/21/presidential-memorandum-building-national-capabilities-long-term-drought>

¹⁸ U.S. Drought Portal, National Drought Resilience Partnership at: <https://www.drought.gov/drought/what-nidis/national-drought-resilience-partnership>

Process to “Refresh” the *National Action Plan*

Addressing issues and needs related to water resources and a changing climate in the U.S. has evolved significantly since the NAP was issued in 2011 and it is appropriate to step back and consider next steps.

During discussions of new directions convened in Spring 2015, two key ideas emerged. First, there is a need for a forum to promote interagency dialogue and to lend continuity to federal work to adapt water resources management to a changing climate. Second, there are additional opportunities for federal agencies to strengthen water resources management to better respond to climate change.

It is in this spirit that the Workgroup has chosen to “refresh” its approach – first by reaffirming its role as a community-of-practice convener and second by articulating particular focus areas for advancement. To address these two goals, the Workgroup decided to “refresh” the 2011 NAP and develop this “Looking Forward” document.

At the outset, the Workgroup convened a listening session webinar to solicit public comments. The Workgroup asked for input on several questions, including:

- What are the most important issues you are dealing with due to current or anticipated effects of climate change?
- In what way can federal agencies facilitate your ability to manage water resources in the face of climate change?
- What are your greatest training and outreach needs?
- What are the most important decision support tools that could be provided by federal agencies?
- What are the most important data gaps or research topics that federal agencies should be addressing?

Comments submitted during and after the webinar were incorporated into deliberations. The Workgroup also reviewed several recent documents that identified particular needs for building resilience in the water resource management sector. These documents included an April 2014 report by the Advisory Committee on Water Information, titled *Next Steps for Managing Freshwater Resources in a Changing Climate*¹⁹; the November 2014 *Recommendations of the State, Local, and Tribal Leaders Task Force On Climate Preparedness and Resilience*²⁰; and the *Priority Agenda for Enhancing the Climate Resilience of America’s Natural Resources (Priority Agenda)* of the federal interagency Climate and Natural Resources Working Group published in

¹⁹ *Next Steps for Managing Freshwater Resources in a Changing Climate*, April 10, 2014.

http://acwi.gov/climate_wkg/climate_water_recommendations_report_4_21_14_final_draft.pdf.

²⁰ State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, Recommendations, November, 2014. <https://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience/taskforce>.

October 2014²¹. The workgroup also considered the actions identified in the Federal Action Plan for drought resilience, developed by the National Drought Resilience Partnership.²²

Considering progress made to date, input received in the listening session, and review of recent reports and recommendations, the Workgroup decided to re-focus on three substantive themes:

- Data and Research
- Planning and Decision Support
- Training and Outreach

Interagency teams of federal staff drawn from the Workgroup were formed into four teams to address these three themes plus ongoing Workgroup management. These themes form the organizational structure for this document represented as chapters of this report. These chapters are followed by Appendices providing: a summary of the themes and opportunities identified by the Climate Preparedness and Resilience Council's report, *Opportunities to Enhance the Nation's Resilience to Climate Change* (Appendix A), an inventory of major hydro-climate data collection systems in the U.S. (Appendix B), description of regional collaborations (Appendix C), and a summary of strategic actions and lead agencies (Appendix D).

Further, each team was directed to focus attention in three areas - primarily related to needs identified by the State, Local, and Tribal Leaders Task Force:

- Evaluate long-term risks of climate change on water resources availability;
- Provide guidance on assessments of vulnerability of water infrastructure; and
- Promote integrated watershed management and planning to protect water quality and quantity.

In addition, the Workgroup intends to continue to actively engage in the Water Resource Management Theme of the Climate Data and Tools Initiative, which includes both *Climate Data.gov* and the *Climate Resilience Toolkit*²³, and will continue to inform and advise future interagency activities pertaining to climate and natural resources, such as those under the Climate and Natural Resources Working Group under the President's Climate Action Plan.

²¹ *Priority Agenda*, 2014. Climate and Natural Resources Working Group.

https://www.whitehouse.gov/sites/default/files/docs/enhancing_climate_resilience_of_americas_natural_resources.pdf.

²² Federal Drought Action Plan:

https://www.whitehouse.gov/sites/default/files/docs/drought_resilience_action_plan_2016_final.pdf

²³ <https://www.data.gov/climate/> and <https://toolkit.climate.gov/>.

Federal agencies are implementing many other activities to address climate change adaptation and resilience in addition to the strategic actions articulated in the 2011 NAP and related reports. This document does not attempt to comprehensively inventory, track, or document all the efforts underway that are addressing the impacts of climate change on water resources. Rather, the actions identified in this report were selected either to address important gaps or to lend support for particularly important activities that, in the Workgroup’s view, merit further consideration.



Photo courtesy of the Environmental Protection Agency

1 DATA AND RESEARCH

Various users of environmental and water information have expressed concerns related to the state of water data collection -- how well observation networks are being sustained now and into the future to provide adequate and consistent data collection for evaluation of long-term trends in hydrological and meteorological conditions, how this information is transferred between agencies and to the public, how to best use information to address climate change issues, and how to develop partnerships supporting these efforts.

The recent report, *Opportunities to Enhance the Nation's Resilience to Climate Change*, calls on federal agencies to advance science-based information and tools to address climate change risk. In addition, the Advisory Committee on Water Information (ACWI) made the following recommendations related to water information and climate change:

- *Ensure continuity and viability of long-term hydro-climate observations and data management systems.*
- *Enhance data access and interoperability of data systems. This includes the development of an integrative tool to assist in the access to data and information from multiple sources.*
- *Bolster critical data sets, including those related to groundwater, stream and river flow, waterborne disease, water use, and paleoclimate reconstruction.*

Of the three State, Local, and Tribal Leaders Task Force recommendations that the Workgroup is tackling, one focuses specifically on water information:

Promote risk assessment information and risk analyses to identify “hot spots” across the country where water demand is high and water availability is low, [including through] the national water census, [highlighting] water resource availability issues, further collaborating with state and tribes, and developing potential frameworks in collaboration with partners.

The Data and Research Team concurs with these recommendations. Federal agencies have long played a significant role in supporting data collection, data analysis, and modeling, providing essential information for many types of decisions. Water supply managers, flood control engineers, land use planners, and many others have long relied on federal data systems to inform planning and design – and need to understand and prepare for the added complications posed by climate change. Federal agencies are working to maintain and improve the availability and accessibility of water data and information, including information to inform decision-making in light of climate change. For example:

- The Open Water Data Initiative (OWDI)²⁴ of ACWI was started to “integrate currently fragmented water information into a connected, national water data framework and

²⁴ Open Water Data Initiative. <http://acwi.gov/spatial/index.html>,

leverage existing systems, infrastructure and tools to underpin innovation, modeling, data sharing, and solution development.”

- NOAA’s National Weather Service recently created a new Office of Water Prediction and opened the new National Water Center to provide water prediction services, including a national water model, and to complement existing regional river forecast centers.
- The National Groundwater Monitoring Network²⁵, that includes multiple agencies, is working to improve the accessibility of groundwater information.
- Coastal communities are collaborating to add LIDAR data for improved mapping of coastal flood risk²⁶.
- The U.S. Forest Service and partners have developed the National Stream Internet²⁷, a statistical and geospatial framework for organizing physical, chemical, and biological data about streams, which includes the NorWeST Stream Temperature regional database and modeled stream temperatures for use in climate scenarios for streams and rivers across the western U.S.

While efforts are underway to make existing datasets more accessible, the underlying data collection networks must also be strengthened. Further, while some monitoring networks provide good spatial and temporal coverage, others do not. It is important to sustain these networks and fill gaps. Appendix B Appendix B: Inventory of Major Hydro-climatic Data Collection Systems in the United States provides highlights of some of the critical networks that are of particular concern for informing decisions that build resilience to climate change. However, more work remains to support well-informed decisions and to manage current and future risk.

Besides ensuring that water managers have data and information to inform decisions, the federal government also promotes and advances innovation to address increasing competition for water supplies. For example, while managing water depends on the use of energy, producing energy depends on access to water supplies. Research into innovative technologies offer hope for reducing demand on limited water supplies while ensuring a reliable energy grid.

Building on the priority to advance and apply science-based information, technology and tools to address climate risk and to integrate climate resilience into federal agency missions, operations and culture²⁸, the Workgroup recommends focused attention to four key areas.

1. Sustain and expand existing monitoring networks and data collection on hydrologic and meteorological conditions and water demand;

²⁵ National Groundwater Monitoring Network. <http://acwi.gov/sogw/index.html>.

²⁶ Digital Coast. <https://coast.noaa.gov/digitalcoast/tools/slr>.

²⁷ National Stream Internet. <http://www.fs.fed.us/rm/boise/AWAE/projects/NationalStreamInternet.html>.

²⁸ Supra Note 2; *Opportunities to Enhance the Nation’s Resilience to Climate Change, Themes 1 and 2*.

2. Modernize statistical analyses of observational data sets to improve understanding of emerging trends associated with climate change;
3. Improve reliability and accessibility of water-related projections of future conditions; and
4. Enhance water supply through innovative technologies.

These issues are elaborated upon in the following recommendations and strategic actions that the Workgroup believes should be prioritized.

1.1 RECOMMENDATION: SUSTAIN AND EXPAND EXISTING MONITORING NETWORKS AND DATA COLLECTION ON HYDROLOGIC AND METEOROLOGICAL CONDITIONS AND WATER DEMAND

Federal agencies managing freshwater data systems work with states and other partners to provide the most complete and reliable data possible. The nation has many monitoring systems and data networks that are important for protecting public health and aquatic resources, such as those for streamflow, water quality, groundwater, meteorology, snow and ice, soil moisture, wetlands, and aquatic habitat. However, monitoring systems and data networks need ongoing support to maintain and expand their value. In fact, even robust networks have gaps in terms of spatial coverage or monitoring capabilities.

Given the diverse range of federal agencies that support these systems, strong communication among agencies helps to focus resources on critical priorities and avoid duplication of effort.

Some steps that federal agencies should take to build on this progress and strengthen cooperation and communication on water data issues, and thus strengthen the capacity to support informed climate adaptation decisions, are described below.

1.1.1 Strategic Action - Identify and address data gaps and needs for water resource management

The federal agency managers of the multiple data systems related to water resources would benefit from a forum for sharing information about operations of the systems, planned changes, and options for addressing emerging challenges such as climate change. These activities should be a regular agenda item for the Workgroup by forming a subgroup focused specifically on this topic.

The subgroup should consider convening a national water data forum on this issue as well as conducting a more comprehensive survey of monitoring systems with a special focus on data needed by climate change adaptation decision-makers.

Goals for this subgroup's activities would include identifying opportunities for federal agencies to collaboratively fill gaps in water data, expand spatial coverage of existing data collection systems, co-locate systems wherever possible, strengthen data collection on population and habitat trajectories of aquatic species, and make other improvements that would strengthen data collection and management to support water resource management in a changing climate.

Some of these improvements may involve little or no cost and can be adopted using existing resources or by modifying existing processes. Other priority improvements may require supplemental funding in the budgets of individual agencies.

1.1.2 Strategic Action - Expand adoption of regional monitoring networks to establish baseline conditions for evaluating impacts due to climate change

The Workgroup realizes that it is challenging to discern changes in water resources variables that are due to the impacts of climate change versus land use change or other stressors. Monitoring climate-sensitive water parameters at reference sites – those that are located in watersheds that have minimal disturbance from human activity - offer an opportunity to try to understand such causation. Citing the ACWI²⁹:

A significant challenge faced by water-resource scientists in the public and private sectors is the need for reliable long-term data and information from watersheds minimally disturbed by human activities. Monitoring in areas with minimal human disturbance helps to provide (1) an understanding of natural patterns of variability that can be used to differentiate changes due to land and water use from changes associated with natural climatic cycles and (2) reference information that can be used to establish water-quality criteria or appropriate expectations for watershed restoration....These synoptic measurements provide important information for understanding natural spatial patterns and variability. ...Unfortunately, there are relatively few sites among networks with long-term records for streamflow, water chemistry, and stream ecology necessary to distinguish changes associated with natural climatic cycles.

Highlighting the availability of data and expanding data collection from reference monitoring sites can yield information that broadens decision makers understanding of what to expect in the future and how to target protective activities. Therefore, the Workgroup intends to work with Agencies and the ACWI to further inventory and, where possible, expand such networks and make this information more readily available.

1.2 RECOMMENDATION: MODERNIZE STATISTICAL ANALYSES OF OBSERVATIONAL DATA SETS TO IMPROVE UNDERSTANDING OF EMERGING TRENDS ASSOCIATED WITH CLIMATE CHANGE

Various Federal agencies have historically compiled statistical analyses based on observational data that are used in many ways throughout society. For example, NOAA Atlas 14 is based on precipitation gages throughout the U.S. and provides intensity, duration, and frequency estimates used in engineering designs for applications such as stormwater infrastructure. USGS analyzes streamflow gages to compile stream flow statistics used, for example, in water quality

²⁹ Advisory Committee on Water Information, National Water Quality Monitoring Council. National Network of Reference Watersheds, at: <https://my.usgs.gov/nnrw/main/home>.

evaluations and infrastructure design for floods, and the Bulletin 17B standard provides guidance on estimation procedures for flood frequency.

Such statistical methods are foundational for engineers and water managers. Concerns have been raised on two aspects of these methods. First, some of the statistics have not been updated in many years; for example, some have not included analyses of more recent data, while others may not be based on more advanced methods, thus raising concerns about the accuracy of the statistics. Second, statistical methods developed in the past did not necessarily take into account a nonstationary climate, and therefore designing systems based on the past may not be protective under future climate regimes without some further consideration.

Given the importance of these heavily used statistics, new analysis of historic data is needed to understand how water-specific variables are changing, whether changes are consistent with climate model projections, and how to understand climate trends along with other drivers such as water diversion or land use change. To this end, the Federal government should work with stakeholders such as the ACWI and standards setting bodies to re-evaluate, update and modernize statistical analyses of observational data as appropriate and to evaluate options for evaluating nonstationary trends that could inform decision making under future climates. In particular, the Workgroup recommends the following priorities.

1.2.1 Strategic Action – Update National Oceanic and Atmospheric Administration Precipitation Frequency Datasets

These datasets are used to help estimate the severity of real events and to inform infrastructure design. The current approach to develop the data is based on a stationary climate. NOAA has done some work to consider how to address non-stationary climate in NOAA Atlas 14 statistical estimates of intensity, duration, and frequency of precipitation. Furthermore, statistics for several parts of the country have not been updated in recent decades. The Workgroup strongly recommends that Agencies work to ensure that this work is undertaken in the near future.

1.2.2 Strategic Action – Strengthen Flood Frequency Guidelines

Flood Frequency Guidelines, known as Bulletin 17B, support planning and engineering design to reduce flood risks. Bulletin 17B was published in 1982, and is currently being updated as Bulletin 17C by the Subcommittee on Hydrology of the ACWI³⁰. The proposed Bulletin 17C guidelines, while an improvement from the older Bulletin 17B methods, do not provide guidance on methods for considering potential climate change. The Workgroup recommends that follow-on work be done to develop best practices for considering non-stationarity in flood frequency analyses.

³⁰ Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Work Group - Bulletin 17C, <http://acwi.gov/hydrology/Frequency/b17c/>.

1.2.3 Strategic Action – Improve Streamflow Statistics

Many different users at the Federal, tribal, state, and local level use in-stream flow statistics to design and manage water infrastructure and water quality. Streamflow data are collected by USGS, USACE, as well as states. Similarly, USGS and others compute statistical estimates. USGS and USEPA are working to update statistical methods and to explore ways to evaluate potential future impacts of climate change. More work is needed to ensure access to updated flow statistics. In addition, integrated analysis of such streamflow statistics along with information on groundwater, precipitation, and evapotranspiration would provide a more complete picture of local and regional water conditions and how they may be changing.

1.3 RECOMMENDATION: IMPROVE RELIABILITY AND ACCESSIBILITY OF WATER-RELATED PROJECTIONS OF FUTURE CONDITIONS

A substantial amount of work is underway in the community of researchers who produce and use projections of future climate risks and impacts. This community includes parts of many federal agencies as well as state, local, tribal, and private-sector organizations. Despite this growing body of work, some water resource managers still find it difficult to understand and appropriately use these projections. In an effort to improve accessibility and utility of projections, activities are underway to catalogue, describe, and provide guidance about information for different users. Note: discussion of improving guidance on use of climate models and downscaling is included in Section 2.2.

1.3.1 Strategic Action - Evaluate the feasibility of developing the capability to project water temperature under future climates

Climate models commonly generate projections in terms of changes in air temperatures, precipitation, extreme weather, and rain/snow shifts but do not project changes in water temperatures. There is growing evidence, however, that water temperatures are increasing in water bodies at rates that are different than the increases in ambient air temperatures. In addition, even small increases in water temperature have the potential to degrade water quality and, more specifically, promote harmful algal blooms or threaten cold-water fisheries. The Workgroup will work with federal agency research programs and the academic community to conduct a preliminary evaluation of methods that project changes in water temperatures for various types of water bodies in different regions of the country.

1.3.2 Strategic Action - Evaluate the feasibility of integrating climate-impacted hydrology projections with projections of population and land use

Climate models project changes in precipitation and other hydrologic variables of interest. These projections can be used to estimate long-term changes in hydrology that are critical for long-term water resources planning and engineering design. Changes to either surface water or groundwater are central to many climate change vulnerability assessments and response plans.

In addition to climate, surface water and groundwater are also influenced by the condition of the watershed and variables such as soil moisture and groundwater recharge. Land use, water demand, and water system operational decisions also affect both streamflow and groundwater levels; land use in particular is closely correlated with changes in population and resulting changes in impervious surfaces that affect watershed conditions and demand for water.

Some long-term models are available that project changes in population and land use on time-scales comparable to those of climate change models. Examples include USEPA's Integrated Climate and Land-Use Scenarios (ICLUS)³¹ database, USGS's FORE-SCE mode³², USDA's Regional Environment and Agriculture Programming (REAP) model³³, and the Forestry and Agricultural Sector Optimization Model (FASOM)³⁴. Previous studies³⁵ that integrate changes in land use, population, groundwater recharge, and water demand with climate model projections suggest such integration can have significant effects on projections of future streamflow and groundwater supply in specific watersheds and at specific spatial scales. The Workgroup will work with the federal agency research programs and the academic community to identify and expand (where feasible) research efforts on integrating these projections to generate more reliable projections of streamflow, water demand, groundwater levels, and other impacts.

1.4 RECOMMENDATION: ENHANCE WATER SUPPLY THROUGH INNOVATION

Federal agencies support research into water treatment technology that enables the safe and productive use of nontraditional water sources (e.g., saline, brackish, impaired or artificially-recharged groundwater, etc.) for major water use sectors, such as agriculture, thermoelectric cooling, and fuels production. Increased water use efficiency as well as the use of nontraditional water by major water users has the potential to mitigate shortages of freshwater by displacing or

³¹ Integrated Climate and Land-Use Scenario, USEPA, <http://www.epa.gov/iclus>.

³² The FORE-SCE model: a practical approach for projecting land cover change using scenario-based modeling. Terry L. Sohl, Kristi L. Saylor, Mark A. Drummond, Thomas R. Loveland. *Journal of Land Use Science* Vol. 2, Iss. 2, 2007

³³ Advancement in the USDA REAP model, maintained by the Economic Research Service, incorporate both surface water and groundwater scarcity as constraints on irrigation adaptations as shown in Marshall, E., M. Aillery, S. Malcolm, and R. Williams (2015). At: http://www.ers.usda.gov/webdocs/publications/err201/55559_err-201.pdf.

³⁴ Drs. Bruce McCarl (Texas A&M University) and Darius Adams (Oregon State University) developed the Forestry and Agricultural Sector Optimization Model (FASOM) initially. A research consortium that includes members from USEPA, USDA, USDA Forest Service, Duke University, RTI International, Oregon State University and the Electric Power Research currently maintains it. A variant of the FASOM model with Greenhouse Gases (FASOM-GHG) has been used in several EPA analyses and USDA's Resources Planning Assessment. The EPA peer review of the FASOM model by EPA can be found here:

http://www3.epa.gov/climatechange/Downloads/EPAactivities/peerreview_FASOM.pdf.

³⁵ See, for example, *Investigating the Sensitivity of U.S. Streamflow and Water Quality to Climate Change: U.S. EPA Global Change Research Program's 20 Watersheds Project*, T. E. Johnson; J. B. Butcher, M.ASCE; A. Parker, M.ASCE; and C. P. Weaver. *Journal of Water Resources Planning and Management*, Volume 138, Issue 5, September 2012. At: [http://ascelibrary.org/doi/abs/10.1061/\(ASCE\)WR.1943-5452.0000175](http://ascelibrary.org/doi/abs/10.1061/(ASCE)WR.1943-5452.0000175).

augmenting its use. In addition, improving energy efficiency and energy recovery in water systems has the potential to reduce energy-related costs and climate emissions.

1.4.1 Strategic Action - Enhance water supply through investment in energy-water technologies

Energy and water are interdependent, and the availability and predictability of water resources can directly affect energy systems and energy security. Changes in hydrology in major regions of the country will not only strain water resources, but also will likely pose significant problems for the domestic energy sector that relies heavily on secure and reliable water availability. For example, thermoelectric power generation and fuels production each withdraw large quantities of fresh water. Expanded use of nontraditional waters, improving water reuse, and deploying water efficient technologies for energy production and electricity generation can protect and increase the Nation's water supply. The Department of Energy (DOE) is investing in research, development and demonstration of efficient heat exchanger and other technologies to increase fuel efficiency and reduce water requirements at thermoelectric power plants.

Energy efficient water treatment and conveyance technologies can significantly reduce energy use and enable the use of nontraditional waters. While technologies such as desalination have been practiced at commercial scales for decades, the production of water of acceptable quality requires significant amounts of energy, and efforts are needed to reduce the cost, energy input, and associated greenhouse gas emission levels. Subject to Congressional appropriation, the Department of Energy will launch a new Clean Water Energy Innovation Hub in FY17 focused on researching and developing technologies to reduce the cost, energy input, and carbon emission levels of treatment technologies. DOE also plans to invest in complementary research on technologies relevant to fossil, concentrated solar power, and geothermal applications.

1.4.2 Strategic Action - Improve water use efficiency in agriculture

Agricultural irrigation relies on access to significant quantities of water and, under pressure from climatic challenges such as wide-spread regional drought, increasingly must compete for limited supplies with municipal users, the energy sector, and ecological needs. While this sector has significantly increased its water use efficiency over the past decades, in some regions greater efficiencies are still needed to ensure a reliable food supply. USDA will continue to work to find ways to improve agricultural technologies that conserve water and increase efficiencies when such changes can avoid adverse or unintended consequences such as reduced groundwater recharge.

1.4.3 Strategic Action - Advance innovation in the use of aquifer storage and recovery

Artificial recharge (AR) and aquifer storage and recovery (ASR) are processes that convey water underground. These processes replenish groundwater stored in aquifers for beneficial purposes. Although the terms are often used interchangeably, they are separate processes with distinct objectives. AR is used solely to replenish water in aquifers while ASR is used to store water that is later recovered for reuse. Water injected into AR and ASR wells or infiltrated from surface

recharge areas includes water treated to drinking water quality by a public water treatment system, untreated groundwater and surface water, treated wastewater effluent that would otherwise be discharged to surface water, reclaimed or recycled water, as well as captured stormwater.

As of 2009, approximately 1,200 AR and ASR wells (excluding recharge ponds) existed nationwide, having quadrupled between 1999 and 2009. ASR and AR wells have been gaining attention as important water management tools in recent year as they are being increasingly viewed as an important supplemental source of water supply. Increased recharge from dedicated surface areas, including working agricultural lands, is also gaining attention as an option to increase groundwater supplies. According to the National Ground Water Association³⁶, “additional research is needed on the long-term physical and chemical impacts on aquifers, optimal management in different environments, uses of stormwater and reclaimed water, and institutional considerations.” Federal agencies will continue to support research on managed aquifer recharge as a potential means of stabilizing and enhancing water supply to inform state and local efforts while ensuring public health and safety.

1.4.4 Strategic Action – Promote innovative financing structures to incentivize investment in large scale green infrastructure projects to enhance water supply and water quality

Green infrastructure is defined as strategically planned and managed networks of protected green space that conserve ecosystem values and functions and provide ecological services of benefit to human populations. It includes local, urban-based stormwater infrastructure like permeable pavement, rain gardens, and green roofs; as well as watershed-scale projects like healthy wetlands, forests and land conservation.

In addition to water supply and water quality benefits, green infrastructure can provide a range of other environmental and community benefits including decreasing energy use, reducing urban heat island impacts, and improving air quality. Green infrastructure can create more resilient communities and may in some instances be cheaper to install, operate and maintain than traditional gray infrastructure. Green infrastructure can also increase the value of adjacent properties, recharge aquifers, stabilize the release of water through the system; or be more aesthetically pleasing. Other co-benefits offered by green infrastructure are providing recreational opportunities and wildlife habitat, and carbon sinks.

Overall, green infrastructure can also be viewed as a set of preventative measures rather than as remediation. For example, after back-to-back storms in 1997 and 1998 resulted in millions of dollars in property damage in the Milwaukee region, the Milwaukee Metropolitan Sewerage District launched a Greenseams program to conserve land upstream. Since 2001, The

³⁶ National Ground Water Association Information Brief, 2014, <http://www.ngwa.org/Media-Center/briefs/Documents/Managed%20Aquifer%20Recharge.pdf>, accessed August 8, 2016.

Greenseams program has protected more than 3,300 acres of flood-prone land in 28 communities with 1.1 million people in greater Milwaukee, while providing natural settings that improves the public's health and quality of life³⁷.

EPA and federal partners have been working with municipalities and others to promote green infrastructure. EPA's Clean Water State Revolving Fund Program, for example, recently released a memorandum that promotes increased financing of green infrastructure projects nationally³⁸. Another partnership is the Green Infrastructure Community of Practice, coordinated by the U.S. Forest Service and the Conservation Fund, and is a collaborative network of organizations and agencies that actively promote and implement the green infrastructure approach to strategic conservation.

Despite the potential benefits, large-scale green infrastructure projects are sometimes perceived as higher-risk because there are few operational projects to serve as models for demonstrating with certainty that large investments will result in intended outcomes. More large-scale projects can be incentivized using innovative financing structures such as Pay for Success (PFS) that shifts project risk from the risk-averse municipality/utility to the more risk-tolerant private investor. Repayment is then based upon performance of the green infrastructure³⁹. Federal agencies, states, and local communities have been successfully using PFS financing for a variety of social service projects and a green infrastructure project⁴⁰. To expand large scale green infrastructure projects that provide greater water quality, water supply, and other societal benefits, EPA's Water Infrastructure and Resiliency Finance Center can promote innovative financing methods such as PFS by educating municipalities, green banks and state SRF programs of their potential to provide credit enhancements.

1.4.5 Strategic Action – Advance innovation in the use of water markets to increase cost effectiveness of projects that increase water quality and quantity

Aging infrastructure, population growth, economic pressures and increasing risks from extreme weather events are challenging communities to keep up with the costs of providing safe, reliable

³⁷ See: Greenseams Milwaukee, <http://www.conservationfund.org/projects/greenseams-program>.

³⁸ See: Green Infrastructure Policy for the Clean Water State Revolving Fund Program, at: <https://www.epa.gov/cwsrf/green-infrastructure-policy-cwsrf-program>.

³⁹ For more information about Pay-for-Success, see, for example: https://www.whitehouse.gov/sites/default/files/omb/budget/fy2017/assets/fact_sheets/improving-outcomes-through-pay-for-success_0.pdf and <http://www.payforsuccess.org/resources/social-innovation-fund-releases-2016-pay-success-notice-funding-availability>.

⁴⁰ For example, D.C. Water issued the nation's first Environmental Impact Bond (EIB), a \$25 million privately placed bond issue to fund a 20-acre green infrastructure project. The transaction allocates a portion of GI performance risk to the investors who will forgo a portion of invested capital if performance falls below certain thresholds. This provision was a critical element in the city's willingness to go forward with the pilot project. This project funds a portion of the District's \$2.6 billion program to control stormwater runoff, improve water quality, and create a healthier future for District residents. https://www.dwater.com/news/listings/press_release783.cfm.

water supplies. In particular, economically distressed communities often do not have access to the most affordable water sources. Service providers may not have access to the most cost-effective mechanism to protect water quality and to deliver clean water. Water markets can help improve cost efficiency – whether by the trading of water rights or water quality credits – and allow greater access to safe and affordable water using the most efficient mechanisms. Water markets can also help communities meet other social and environmental goals, including improving air quality and public health and reducing greenhouse gases.

Federal agencies such as USDA⁴¹ can help provide technical assistance for program design and execution for state, tribal, local, and regional authorities interested in establishing water markets to determine existing and needed authorities and by providing technical assistance for program design and execution. Workgroup members will evaluate options for increasing the visibility of these types of opportunities.



Photo courtesy of the US Geological Survey

⁴¹USDA Office of Environmental Markets, at: <http://oem.usda.gov/what-are-environmental-markets>.

2 PLANNING AND DECISION SUPPORT

This chapter highlights recommendations and strategic actions that support planners, policy makers, and decision makers to manage freshwater resources in a changing climate. Existing tools as well as those that are in development are considered in order to identify particular areas that remain challenging. For example, some of the challenges expressed by stakeholders are that decision makers may not know how to find, select, or use existing tools. This could be addressed by developing various scenarios that could be considered prior to making a decision. For example, the Office of Science and Technology Policy, through existing interagency work groups or committees, could provide a consistent range of national, regional, and local scenarios based on downscaled climate information with which to evaluate options. Another challenging area is helping decision makers understand how to embrace uncertainty in decision processes.

This section reframes and combines aspects of three of the priority areas from the 2011 NAP, i.e., strengthen vulnerability assessments, expand water use efficiency, and support integrated water resources management. The ACWI also made recommendations in these areas, including⁴²:

- Develop guidance and build capacity for assessing vulnerability.
- Collaborate with non-federal water partners to improve future tool development.
- Prioritize agriculture for development of "nationally consistent metrics for water use efficiency".
- Update federal efficiency standards for showerheads, faucets, toilets, and urinals.
- Promote water efficiency and reuse/reclamation.
- Create regional Federal Agency Support Teams modeled after the Western States Federal Agency Support Team (WestFAST).
- Create incentives for state, interstate, local, and tribal governments to plan on a watershed basis for preparedness and resilience.
- Create incentives to incorporate ecosystem services (i.e., natural capital).

In addition, the State, Local, and Tribal Leaders Task Force recommended the following focus areas related to policy, planning, and decision support⁴³.

- Identify “hot spots” where water demand is high and water availability is low.

⁴² *Next Steps for Managing Freshwater Resources in a Changing Climate*, Water Resources Adaptation to Climate Change Workgroup to the Advisory Committee on Water Information, April 10, 2014.

http://acwi.gov/climate_wkg/climate_water_recommendations_report_4_21_14_final_draft.pdf

⁴³ *Recommendations to the President*, President’s State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, November, 2014.

https://www.whitehouse.gov/sites/default/files/docs/task_force_report_0.pdf

- Bridge the communication gap between science and management to address downscaling, decision support, vulnerability assessment, and practical guidance.
- Establish regional interagency water security partnerships with state, local, and tribal partners.

There are several activities underway throughout the Federal government that are not included in the current set of recommendations. Their importance should not be diminished, however, as they are critical activities that need federal agencies to follow through. Examples include incentivizing use and protection of ecosystem services, i.e., natural capital;⁴⁴ and adopting and promoting green infrastructure to manage stormwater, reduce urban heat island effects, and provide other benefits.⁴⁵

Considering past recommendations, ongoing activities, and recent developments, including the need to support community efforts to enhance climate resilience, facilitate co-production of knowledge and tools, and integrate climate resilience into federal agency missions⁴⁶, the Workgroup recommends the following:

1. Advance regional coordination among federal water resource management agencies to support climate change adaptation and resilience efforts;
2. Develop guidance and provide assistance to communities and water resource managers on use of climate change information and tools for assessing vulnerability and building resilience.

2.1 RECOMMENDATION: ADVANCE REGIONAL COORDINATION AMONG FEDERAL WATER RESOURCE MANAGEMENT AGENCIES TO SUPPORT CLIMATE CHANGE ADAPTATION AND RESILIENCE EFFORTS

Many Federal agency climate change adaptation and resilience activities are underway across the country, and coordination has advanced. Partnerships and activities underway include the Department of Interior Climate Science Centers (CSCs) and Landscape Conservation Cooperatives, NOAA's Regional Integrated Science and Assessments (RISAs), climate adaptation

⁴⁴ For information about Ecosystem Services, see: *Incorporating Ecosystem Services into Federal Decision Making*, October 7, 2015. <https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf>

⁴⁵ For information about Green Infrastructure, see also: Federal Agency Support for the Green Infrastructure Collaborative, http://www.epa.gov/sites/production/files/2015-10/documents/federal-support-for-green-infrastructure-collaborative_508.pdf

USEPA Green Infrastructure Program, <http://www.epa.gov/green-infrastructure>.

National Park Service INSTEP for Design and Construction Transportation Projects, <http://www.nps.gov/articles/transinstep.htm?>

National Association of Regional Councils, *A Roadmap to Green Infrastructure in the Federal Agencies*, <http://narc.org/environment/green-infrastructure-and-landcare/roadmap/>.

⁴⁶ *Supra* Note 2; *Opportunities to Enhance the Nation's Resilience to Climate Change*. The actions listed here support all three themes.

work in EPA's ten regional offices, the Army Corps of Engineers Silver Jackets teams, and the U.S. Department of Agriculture (USDA) Climate Hubs, as well as other federal activities (see **Appendix C: Regional Collaborations** for more description). Despite these many activities, there are still opportunities to improve coordination to assist state, tribal, and local partners.

2.1.1 Strategic Action - Develop new regional Federal Agency Support Teams (X-FAST) for water resources management

As suggested in the CNRWG *Priority Agenda*, federal agencies will use the Western States Water Council's Federal Agency Support Team (WestFAST) as a template and model to facilitate collaboration between other states, tribes and the federal government regarding water resources management generally, and water-related climate issues more specifically. The success of WestFAST is a model for addressing cross-boundary and multi-institutional stakeholder-driven issues, including those that are affected by federal activities or that could benefit from federal engagement. The federal X-FAST team will work to develop potential new regional opportunities to work with stakeholders, identify regional issues, and recommend focus areas that would benefit from involvement by an X-FAST or other regional interagency team.

2.1.2 Strategic Action - Expand engagement of federal water resource agencies in regional cooperative efforts on climate science and decision-making

Federal agencies have deployed substantial resources to develop climate science at the regional level and support state, tribal, and local climate resilience efforts. including USDA's Climate Hubs, NOAA's RISAs, and DOI's CSCs. There has been some engagement of water resource management agencies in these efforts; for instance, the Bureau of Reclamation is co-lead for two LCCs, and EPA and USACE participate on many LCC Steering Committees.

Federal agencies will continue to strengthen support for state, tribal, and local climate resilience by expanding participation of federal water resource management agencies in the regional climate science and services effort. A key step in this direction is for federal water resources management agencies to more consistently participate in the existing regional programs (e.g., Hubs, RISAs, CSCs, and LCCs). In addition, these components of federal agencies should work together to coordinate investments and stakeholder engagement including with entities such as state, regional, tribal, and local planning organizations. For example, under section 10 of the Sustainability Executive Order, EO 13693⁴⁷, agencies are working together to assure that climate services at the regional level are well coordinated. The water resources management agencies

⁴⁷ Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*, available at: <https://www.whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade>

should support this work to strengthen cooperation among federal agencies providing climate resilience services at the regional level.

2.1.3 Strategic Action – Encourage agencies to consider the effects of climate change on water resources and the implications for federal agency supply chains

While the direct effects of climate change may disrupt the functioning of Federal, tribal, state, and local governments and communities, indirect effects may be as significant because of climate change impacts on suppliers to these organizations and communities. Changes in sea level and changes in the frequency, intensity, and duration of storms have the potential to prevent, disrupt, or delay the production and delivery of goods and provision of critical services; and regional drought can result in insufficient water for operations. The large number and geographical dispersion of suppliers across the United States and around the world makes it likely that a significant fraction of all suppliers will likely be affected at some point in the future by climate change. Agencies are already directed in Executive Order 13693 to consider the need to improve climate adaptation and resilience with respect to agency suppliers and supply chains. The Workgroup will initiate conversations with the Office of Federal Sustainability and collaborate to provide information on the effects of climate change on water resources and its implications for federal agency supply chains in order to inform their overall climate change adaptation and sustainability planning.

2.1.4 Strategic Action - Develop case studies on restoration of wetlands and forests to build resilience

Wetlands provide a range of services for society; they buffer the impact of storms, filter pollutants, and sequester carbon. Forests also filter pollutants and sequester carbon and are a significant source of fresh water. For example, 65% of California’s water comes from the 17% of land in the state’s federally managed forests. Federal, state, and tribal governments are working to understand impacts of climate change on these services and how to increase protection of wetlands and restoration of both wetlands and forests, in order to effectively increase community resilience. Building on the wetland mapping work referenced in the 2011 NAP, the Workgroup now recommends that agencies increase collaboration to conduct pilot studies to inform restoration of key coastal and freshwater wetlands to both protect wetlands from the impacts of climate change where feasible as well as to help build community resilience. The Workgroup also recommends increased public and private effort for forest restoration, particularly in the West, to return forests to their natural density, reducing the risk of catastrophic wildfire and increasing the provision of clean water from forested watersheds.

2.1.5 Strategic Action – Build the capacity of Silver Jackets teams to incorporate risks due to climate change in emergency planning

Silver Jackets teams across the country bring together multiple state, Federal, tribal, and local agencies to learn from one another and apply their knowledge to reduce the risk of flooding and

other natural disasters and enhance response and recovery efforts when such events occur. USACE will develop guidance to expand capabilities of Silver Jackets teams to incorporate climate preparedness and resilience in their emergency management activities. This will enable teams to better respond to the needs of communities dealing with climate change by connecting Silver Jackets team members to USACE and other federal agency climate preparedness and resilience resources, including agency and subject matter expert points-of-contact as well as online reports, databases, and tools that are relevant to flood risk management. In addition, the Workgroup will document case studies and develop other means of promoting peer-to-peer learning.

2.2 RECOMMENDATION: DEVELOP GUIDANCE AND PROVIDE ASSISTANCE TO COMMUNITIES AND WATER RESOURCE MANAGERS ON USE OF CLIMATE CHANGE INFORMATION AND TOOLS FOR ASSESSING VULNERABILITY AND BUILDING RESILIENCE

There is a plethora of new tools, data, and trainings being produced, which, while responsive to demand, can, in turn, contribute to confusion and duplication of effort. This recommendation asks that we take a step back and help users better understand the resources that are available and how to begin to use them in decision-making.

2.2.1 Strategic Action - Develop an online dashboard to help water resource managers and urban planners prepare for and respond to extreme events

In response to stakeholders' request, NOAA is leading an effort to develop a dashboard for centralized access to a variety of information sources that can be quickly accessed and customized for local use. Such a dashboard of existing sources would enable users to access datasets related to forecasts and outlooks, e.g., precipitation totals and outlooks, observations, daily summaries from weather stations, current drought, etc.; and, people and assets, e.g., land cover and watersheds. Using hyperlinks, the water managers and planners would be able to go directly to the data sources for more information or to directly download data sets.

2.2.2 Strategic Action - Streamline access to climate adaptation information for the water resource management theme of the U.S Climate Resilience Toolkit

A wealth of climate adaptation information has come online in recent years, so much so that stakeholders express frustration at the prospect of wading through it all to find what is relevant to the decisions they are seeking to inform. NOAA will collaborate with partners to refine the user interface to the Climate Resilience Toolkit (CRT or Toolkit) that will connect people to specific tools and resources that fit their particular needs and interests. Reducing the time it takes to find useful tools for a wide variety of applications and information relevant to water resource decision makers will increase the uptake of these products that were developed to help build the nation's resilience to climate change and other stressors.

2.2.3 Strategic Action - Adopt a system for coordinating vulnerability assessments and advancing peer-to-peer learning

More and more communities and institutions have been evaluating the vulnerability of many different aspects of the natural and built systems at different scales, using various methods and for diverse issues. Stakeholders have expressed interest in a means of facilitating geographic coordination as well as peer-to-peer learning. There is value in making a publicly available consolidated repository of completed vulnerability assessments, and therefore the Workgroup will evaluate options for more fully filling this need. The Workgroup currently recommends that federal agencies consider adopting and promoting the Climate Registry on the Assessment of Vulnerability (CRAVe)⁴⁸ that was developed by USGS and the non-profit EcoAdapt to share knowledge of climate change and wildlife, ecosystems, and other resources. The registry enables users to enter information or metadata on climate change vulnerability assessment projects completed or underway across the country, pooling examples from Federal, state, local, and tribal governments.

Citizen science networks are also an important means of advancing peer-to-peer learning. For example, the Alaska Native Tribal Health Consortium coordinates the LEO Network⁴⁹ that leverages local and traditional knowledge to supplement more quantitative monitoring programs. The Workgroup will promote such citizen science efforts.

2.2.4 Strategic Action – Continue to develop, distribute, and provide guidance on the use of projected future climate information for water resources management

Many federal agencies, including members of the Workgroup, have self-organized into groups to produce or use projections of future climate based on their needs, and application. Some of those groups are also creating guidance on appropriate uses for different types of future projections. These efforts to provide guidance and information on future projections, including downscaled model results, are being collected and indexed to aid users with specific needs in finding the information they need.

For example, the CRT⁵⁰ is a central repository within the U.S. government for projections of future climate made using multiple different approaches. It is designed to be a continuing work-in-progress and does not include all possible future projections, but is more comprehensive and easier to use than other sites serving future climate projections that for different types of users. In addition, the U.S. Global Change Research Program⁵¹ is developing the Global Change

⁴⁸ USGS and EcoAdapt, Climate Registry for the Assessment of Vulnerability, <https://nccwsc.usgs.gov/crave/>.

⁴⁹ The Local Environmental Observer (LEO) Network: The eyes, ears, and voice of our changing environment, <https://www.leonetwork.org/en/leo/about>

⁵⁰ Climate Resilience Toolkit, <http://toolkit.climate.gov>.

⁵¹ U.S. Global Change Research Program, <http://data.globalchange.gov>.

Information System where examples of appropriate uses of future climate projections will be collected along with links to the projections and example uses.

The Workgroup will continue to explore ways to improve accessibility, utility, and user-friendly methods for using climate projections in various kinds of water-related decision processes for different types of users.

2.2.5 Strategic Action - Evaluate options for providing credit within the FEMA Community Rating System for the development of watershed scale plans for managing flooding that consider projected climate changes

The National Flood Insurance Program's (NFIP) Community Rating System (CRS) provides incentives for local communities to adopt flood protection standards and practices that exceed the minimum standards of the NFIP and that will reduce flood damage and cost. Communities that adopt specific practices are provided CRS credits that reduce flood insurance policy premiums. We recommend the CRS program examine current credits and evaluate potential options for providing credits for the adoption of climate resilience plans by water infrastructure facilities within the community or region and for the adoption of watershed scale plans for managing flooding that consider projected climate changes.



Photo courtesy of the Environmental Protection Agency

3 TRAINING & OUTREACH

As previously discussed, federal and non-federal decision makers have expressed a need for better understanding of how to use climate and hydrological data, information, and tools as they develop climate change vulnerability assessments and response plans and make a range of other climate adaptation decisions. As a result, a variety of organizations including federal agencies, tribal and local governments, land-grant universities, and NGOs, have been working to address this need. Their collective efforts have resulted in numerous training sites, recorded webinars, and written materials for water resources decision-makers.

These training materials are of varying quality, are found in various websites and other formats, and have been created for different audiences with a wide variety of backgrounds. Given increased interest in using these products, often by those who have limited scientific background, there is a need to streamline access to some of these resources to make them more readily findable, provide appropriate guidance on best practices for using information, and provide a service by making them easier to use.

This opportunity is broad in nature and must be planned to meet the needs of people with varying specialties, skill levels, and project focus. For example, an overview of principles and issues associated with climate adaptation could prove helpful for a policy maker or manager unfamiliar with climate change. On the other hand, an engineer who is concerned with water system operations and design might require an introduction to global change models and climate risk assessment prior to running very specific analytical methods.

The need for a more considered focus on meeting training needs has been recognized on a number of fronts. For example, in 2014, the Climate Change Workgroup of the Advisory Committee on Water Information made the following recommendations for training and capacity building, briefly summarized:

- Develop mechanisms to facilitate sharing of research and capacity building for climate change adaptation; and
- Expand workforce training, college traineeships, training of technical service providers, and training for laypersons.

Climate Literacy

Climate literacy is an understanding of your influence on climate and climate's influence on you and society. A climate-literate person:

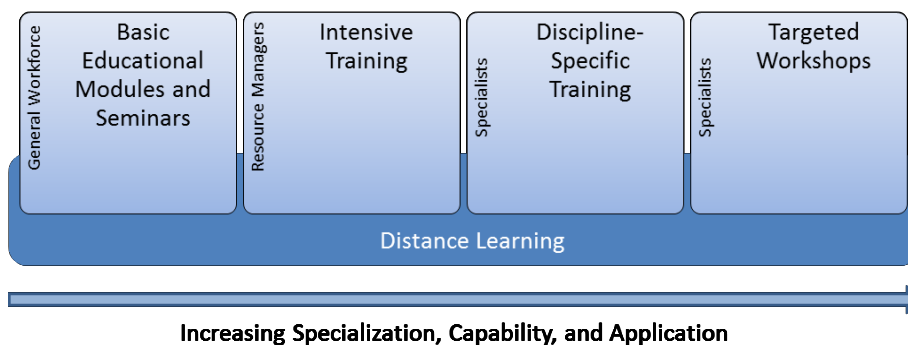
- Understands the essential principles of Earth's climate system;
- Knows how to assess scientifically credible information about climate;
- Communicates about climate and climate change in a meaningful way; and
- Is able to make informed and responsible decisions with regard to actions that may affect climate.

-- *Climate Literacy: The Essential Principles of Climate Science*, U.S. Global Change Research Program, at:
https://downloads.globalchange.gov/Literacy/climate_literacy_highres_english.pdf.

In addition, the *Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources* called for the development of a framework for education and training to ensure climate literacy in the federal workforce. Subsequently, the *Federal Framework for Building Climate Literacy and Capabilities* was published December 15, 2015. The Framework describes the importance of a workforce that is able to:

- Understand the diverse range of impacts that a changing climate has on natural, cultural, and historic resources and infrastructure, including the underlying scientific principles, historic trends in natural resource conditions, modeled projections of future changes, and uncertainties associated with such projections;
- Critically assess the adequacy of existing institutional planning and decision-making processes within the context of climate risks;
- Routinely assess and communicate the climate risks associated with continuing or departing from business-as-usual operations, including the vulnerability of managed systems; and
- Communicate meaningfully with the public to invite participation in climate preparedness, resilience, and adaptation.

To achieve these objectives, several types of training are needed to meet the needs of different types of users. Training for the general workforce can be basic while resource managers and decision makers may need more advanced training. Additionally, different missions involve a variety of disciplines and information needs, therefore special attention must be paid to developing training that is directly applicable and that equips personnel with specialized functions.



Conceptual diagram of educational, training, and developmental efforts leading to increased climate preparedness. -- *Federal Framework for Building Climate Literacy and Capabilities*, December 15, 2015

The activities described in this chapter address these recommendations. Furthermore, the proposed work builds on a number of efforts that federal agencies have made in the last several years. Some examples of progress to date include:

- The Bureau of Reclamation, Army Corps of Engineers, the University Corporation for Atmospheric Research's COMET MetEd program, along with other partners, have developed training for water resource professionals incorporating climate science into

hydrologic assessment studies (<http://www.ccaawwg.us/index.php/education/recent-training>).

- USEPA and its partners present Climate Ready Water Utilities webinars for water utility managers (<http://www2.epa.gov/crwu>).
- NOAA and its partners have been hosting monthly webinars on “Climate Information for Managing Risks in Water Resources.” (<http://cpo.noaa.gov/ClimatePrograms/ClimateandSocietalInteractions/SARPPProgram/WebinarsandWorkshops.aspx>).
- The Fish and Wildlife Service has developed climate training for conservation professionals (<http://training.fws.gov/courses/programs/climate-change/>).
- The U.S. Forest Service has implemented comprehensive climate change education that provides a foundational overview of climate change science, the effects of climate change on forest and grassland ecosystems, and how the agency can respond to climate change through land management alternatives⁵². The agency also conducts water resource⁵³ and groundwater stewardship training sessions for land managers in National Forests that includes climate change impacts and adaptation options.
- USDA and its partners have convened a ThinkWater Education Summit to increase the impact of existing water education curriculum (<http://www.h2osummit.org/>).

Given the continuing need for training and outreach, and considering the work already underway by a number of agencies and collaboratives, the Workgroup will focus attention in three key areas that advance capacity to apply science-based information; integrate climate resilience into federal agency missions and operations; and support communities to enhance resilience⁵⁴:

1. Increase involvement in the U.S. Climate Resilience Toolkit Water Resource Management Theme;
2. Support and enhance the Climate Change and Water Working Group Professional Development Series; and
3. Engage State Water Resource Research Institutes on Building Climate Resilience.

3.1 RECOMMENDATION: INCREASE INVOLVEMENT IN THE U.S. CLIMATE RESILIENCE TOOLKIT WATER RESOURCE MANAGEMENT THEME

The CRT⁵⁵ is a key component of the Climate Action Plan ‘s charge to build a centralized website that can better convey data, information, and tools to the public so they can better understand their risks and vulnerabilities to a changing climate and improve their resilience to extreme

⁵² Climate Change Resource center, <http://www.fs.usda.gov/ccrc/education>.

⁵³ Water Resources Management for Line and Staff Officers (WRMLO) Training, <http://www.fs.fed.us/biology/education/workshops/wrmlo/>.

⁵⁴ *Supra* Note 2; *Opportunities to Enhance the Nation’s Resilience to Climate Change*. The actions listed here support all three themes.

⁵⁵ Climate Resilience Toolkit, <https://toolkit.climate.gov/>.

events. Under NOAA’s leadership, federal agencies have been working towards answering users’ calls for a one-stop shop for climate adaptation information. The Toolkit provides scientific tools, information, and expertise to help those interested in managing their climate-related risks and opportunities. Within the Toolkit are resources available by various topics, including water resource management.

The Workgroup is uniquely positioned to add content and increase the capabilities of the Toolkit’s Water Resource Management Theme to provide purposeful climate and hydrological information, tools, and training for decision and policy makers. The Workgroup should ensure that the Water Resource Management Theme is populated with information and training that meets the needs of a wider variety of water resource professionals grappling with climate-related risks and opportunities. In addition, the Workgroup should ensure that the site is kept up to date as new tools become available.

3.1.1 Strategic Action – Develop learning progressions to improve the utility and accessibility of the Climate Resilience Toolkit Water Resource Management Theme

While the Toolkit provides a variety of resources and educational opportunities for its users, training resources are listed without sorting for skill levels and types of training. As a result, navigating the toolkit for those with limited climate-related experience may be daunting while those with more knowledge may find it cumbersome. This issue can be addressed by developing a “learning progression” – that is, a system to rate and organize the existing and available training according to a knowledge progression. Under the guidance of the Toolkit organizers, Workgroup members will work with their respective user communities to inventory readily available trainings, recommend sequences for acquiring knowledge for water resource managers, including those with both little and substantial understanding of climate processes, and ultimately to use these progressions to identify information gaps. These are just two examples of ways to improve delivery of appropriate and useful training for the Toolkit’s Water Resource Management Theme users.

3.1.2 Strategic Action - Ensure new water-related training opportunities are accessible through the Climate Resilience Toolkit

Federal agencies continue to develop information and training targeted to their constituents that are useful to a variety of users. However, there is potential for federal agencies to duplicate efforts, for example, by creating similar training such as Climate 101-type lessons. To ensure comprehensive access to available information and to avoid duplication of effort, the Workgroup should ensure that new offerings are routinely linked to the Toolkit.

Further, while the Toolkit has many different offerings, some users need instruction on how to apply them, especially with regards to more complex scientific information such as models employing downscaled climate projections that are difficult for many to understand and apply to their local situations. To fill this need, the Workgroup should collaborate with the NOAA

outreach team to conduct live and recorded webinars demonstrating use of the tools for beginners, intermediate and advanced users, all of which can then be posted online.

3.1.3 Strategic Action - Build a network of technical expertise on water and climate change, available on request

Currently users of the Toolkit can access experts through the “Expertise” section, which consist primarily of state climatologists and federal staff involved with the USDA Climate Hubs, NOAA’s RISAs, and USGS’ CSCs and LCCs. The expertise section of the Toolkit should be expanded to include other federal agency expertise across the country relevant to water resource managers, including regional, local, tribal, and academic experts as well as universities’ Cooperative Extension Services and Water Resources Research institutes.

3.1.4 Strategic Action - Form stakeholder partnerships to improve delivery of training on use of existing tools and to identify new training needs

The Workgroup should form a stakeholder partnership to evaluate existing water-related tools and identify gaps to be filled. At a minimum, these partnerships should address basic climate literacy; intensive and discipline-specific training and targeted workshops; and climate leadership development. Several private sector and nonprofit organizations have developed their own delivery mechanisms, such as the Climate Adaptation Knowledge Exchange (CAKE), Association of Climate Change Officers (ACCO), Climate Central, and others. These voices add innovative and creative perspectives that should be considered for inclusion in the Climate Resilience Toolkit to fill out the one-stop shop concept.

Further, the President’s Council of Advisors for Science and Technology (PCAST)⁵⁶ recommends that the federal government improve development and dissemination of information relevant to the private sector through public-private partnerships. The Workgroup will specifically reach out to private sector decision makers in the water sector to improve relevant offerings in the Climate Resilience Toolkit and to improve outreach.

3.1.5 Strategic Action - Develop a focused communication and outreach effort to expand awareness of the Toolkit offerings

To date, the focus of Toolkit activity among federal agencies has been primarily to build and populate it. In order to increase awareness of how Toolkit content could help communities, the Workgroup recommends redoubling outreach efforts. Furthermore, messaging and content of outreach is best targeted to particular communities of practice. The Workgroup will work with NOAA to develop water-related outreach, including considering convening a workshop with water-related intermediary organizations. This could help with outreach as well as understanding

⁵⁶ President's Council of Advisors on Science and Technology, <https://www.whitehouse.gov/administration/eop/ostp/pcast>.

unmet user needs. Such engagement has the potential to provide use cases for additional case studies to expand the Toolkit content as well.

3.2 RECOMMENDATION: SUPPORT AND ENHANCE THE CLIMATE CHANGE AND WATER WORKING GROUP PROFESSIONAL DEVELOPMENT SERIES

The federal Climate Change and Water Working Group (CCAWWG) was formed in 2007 to advance engineering and scientific collaborations in support of water management under a changing climate. It is an effective working-level forum among federal agencies that fosters communication, as well as operational, and research partnerships to meet user needs across the water resources and science communities of practice. Since 2012, CCAWWG agencies have been working with the University Corporation for Atmospheric Research COMET MetEd Program⁵⁷ and NOAA RISAs to develop climate change training resources⁵⁸. Several online and classroom courses have already been developed and delivered through COMET MetEd. The knowledge, capabilities and insights developed through this activity provide a guide for future efforts.

Two COMET MetEd Professional Development Series have been developed and piloted:

- (2015-present) General Water Resource Audiences: *Integrating Climate Change Adaptation into Water, Environmental, and Land Resources Management*
- (2012-present) Water Resource Technical Professionals: *Assessing Natural Systems Impacts under Climate Change*

The series feature a mix of instructor-led and online, self-paced courses, with the latter served through COMET's MetEd website.

3.2.1 Strategic Action - Continue to add new content to the Climate Change and Water Working Group Professional Development Series

Climate training collaborators continue to develop, pilot and deliver courses in both series. Planned offerings in 2016 include the following instructor-led courses unless otherwise noted:

- General Water Resource Audiences: (Winter 2016) General Principles of Climate Change Integration into Water Management (*online*); (Spring 2016) Integrating Climate Change into Long-term Planning and Environmental Compliance.

⁵⁷ The COMET® MetEd Program was established in 1989 by UCAR and NOAA's National Weather Service to promote a better understanding of meteorology among weather forecasters. The COMET MetEd mission has expanded, and today COMET MetEd uses innovative methods to disseminate and enhance scientific knowledge in the environmental sciences. See: http://www.comet.ucar.edu/who_about_us.php

⁵⁸ <http://www.cawwg.us/index.php/education/recent-training>

- Water Resource Technical Professionals: (Spring 2016) Sedimentation Impacts under Climate Change; (Summer 2016) Coastal Impacts and Vulnerability under Sea Level Change; (Fall 2016) Hydrologic Impacts under Climate Change.

After 2016, the development partners should continue to add course subjects with both online and instructor-led format, where initial instructor-led offerings are residence-based followed by future offerings converted to virtual format that allows greater remote participation at lower cost.

3.2.2 Strategic Action – Work with the Climate Change and Water Working Group to identify gaps in training and develop courses to broaden offerings

The Climate Change and Water Working Group (CCAWWG) offers a successful model for inter-agency collaboration for developing professional coursework. While coursework has, to date, been developed largely for personnel in operational agencies such as the Bureau of Reclamation and the Corps of Engineers, students from state and local agencies and several non-profit organizations have been recruited and have successfully taken these courses as well. Furthermore, the physical hydrology training created to date is common to many other impacts assessments and is useful as primary input to a range of potential users, as evidenced by the wide range of students already benefiting from this training series. It is intended that other federal agencies will continue to add professional development course work building on this foundation.

The Workgroup agencies will work (as is applicable) with CCAWWG and COMET MetEd to identify the most needed course topics and develop additional coursework that will serve policymaking and operational demands relevant to their agencies and their constituencies.

3.2.3 Strategic Action - Identify ways to sustain the Climate Change and Water Working Group Professional Development Series and expand the student base

The CCAWWG professional development series is intended to serve the demand for technical and managerial training while becoming a financially sustainable activity fueled and funded by broader demand from private and public sector users. The Workgroup will collaborate with CCAWWG to identify ways to sustain the platform, ensure that agency personnel are taking advantage of the training opportunities, and expand the non-federal student base. Such an effort would require exploring marketing and pricing methods and ways to offer competitive incentives for seeking professional continuing education courses, working with federal human resources offices to develop methods for incentivizing uptake, and engaging senior managers in adopting policies for taking these trainings.

3.3 RECOMMENDATION: ENGAGE STATE WATER RESOURCE RESEARCH INSTITUTES ON BUILDING CLIMATE RESILIENCE

3.3.1 Strategic Action - Engage with State Water Resources Research Institutes to advance research and education on building resilience in the water sector

State Water Resources Research Institutes (WRRI) are congressionally authorized federal-State partnerships which facilitate research to aid in the resolution of state and regional water problems, promotes the dissemination of research results, provides training of scientists and engineers through their participation in research, and provides competitive grants. The 54 institutes or centers, collectively known as the National Institutes for Water Resources (NIWR), are supported by USGS through Annual Base Grants, National Competitive Grants, Coordination Grants, and a Student Internship Program. They are located at land-grant universities or colleges/universities designated by a governor or state legislature.

These important institutes are in a position to materially advance the nation’s resilience to climate change. The Workgroup will engage with WRRI to identify opportunities to advance research and education on building resilience in the water sector.⁵⁹

There is one issue that will define the contours of this century more dramatically than any other and that is the urgent and growing threat of a changing climate.

- President Barack Obama, September 2014, addressing the United Nations



Photo courtesy of the Environmental Protection Agency

⁵⁹ See: <http://water.usgs.gov/wrri/>

4 WORKGROUP MANAGEMENT AND COORDINATION

Since its inception in 2009, the Workgroup has been co-chaired by CEQ, USGS, and USEPA and has had active participation of six to eight other agencies concerned with the management of water resources in a changing climate. The Workgroup serves three key functions:

- to facilitate interagency coordination, collaboration, and dialogue on climate change and water matters;
- to ensure long-term continuity and representation about water-related climate change issues; and
- to identify and address evolving priorities for effective management of water resources as the climate changes.

Over the past five years federal activity on climate change adaptation has increased as federal, state, and tribal governments, local communities and other stakeholders seek guidance on addressing climate change. The need for the kind of role performed by this Workgroup is expected to continue for the foreseeable future given the importance of managing water resources in a changing climate and the ongoing challenges. This is underscored by the objectives laid out in the *Opportunities Report*, to guide sustained and coordinated actions among federal agencies and to empower stakeholders to continue working with federal agencies on shared resilience priorities. In particular, the following actions directly apply to the recommendations that federal agencies support cross sector collaboration, build capacity and meaningfully engage state, tribal, and local leaders, and continue to integrate climate resilience into federal agency missions, operations and cultures.

Recognizing resource constraints in light of the wide range of activities underway, it remains a priority to:

1. Ensure effective support for the Workgroup to maintain continuity of interagency collaboration and leadership on climate change adaptation among federal water resource agencies; and
2. Expand collaboration and communication with partners and stakeholders.

4.1 RECOMMENDATION: ENSURE EFFECTIVE SUPPORT FOR THE WORKGROUP TO MAINTAIN CONTINUITY OF INTERAGENCY COLLABORATION AND LEADERSHIP ON CLIMATE CHANGE ADAPTATION AMONG FEDERAL WATER RESOURCE AGENCIES

To date, three agencies have served as workgroup co-chairs: USGS (a research agency), USEPA (a policy agency), and CEQ (the Administration). Initially, CEQ provided lead staff support with the assistance of USEPA and USGS. Since 2012, the lead staff support role has been assumed by USEPA. In addition, CEQ's leadership has been – and continues to be - essential for ensuring communication between the Workgroup and the various other activities initiated by the Administration over the years.

4.1.1 Strategic Action – Rotate Workgroup leadership among member agencies to provide fresh perspectives in leadership

The Workgroup recommends that the leadership structure be reevaluated to share responsibilities and to adapt to changing needs. One recommended option would be to have the science agency and policy agency leadership role rotate every other year. In other words, each year one of the two agency co-chairs will rotate out and a new co-chair from a member agency will rotate in as agreed to by Workgroup members. Thus, each agency will serve in a leadership role for two years. CEQ would remain a co-chair throughout. This structure serves three purposes: it provides continuity of structure, it shares the role of responsibility, and it brings in fresh perspective on the leadership of the Workgroup.

4.1.2 Strategic Action – Strengthen staffing to support the Workgroup

An effective coordination mechanism depends upon the ability to maintain ‘the big picture,’ to serve as a central coordinator, and to engage with activities that are not directly and immediately related to the activities that Workgroup members are implementing. As the nation’s concerns with climate change ramp up, coordination becomes more essential. The Workgroup has had an effective coordination function to date, but alternative staffing arrangements that could provide more robust support need to be evaluated. The co-chairs will seek to identify a means to improve availability of staff support to ensure the robust functioning of the Workgroup, including support for:

- Workgroup operations, e.g., convening meetings, producing reports and workplans;
- Implementing key climate adaptation actions and consulting with member agencies;
- Coordinating with other federal climate change adaptation activities, e.g., the National Ocean Policy implementation team; Fish, Wildlife and Plants Strategy Joint Implementation Working Group; Climate and Natural Resources Working Group, Climate Data and Tools Initiative, National Drought Resilience Partnership, U.S. Global Change Research Program, and others that may be formed in the future;
- Engaging and supporting the Climate Workgroup of the ACWI⁶⁰ and finding opportunities to engage stakeholders in other forums;
- Engaging federal agencies that may not currently be members of the Workgroup, e.g., as the U.S. Fish and Wildlife Service and the National Marine Fisheries among others; and
- Identifying opportunities to integrate the Workgroup with regional federal initiatives.

⁶⁰ ACWI is an existing public advisory body 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. In 2012, in response to a recommendation in the 2011 NAP, ACWI established the Subcommittee on Water Resources Adaptation to Climate Change (herein referred to as the ACWI Climate Workgroup). More information on ACWI is available at: http://acwi.gov/climate_wkg/index.html.

4.2 RECOMMENDATION: EXPAND COLLABORATION AND COMMUNICATION WITH PARTNERS AND STAKEHOLDERS

4.2.1 Strategic Action – Continue engagement with the Advisory Committee on Water Information Climate Workgroup

The Climate Workgroup of the ACWI is an important venue for dialogue between Federal agencies and state, tribal, local, and private sector water resource stakeholders. The 40-member committee has been a valuable source of input and feedback, and the Workgroup intends to continue to support and engage with it.

4.2.2 Strategic Action – Convene a dialogue with the NOAA Office of Water Prediction to promote inter-agency collaboration on building resilience to climate change

NOAA’s National Weather Service recently formed a new Office of Water Prediction and announced the opening of the new National Water Center with the mission to strengthen water prediction services. A key product of the Center is a National Water Model that was initially released in August 2016 to strengthen predictions of streamflow in three forecast configurations (i.e.; short range; 0-15 hours; medium range; 0 5 days and long range; 0 – 30 days). The new model provides hydrologic forecasts at 2.7 million locations nationwide, up from 4000 locations previously, and is intended as a powerful tool to aid communities in adapting, preparing for, and responding to heavy precipitation, extreme flood and drought conditions. The Center complements the existing regional River Forecast Centers and other weather-related decision-support services that NOAA provides.

Given the variety of activities underway throughout the Federal government and private sector to modernize water data systems and methods for understanding, planning for, and responding to the impacts of climate change, it is essential to ensure that efforts are coordinated, integrated and communicated. The Workgroup will convene a dialogue in support of these goals and invite the NOAA Office of Water Prediction to join the Workgroup.



Photo courtesy of Trisha Shears

APPENDICES

Appendix A: Opportunities to Enhance the Nation's Resilience to Climate Change

Appendix B: Inventory of Major Hydro-climatic Data Collection Systems in the United States

Appendix C: Regional Collaborations

Appendix D: Summary of Strategic Actions

APPENDIX A: OPPORTUNITIES TO ENHANCE THE NATION’S RESILIENCE TO CLIMATE CHANGE
Council on Climate Preparedness and Resilience, October 2016

Theme	Opportunities for Future Federal Action
Advancing and Applying Science-Based Information, Technology and Tools to Address Climate Risk	Improve awareness and dissemination of climate information
	Enhance usability of climate tools for decision-making
	Facilitate co-production of knowledge and tools
	Improve understanding of the economics of climate change
	Evaluate progress and performance of resilience investments
	Support cross-sector collaboration to advance research and development
Integrating climate resilience into federal agency missions, operations and culture	Strengthen resilience coordination across federal agencies
	Strengthen federal workforce capacity through leadership direction and training
	Expand incentives to make existing and future infrastructure more resilient
	Address national security risks from climate change
	Conserve, restore and manage ecosystems to enhance resilience
	Apply climate-resilient approaches to international development
Supporting community efforts to enhance climate resilience	Build capacity, meaningfully engage the community and invest in local leaders
	Strengthen place-based approaches to climate resilience
	Integrate resilience into social service delivery
	Improve navigability of federal resources
	Encourage broad adoption of pre-disaster hazard mitigation

APPENDIX B: INVENTORY OF MAJOR HYDRO-CLIMATIC DATA COLLECTION SYSTEMS IN THE UNITED STATES

Note: this is not a comprehensive list but is provided as an initial inventory

Variable	Network or Database	Agency	Mission	Status	Gaps
Streamflow	National Water Information System (NWIS) http://waterdata.usg.gov/nwis River information: http://water.weather.gov/ahps	U.S. Geological Survey NOAA NCEI	Provides streamflow information for water management, engineering design, emergency planning, recreation, and scientific study	Funding for 8100+ real time gages comes from a mix of federal, state, and local sources.	There are clear differences in the density of the streamflow network in different parts of the country. Additional analysis is needed to optimize addition of new gages for the purposes of climate monitoring.
Water Temperature and Other Water Quality Variables	National Water Information System (NWIS) http://waterdata.usg.gov/nwis	USGS	Provide current and historical information on water quality for the United States.		The availability of historical records varies greatly by constituent and location in the United States
Physical, Chemical and Biological	National Stream Internet http://www.fs.fed.us/rm/boise/AWAE/projects/NationalStreamInternet.html	U.S. Forest Service	Statistical and geospatial framework to support robust inferences about stream network conditions		
Water Temperature	NorWeSt http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html	U.S. Forest Service	Based on the National Stream Internet, for current and future conditions under various climate change scenarios		
Meteorological Variables	Quality Controlled Local Climatological Data (QCLCD)	NOAA-NCEI	National and global datasets on meteorology and climate-related variables.	Many different datasets are available including data from land-based	

	https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd Global Historical Climatology Network-Daily (GHCN-D) https://www.ncdc.noaa.gov/oa/climate/ghcn-daily/ Precipitation Frequency: http://www.nws.noaa.gov/oh/hdsc			observations, radar observations, and satellite observations.	
Integrated Water Modeling	http://water.noaa.gov/ http://water.noaa.gov/about/nwm	NOAA National Weather Service, Office of Water Prediction	Continental-scale hydrologic forecasting system, connecting atmospheric conditions to river and streamflow forecasts, including a water information mapping interface designed to integrate a range of water information.	Experimental design became operational in August 2016. Currently includes snow depth and snow water equivalent. In the future, will migrate river observation and forecast information and precipitation frequency estimates.	Content from additional sites will be migrated to this new site over the few years.
Soil Moisture	Soil Climate Analysis Network (SCAN)	USDA Natural	As part of the Snow Survey and Water Supply	A typical SCAN site monitors soil moisture	Numerous soil moisture networks across the U.S. are managed by

	http://www.wcc.nrcs.usda.gov/scan/	Resources Conservation Service	Forecasting Program, USDA administers a soil climate monitoring program consisting of 200 automated data collection sites focusing on agricultural areas throughout the U.S.	content at several depths, air temperature, relative humidity, solar radiation, wind speed and direction, liquid precipitation, and barometric pressure.	different federal, state and university groups. A coordinated effort to incorporate these networks into a National Soil Moisture Network, combining in situ measurements with remote sensing data collection and modeling, would provide a single product. The different networks would need a common set of standards and specifications for sensors, data format and other parameters. Additional in situ stations would be needed in areas of sparse coverage to allow for adequate spatial distribution of data collection.
Snow	<p>Snow Survey and Water Supply Forecasting Program http://www.wcc.nrcs.usda.gov/partnerships/links_wsfs.html</p> <p>Snow Information: http://www.nohrsc.noaa.gov</p>	<p>USDA Natural Resources Conservation Service</p> <p>NOAA NCEI</p>	To provide critical high elevation climate information from the major water yield areas of the mountainous west and play a key role in providing near real-time precipitation, air temperature and snowpack information to forecast streamflow volumes	Over 1,100 manual snow courses and 865 automated SNOTEL sites across the western US. Expansion in the number of automated is needed.	There are some networks in the eastern US, including data collection for water supplies for NYC and in Maine, but otherwise in situ snowpack measurements for much of the country does not exist. Increased snowpack data collection using automated stations and potentially volunteer observers, similar to CoCoRaHS, combined with remote sensing, such as NOAA's NOHRSC, could improve assessment of annual snowpack.
Groundwater	National GW Monitoring Network	FACA on Water Informa-	Integrate groundwater measurements from different networks into	Integration of networks is just beginning.	Includes USGS Climate Response Network that monitors wells sensitive to climate conditions.

	http://cida.usgs.gov/ngwmn/	tion (ACWI) managed by USGS	one nationally accessible framework. Groundwater can be an integrator of short and long-term climate signals; thus long-term groundwater data can be valuable for monitoring climate effects.	An expansion of the USGS Climate Response Network is underway in support of research on climate effects. The ACWI Subcommittee on Ground Water is building a National Groundwater Monitoring Network composed of data from willing State and federal agencies. effects research.	Incomplete in spatial coverage; gaps in monitoring groundwater quality and deep aquifers. A network sites providing uninterrupted, long-term water level or spring discharge records can be supplemented with data collected by federal and State agencies. Implementation of these two networks is in the early stages. Support for their continued development is needed to assure that these critical data will be available for future climate
Wetlands	National Wetland Inventory 2.0 https://www.fws.gov/wetlands/ National Wetland Condition Assessment (NWCA) https://www.epa.gov/national-aquatic-resource-surveys/nwca	U.S. Fish and Wildlife Service USEPA	Provides wetland maps geospatial data, and wetland trends to resource managers and the public; includes a Wetland Mapper; indicators of chemical, physical and biological integrity of wetlands.		
Water Use and Availability	NWISWeb interface Water Data for the Nation http://water.usgs.gov/watuse/data/	USGS	The USGS has laid a foundation of water use data through its Water Use in the U.S. Surveys, carried out every five	Data compiled from state and local sources on a 5-year cycle.	Need support for the USGS WaterSMART initiative to: - develop platforms to integrate data needed to help water managers assess water

			years since 1950. The USDA, DOE, and EPA also have programs that consider water use.	There is limited site-specific data and information on consumptive use.	<p>availability and use for both surface water and groundwater systems.</p> <ul style="list-style-type: none"> - develop a site-specific water use database for public water systems to better assess consumptive use of irrigation by better estimating evapotranspiration. - develop metrics and indicators to assess water use. - support basin and geographic focus area studies that evaluate supply and demand
Multiple Variables	<p>FLUXNET</p> <p>http://fluxnet.ornl.gov/</p>	NASA	<p>Coordinates regional and global observations to measure the exchanges of CO₂, water vapor, and energy between terrestrial ecosystems and the atmosphere. Used to examine ecosystem dynamics to scale up the findings or to parameterize ecosystem models</p>		Limited in-situ monitoring data for calibration and validation of models of spatially distributed ET.
Public Health Data	<p>The Waterborne Disease and Outbreak Surveillance System</p> <p>http://www.cdc.gov/mmwr</p>	Center for Disease Control	<p>WBDOSS collects data on waterborne disease and outbreaks associated with recreational and drinking water, environmental, and undetermined water exposures.</p>	<p>Data collected have been published in CDC reports from 1971 to 1984 and in the Morbidity and Mortality Weekly Report, since 1985.</p>	<p>Expand state waterborne disease surveillance capacity in Great Lakes basin states to improve disease surveillance systems, including for water quality issues such as harmful algal bloom events & illnesses.</p>

				Data on waterborne diseases in the United States are documented and reported by state and local health departments to the CDC.	
Local and Traditional Knowledge	<p>The Local Environmental Observer (LEO) Network https://www.leonetwork.org/en/leo/about</p> <p>Citizen Science Portal https://www.citizenscience.gov/</p>	<p>Alaska Native Tribal Health Consortium</p> <p>General Services Administration and the Wilson Center</p>	<p>LEO is a network of local observers and topic experts who share knowledge about unusual animal, environment, and weather events.</p> <p>Citizen scientists can provide information that would not otherwise be available due to time, geographic, or resource constraints.</p>	<p>LEO helps the tribal health system and local observers to share information about drivers of environmental change. Mobile app developed in 2015.</p> <p>Citizenscience.gov is designed to support use of crowdsourcing and citizen science.</p>	Tribal traditional knowledge is key to understanding how climate change is affecting native American cultures. LEO is one model for connecting tribal communities.
Aquatic Animal Health	<p>National Wild Fish Health Survey Database https://www.fws.gov/wildfishsurvey/</p>	U.S. Fish and Wildlife Service	To assess health status of aquatic animal health in the wild, FWS conducts opportunistic sampling of aquatic animals to assess their health status and maintains a Wild Fish Health Survey Database. The database includes a mapper that can be used to cross reference climate and water level data with health status.	<p>Data from 2009-2015 available to the public</p> <p>This is the only database of its kind and is widely used both nationally and internationally</p>	Limited to opportunistic data collection by partners and contains geographic limitations.

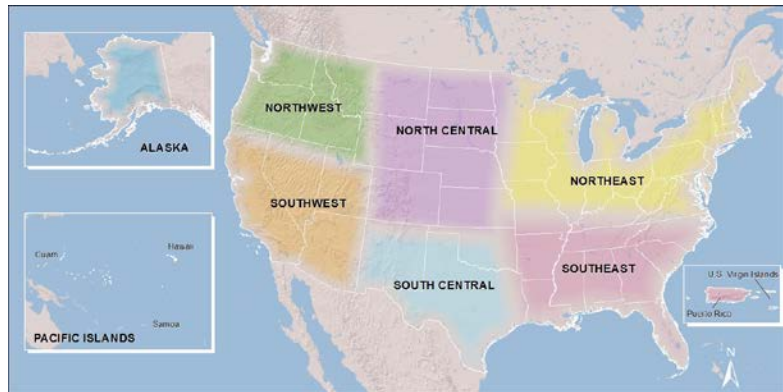
APPENDIX C: REGIONAL COLLABORATIONS

DOI Climate Science Centers

<https://www.doi.gov/csc>

The regional Department of the Interior Climate Science Centers (CSCs) partner with natural & cultural resource managers to provide science that helps fish, wildlife, ecosystems & the communities they support adapt

to climate change. The Climate Science Centers conduct cutting-edge research projects at local, regional and national scales; and produce products that include climate, water and ecosystem modeling, and geospatial, habitat, and species-level data. The CSCs are built upon federal-university partnerships; provide educational opportunities for students and early career scientists through fellowships, workshops, and training; and work with tribes and indigenous communities to better understand their specific vulnerabilities to climate change and to help them adapt to these impacts. The CSCs are dependent upon engagement with a community of stakeholders to define research priorities and initiatives. There are eight DOI CSCs:



- Alaska CSC
- Pacific Islands CSC
- North Central CSC
- South Central CSC
- Southeast CSC
- Northeast CSC
- Southwest CSC
- Northwest CSC

DOI Landscape Conservation Cooperatives (LCCs)

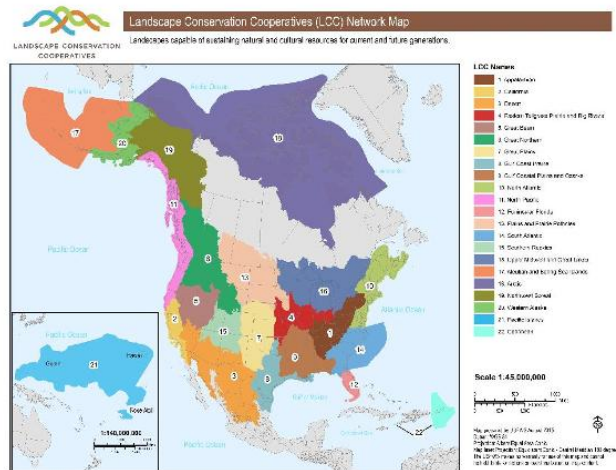
<https://lccnetwork.org/>

Managing the landscapes that provide our natural and cultural resources has become increasingly challenging. The Department of the Interior launched the Landscape Conservation Cooperatives (LCCs) to better integrate science and management to address climate change and other landscape scale issues. By building a network that is holistic, collaborative, adaptive, and grounded in science, LCCs are working to ensure the sustainability of our economy, land, water, wildlife, and cultural resources.

The 22 LCCs collectively form a network of resource managers and scientists who share a common need for scientific information and interest in conservation. Each LCC brings together federal, state, and local governments along with Tribes and First Nations, non-governmental organizations, universities, and interested public and private organizations. Our partners work collaboratively to identify best practices, connect efforts, identify science gaps, and avoid duplication through conservation planning and design.

The 22 DOI LCCs are:

- Aleutian and Bering Sea Islands
- Appalachian
- Arctic
- California
- Caribbean
- Desert
- Eastern Tallgrass Prairie and Big Rivers
- Great Basin
- Great Northern
- Great Plains
- Gulf Coast Prairie
- Gulf Coastal Plains and Ozarks
- North Atlantic North Pacific
- Northwest Boreal
- Pacific Islands
- Peninsular Florida
- Plains and Prairie Potholes
- South Atlantic
- Southern Rockies
- Upper Midwest and Great Lakes
- Western Alaska



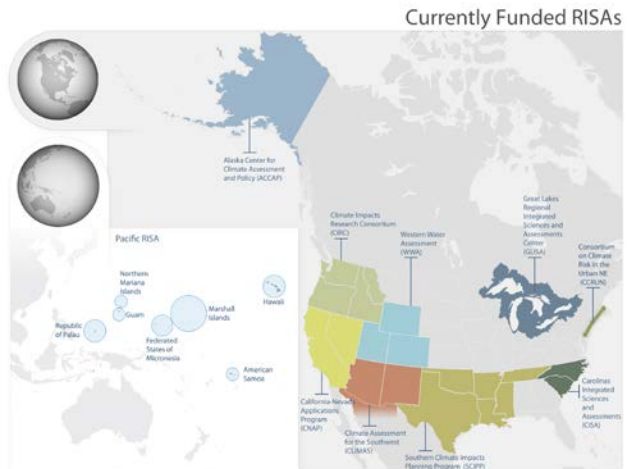
NOAA Regional Integrated Science and Assessments (RISAs)

<http://cpo.noaa.gov/ClimatePrograms/ClimateandSocietalInteractions/RISAProgram/AboutRISA.aspx>

NOAA’s Regional Integrated Sciences and Assessments (RISA) program supports research teams that help expand and build the nation's capacity to prepare for and adapt to climate variability and change. Central to the RISA approach are commitments to process, partnership, and trust building. RISA teams work with public and private user communities to advance understanding of context and risk; support knowledge to action networks; innovate services, products and tools to enhance the use of science in decision making; and advance science policy.

There are nine currently funded NOAA RISAs:

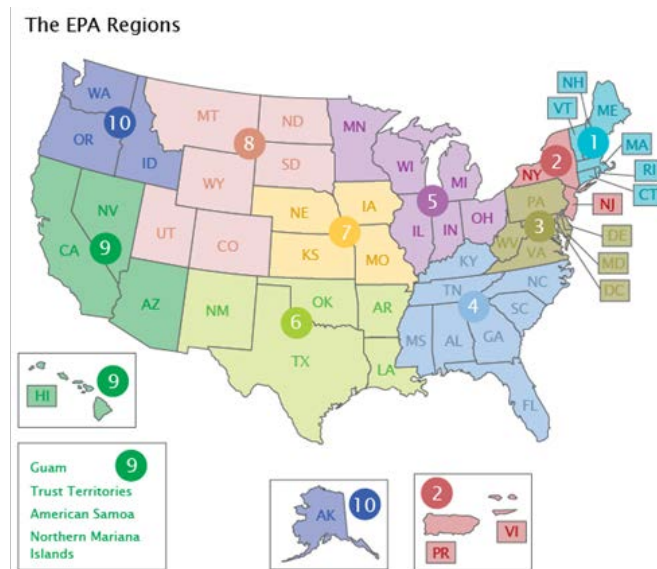
- Alaska Center for Climate Assessment and Policy (AACAP)
- California-Nevada Applications Program (CNAP)
- Climate Impacts Research Consortium (CIRC)
- Western Water Assessment (WWA)
- Climate Assessment for the Southwest (CLIMAS)
- Southern Climate Impacts Planning Program (SCIPP)
- Great Lakes Regional Integrated Sciences and Assessments Center (GLISA)
- Consortium on Climate Risk in the Urban Northeast (CCRUBN)
- Carolinas Integrated Science and Assessment (CISA)



U.S. Environmental Protection Agency

<http://epa.gov/climatechange/>
<http://www2.epa.gov/climate-change-water-sector>

EPA has ten regional offices across the country, each of which is responsible for several states and in some cases, territories or special environmental programs. EPA Regional Office managers and staff work with state and tribal governments in partnerships to implement environmental protection programs authorized under the Clean Air Act, Clean Water Act, Safe Drinking Water Act, Superfund, and Resource Conservation and Recovery Act or other environmental laws. Regional offices also assist local governments and other organizations in developing responses to

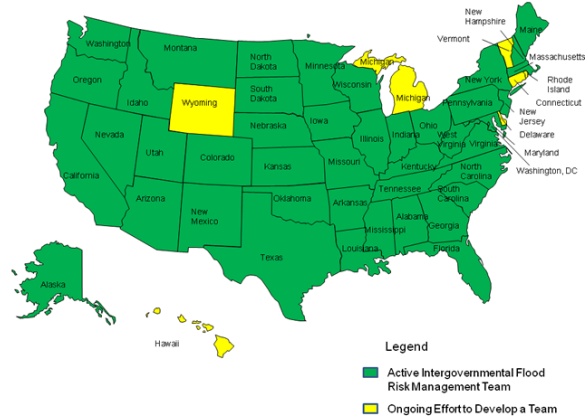


a range of environmental and public health challenges, including the impacts of a changing climate.

U.S. Army Corps of Engineers Silver Jackets

<http://silverjackets.nfrmp.us/>

Silver Jackets teams in states across the United States bring together multiple state, federal, and sometimes tribal and local agencies to learn from one another in reducing flood risk and other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when such events do occur. While some states do not use the “Silver Jackets” name, there are a growing number of states applying the Silver Jackets approach – the ultimate goal is a state-led interagency team in every state. No single agency has all the answers, but leveraging multiple programs and perspectives can provide a cohesive solution.



Although each state Silver Jackets team is unique, common agency participants include state agencies with mission areas of hazard mitigation, emergency management, floodplain management, natural resources management or conservation, etc. Federal participation typically includes the U.S. Army Corps of Engineers and the Federal Emergency Management Agency and often others such as the National Weather Service and the U.S. Geological Survey.

USDA Climate HUBS

<http://www.climatehubs.oce.usda.gov/>

The mission of USDA’s Climate Hubs is to develop and deliver science-based, region-specific information and technologies, with USDA agencies and partners, to agricultural and natural resource managers that enable climate-informed decision-making, and to provide access to assistance to implement those decisions. This is in alignment with the USDA mission to provide leadership on food, agriculture, natural resources, rural development, nutrition, and related issues based on sound public policy, the best available science, and efficient management.

The ten regional USDA Climate Hubs are:

- Northeast
- Southeast
- Caribbean
- Midwest
- Northern Forest



- Northern Plains
- Southern Plains
- Northwest
- Southwest
- California

APPENDIX D: SUMMARY OF STRATEGIC ACTIONS AND LEAD AGENCIES

Team 1: Data and Research (Team Lead: USGS)		
Recommendations	Strategic Actions	Lead(s)
1.1: Sustain and expand existing monitoring networks and data collection on hydrologic and meteorological conditions and water demand.	1.1.1 -Identify and address data gaps and needs for water resource management	USGS
	1.1.2 - Expand adoption of reference monitoring networks to establish baseline conditions for evaluating impacts due to climate change	EPA
1.2: Modernize statistical analyses of observational data sets to improve understanding of emerging trends associated with climate change.	1.2.1 - Update Precipitation Frequency Datasets	NOAA
	1.2.2 – Strengthen Flood Frequency Guidelines	USGS
	1.2.3 – Improve Streamflow Statistics	EPA
1.3: Improve reliability and accessibility of water-related projections of future conditions.	1.3.1 - Evaluate the feasibility of developing the capability to project water temperature under future climates	EPA
	1.3.2 - Evaluate the feasibility of integrating climate-impacted hydrology projections with projections of population and land use	EPA
1.4: Enhance water supply through innovative technologies	1.4.1 - Enhance water supply through investment in energy-water technologies	DOE
	1.4.2 - Improve Water Use Efficiency in Agriculture	USDA
	1.4.3 - Advance innovation in the use of aquifer storage and recovery	EPA, USDA
	1.4.4 – Promote innovative financing structures to incentivize investment in large scale green infrastructure projects to enhance water supply and water quality	EPA
	1.4.5 – Advance innovation in the use of water markets to increase cost effectiveness of projects that increase water quality and quantity	USDA

Team 2: Planning and Decision Support (Team Lead: USACE)		
Recommendations	Strategic Actions	Lead(s)
2.1: Advance regional coordination among federal water resource management agencies to support climate change adaptation and resilience efforts	2.1.1 - Develop new regional Federal Agency Support Teams (X-FAST) for water resources management	USACE
	2.1.2 - Expand engagement of federal water resource agencies in regional cooperative efforts on climate science and decision-making	DOI, NOAA, USDA
	2.1.3 - Encourage agencies to consider the effects of climate change on water resources and the implications for federal agency supply chains	DOD
	2.1.4 - Develop case studies on restoration of wetlands and forests to build resilience	EPA, USACE, USDA
	2.1.5 - -- Build the capacity of Silver Jackets teams to incorporate risks due to climate change in emergency planning	USACE
2.2: Develop guidance and provide assistance to communities and water resource managers on use of climate change information and tools for assessing vulnerability and building resilience	2.2.1 - Develop an online dashboard to help water resource managers and urban planners prepare for and respond to extreme events	NOAA
	2.2.2 - Streamline access to climate adaptation information for the water resource management theme of the U.S. Climate Resilience Toolkit	NOAA
	2.2.3 - Adopt a system for coordinating vulnerability assessments and advancing peer-to-peer learning	USGS
	2.2.4 - Continue to develop, distribute, and provide guidance on the use of projected future climate information for water resources management	NOAA
	2.2.5 - Evaluate options for providing credit within the FEMA Community Rating System for the development of watershed scale plans for managing flooding that consider projected climate changes	FEMA

Team 3: Training & Outreach (Lead: NOAA)		
Recommendations	Strategic Actions	Lead(s)
3.1: Increase involvement in the U.S. Climate Resilience Toolkit Water Resource Management Theme	3.1.1 - Develop learning progressions to improve the utility and accessibility of the Climate Resilience Toolkit Water Resource Management Theme	NOAA, EPA
	3.1.2 - Ensure new water-related training opportunities are accessible through the Climate Resilience Toolkit	NOAA, EPA
	3.1.3 - Build a network of technical expertise on water and climate change, available on request	NOAA
	3.1.4 - Form stakeholder partnerships to improve delivery of training on use of existing tools and to identify new training needs	NOAA, EPA
	3.1.5 - Develop a focused communication and outreach effort to expand awareness of the Toolkit offerings	NOAA
3.2: Support and enhance the Climate Change and Water Working Group Professional Development Series	3.2.1 - Continue to add new content to the Climate Change and Water Working Group Professional Development series	BuRec
	3.2.2 - Work with the Climate Change and Water Working Group to identify gaps and develop courses to broaden offerings	BuRec
	3.2.3 - Identify ways to sustain the Climate Change and Water Working Group Professional Development Series and expand the student base	BuRec
3.3: Engage State Water Resource Research Institutes on building climate resilience	3.3.1 - Engage with State Water Resources Research Institutes to advance research and education on building resilience in the water sector	USGS

Team 4: Management and Coordination (Co-Leads: USEPA, NOAA, CEQ)		
Recommendations	Strategic Actions	Lead(s)
4.1: Ensure effective support for the workgroup to maintain continuity of interagency collaboration and leadership on climate change adaptation among federal water Resource agencies.	4.1.1 – Rotate workgroup leadership among member agencies to provide fresh perspectives in leadership	CEQ, EPA, NOAA
	4.1.2 – Strengthen staffing to support the Workgroup	
4.2: Expand collaboration and communication with partners and stakeholders.	4.2.1 – Continue engagement with the Advisory Committee on Water Information Climate Workgroup	CEQ EPA NOAA
	4.2.2 – Convene a dialogue with the NOAA Office of Water Prediction to promote inter-agency collaboration on building resilience to climate change	

WORKGROUP MEMBERS

Co-Chairs

Council on Environmental Quality - Charles Kovatch
Environmental Protection Agency - Michael Shapiro
National Oceanic and Atmospheric Administration - Wayne Higgins
U.S. Geological Survey - Jerad Bales (retired)

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Rachel Grandpre
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Centers for Disease Control and Prevention

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Christopher Carlson
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Environmental Protection Agency

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Jeff Peterson

FEMA

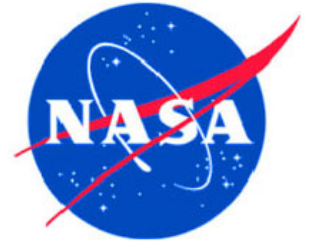
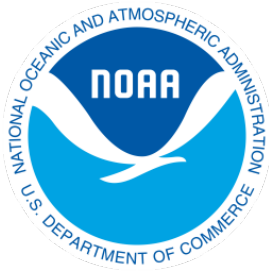
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