Addressing Climate Change in Long-Term Water Resources Planning and Management

User Needs for Improving Tools and Information

Executive Summary

US Army Corps of Engineers®

January 2011

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The full report can be downloaded from the Reclamation Web site at: www.usbr.gov/climate/userneeds.

A Joint Message from the Commissioner, Bureau of Reclamation, and the Director of Civil Works, U.S. Army Corps of Engineers:

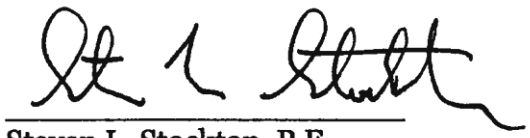
Water resources underpin our quality of life and our national economy. Climate change impacts to water and water-dependent resources present new and complex challenges to the water resources management community. Meeting these challenges will require close collaboration between the water resources management community and the science community to develop and apply new and improved scientific information and technical tools.

With this publication, the Bureau of Reclamation and the U.S. Army Corps of Engineers, as part of the Climate Change and Water Working Group, offer our joint agency perspectives on user needs we have identified to help us meet this challenge for long-term water resources planning. We also recognize the other Federal and non-Federal water resource organizations and interest groups that have contributed their perspectives to this document. We have published these contributed perspectives along with our own, and offer a synthesis of the collective messages heard.

We hope this document takes a step toward communicating a collective expression of needs from the water resources community of practice to the science community and fosters closer collaboration and expedited application of research results. As a next step, we encourage other water and natural resource user and coordination groups, such as the U.S. Department of the Interior (DOI) Landscape Conservation Cooperatives, to assist as new capabilities and new knowledge are applied and new perspectives and insights are gained.

We also encourage the science community to rally behind these needs with collaborative research and development (R&D) efforts to build the capabilities that we have identified. We look forward to effective, collaborative R&D across this community, including organizations such as the DOI Climate Science Centers, National Oceanic and Atmospheric Administration Regional Integrated Science and Assessment Centers, National Science Foundation and other Federal and non-Federal science organizations, as well as our own science capabilities. As water resource management agencies, we stand ready to work with the science community.

Michael L. Connor
Commissioner,
Bureau of Reclamation



Steven L. Stockton, P.E.
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Executive Summary

The Bureau of Reclamation (Reclamation) and the United States Army Corps of Engineers (USACE) recognize that there is a critical need to begin incorporating climate change science into the design, construction, and operations of our water resources management infrastructure. These two agencies, together with the United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA), formed an interagency working group called the Climate Change and Water Working Group (CCAWWG) in 2007 to provide scientific collaborations in support of water management as climate changes. In February 2009, the four agencies produced an interagency report, USGS Circular 1331, *Climate Change and Water Resources Management: A Federal Perspective*, which provides a foundation to guide future policies, methods, and technologies.

Building on the foundation established by USGS Circular 1331, CCAWWG is pursuing a collaborative process to better define the critical capability gaps that face the water management community and to define a sound science strategy for filling the information gaps and providing critical tools. The effort builds on chapter 6, table 2 of USGS Circular 1331 and is guided by the following objectives:

- *Consolidate the Needs of the Water Management Community* - Identify the common needs of the Federal and non-Federal water management community for information and tools required to support adaptation as climate changes.

- *Inform the Scientific Community* - Guide and foster Federal and non-Federal research and technology investments toward meeting these "user-defined" needs.

- *Teamwork* - Generate collaborative efforts across the water management and scientific communities to develop, test, and apply new methods, tools, and capabilities

- *Flexible and Inclusive* - Issue periodic updates as new information and additional perspectives are obtained. It is unrealistic to assume

that all relevant perspectives can be represented in the initial release of a user-needs document. The intent is to seed the initial release with a representative cross section of the other Federal and non-Federal water management perspectives and then use online networking technologies to accommodate input and perspectives across the water management community of practice.

To accomplish this aim, CCAWWG is developing four related documents describing water managers' needs for climate change information to support both short-term and long-term water resources planning and the complementary science strategy to address those needs. The four documents are as shown below, with the current document highlighted.

	Water Resources Planning Time Scale	
	< 5 years	> 5 years
User Needs	Short-Term Needs	Long-Term Needs
Science Strategy	Short-Term Science Strategy	Long-Term Science Strategy

This document, the Long-Term Needs document, describes the water management community's needs for climate change information and tools to support long-term planning. As two of the primary Federal representatives of the water management community, Reclamation and USACE technical specialists and program managers have worked with their planners, water operators, and environmental compliance managers to identify the information and tools most relevant to their programs. Reclamation and USACE also have engaged and consulted with other Federal, State, and local agencies and stakeholder groups that have a role in water and water-related resource management to identify complementary priorities and individual perspectives (see chapter 3 and appendix B).

At the same time, Reclamation and the USACE have begun work on the Short-Term Needs document, describing water managers' needs for information to better manage water resources under short-term climate variability and change. Climate variability involves fluctuations in climate conditions on time scales of months, years, and decades. Improved ability to forecast and use climate variability information would

greatly enhance the ability of water managers and water users to plan their short-term-operations and water delivery schedules. The influence of climate change on short-term climate variability is an additional factor that is now central to this area of concern.

In response to these user-needs documents, the USGS and NOAA will jointly prepare two documents describing respectively a science strategy for meeting short-term and long-term needs for information and tools. Development of those documents also will incorporate perspectives from other Federal and non-Federal representatives of the scientific community.

Note: This report refers to ***planning*** as the analyses conducted to inform decisions about water system development and management. In contrast, USACE defines ***Planning*** as a six-step process in accordance with *Economic and Environmental Principles and Guidelines for Water and Related Resources Implementation Studies* (Water Resources Council 1983) and as authorized by the Water Resources Development Act of 1986 (Public Law 99-662) (see Orth and Yoe 1997). The ***Planning*** process includes decisionmaking under uncertainty, based on information from these analyses. Although decisionmaking is not explicitly addressed in the ***planning*** definition of this report, many gaps in this report address how supporting analyses are affected by knowledge limits and uncertainties. Research to address such gaps, thus, should benefit decisionmaking in ***Planning*** processes.

Audience: This document is meant to help focus research and technology efforts to address information and tools gaps relevant to the water management user community. As such, the primary audience for this document is the research and technology community in position to address these gaps. Such community members include CCAWWG science agencies (NOAA, USGS), other Federal research entities and programs (e.g., National Science Foundation, National Aeronautics and Space Administration, U.S. Environmental Protection Agency, U.S. Department of Agriculture, U.S. Forest Service, Department of Energy), State and local

science centers, academic institutions, and the members of the practitioner community that support climate and water resources research.

Summary of Gap Categories: Technical climate change information may be incorporated into longer-term water resources planning using various methods. For this report, eight technical steps representative of these various methods are used to categorize tools and information needs (i.e., gaps). These steps are:

1. *Summarize Relevant Literature:* For a given planning study, this step involves identifying, synthesizing, and summarizing previous research on global to regional climate change and what it means for the region's water resources.

2. *Obtain Climate Change Information*: This step involves obtaining contemporary climate projections and associated uncertainties that may have been spatially downscaled to finer resolution desired for water resources planning at the regional to local scale. This step also involves consideration of paleoclimate proxies that may imply climate conditions different from those of the observed record.

3. *Make Decisions About How To Use the Climate Change Information*: From the body of climate projections surveyed, decisions must be made on which projections to use and which aspects of these projections to relate to planning assumptions on water supplies, water demands, and operating constraints.

4. *Assess Natural Systems Response*: Based on the preceding step's decisions, this step involves assessing the natural systems response under projected climate conditions. Results from these analyses will be used to set assumptions about future water supplies, water demands, and operating constraints. Types of natural systems responses include watershed hydrology, ecosystems, land cover, water quality, consumptive use requirements of irrigated lands, sedimentation and river hydraulics, and sea level rise.

5. *Assess Socioeconomic and Institutional Response*: This step involves assessing social, economic, and institutional responses to climate change that could influence planning assumptions concerning water demands and

operating constraints (e.g., constraints that determine source of supply preference and/or expected level of operating performance relative to objectives such as flood risk reduction, environmental management, water quality management, water allocation for agricultural and municipal use, energy production, recreation, and navigation).

6. *Assess System Risks and Evaluate Alternatives:* This step involves assessing system risks based on future planning assumptions (informed by Steps 4 and 5); and, as necessary, evaluating long-term management alternatives to address climate change risks. For example, many water resources management studies focus on operations risk and assumptions about future water supplies, demands, and operating constraints. In contrast, infrastructure safety or flood risk reduction studies focus on human safety and economic and environmental damages under assumptions about future extreme hydrologic event probabilities; and water quality studies focus on the interaction between the human activities, landscape hydrology, and aquatic systems.

7. *Assess and Characterize Uncertainties*: This step involves assessing and characterizing uncertainties accumulated during preceding steps (e.g., uncertainties of projecting future factors forcing climate, simulating climate, downscaling climate, assessing natural and social system responses, etc.).

8. *Communicating Results and Uncertainties to Decisionmakers:* This step involves aggregating information from previous steps and then communicating this distilled information to decisionmakers to support planning decisions.

Table ES-1 provides an initial list of gaps in tools and information associated with these steps. Given the geographic areas served by Reclamation and USACE, these gaps may be thought of as being nationally relevant. While this document presents gaps that are particularly relevant for management of Reclamation and USACE water supply and river regulation systems, it was envisioned that these gaps may be generally applicable for long-term management of any type of water infrastructure. To gauge this possibility, feedback on the gaps in table ES-1 was gathered from non-Federal organizations and other Federal agencies. The most-frequent relative priority (i.e., low, medium, high) assigned by Reclamation and USACE for each gap is shown next to the most frequent

relative priority received from all Federal (including Reclamation and USACE) and non-Federal respondents combined. In the event of a tie, the lower priority was assigned. For example, if one gap had an equal number of medium priority responses as high responses, then the gap was assigned a medium priority. An examination of table ES-1 shows the priority rankings assigned by Reclamation/USACE compare favorably with those assigned by all respondents combined with only minor differences (e.g., low versus medium or medium versus high) on 12 of the 39 gaps listed.

Table ES-1. Summary of gaps and relation to other needs assessments

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 1 – Summarize Relevant Literature			
1.01 Access to a clearinghouse of climate change literature relevant to water management or access to a bibliography of recommended literature to represent in literature syntheses.	Low	Low	CCAWWG 2008
1.02 Region-specific literature summaries, regularly maintained and peer-reviewed.	Medium	Medium	CCAWWG 2008
Step 2 – Obtaining Climate Change Information			
2.01 Improved skill in simulating long-term global to regional climate.	High	High	Reclamation 2007, Western States Water Council (WSWC) 2007
2.02 Downscaled data at finer space and time resolutions and for different variables.	High	High	CCAWWG 2008, WSWC 2007
2.03 Information on the strengths and weaknesses of downscaled data and the downscaling methodologies used to develop these data (including both statistical and dynamical methods and associated approaches for climate model bias-correction).	High	High	WSWC 2007
2.04 Indication of conditions of where and when the stationarity assumption of statistical downscaling may not hold (defined above) and should motivate use of dynamical downscaling techniques rather than statistical.	Medium	Medium	CCAWWG 2008, WSWC 2007

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Table ES-1. Summary of gaps and relation to other needs assessments (continued)

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 2 – Obtaining Climate Change Information (continued)			
2.05 Synthesis of sea level projection information and guidance on consistent use in planning for all Reclamation and USACE coastal areas.	Low	Low	
Step 3 – Make Decisions About How To Use the Climate Change Information			
3.01 Understanding on observed climate variability from daily to multidecadal time scales, which underpins interpretation of future variability in climate projections and its relation to planning assumptions.	High	High	Reclamation 2007, WSWC 2007
3.02 Understanding how to interpret future variability in climate projections and relevance to operating constraints on shorter- to longer-term time scales (from daily to multidecadal).	High	High	Reclamation 2007
3.03 Basis for culling or weighting climate projections (if at all) when deciding which projections to use in planning.	Medium	Medium	CCAWWG 2008
3.04 Guidance on how to appropriately relate planning assumptions to either *Period-Change* or *Time-Developing* aspects of climate projections when deciding how to use projections in planning.	Low	Medium	
3.05 Guidance on how to jointly utilize the longer-term climate variability from observed records, paleoclimate, and projected climate information when portraying drought and surplus possibilities in planning.	Medium	High	Reclamation 2007, CCAWWG 2008
3.06 Method and basis for estimating extreme meteorological event possibilities, deterministically or probabilistically, in a changing climate.	High	High	CCAWWG 2008

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Table ES-1. Summary of gaps and relation to other needs assessments (continued)

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 4 – Assess Natural Systems Response – Watershed Hydrology (WH), Ecosystems (E), Land Cover (LC), Water Quality (WQ), Consumptive Use on Irrigated Lands (CU), and Sedimentation and River Hydraulics (SRH)			
4.01 (*WH*) Guidance on strengths and weaknesses of watershed hydrologic models/methods to support scoping decisions in planning.	Low	Low	CCAWWG 2008
4.02 (*WH*) Understanding how climate change should impact potential evapotranspiration and how it is represented in watershed hydrologic models.	High	High	Reclamation 2007
4.03 (*WH*) Method and basis for estimating extreme hydrologic event possibilities, deterministically or probabilistically, in a changing climate. *(Similar to Gap 3.06 but focused here on hydrology rather than meteorological variables)*	High	High	CCAWWG 2008
4.04 (*WH*) Guidance on strengths and weaknesses of available versions of spatially distributed hydrologic weather data that may be used for both watershed hydrologic model development (Step 4) and in climate model bias-correction (Step 2).	Medium	Medium	
4.05 (*WH*) Understanding how climate change should impact groundwater recharge and groundwater interaction with surface water supplies.	Medium	Medium	Reclamation 2007, CCAWWG 2008
4.06 (*E*) Understanding how climate change should impact inland and coastal anadromous fisheries.	Medium	Low	CCAWWG 2008
4.07 (*E*) Understanding how climate change may impact riparian ecosystems and vegetation that affect both longer-term water budgets and ecological resources.	High	Medium	CCAWWG 2008
4.08 (*E*) Understanding translated into model frameworks for assessing climate change responses for fisheries, nonnative riparian vegetation, and other species or habitat conditions.	High	Medium	CCAWWG 2008

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Table ES-1. Summary of gaps and relation to other needs assessments (continued)

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 4 – Assess Natural Systems Response – Watershed Hydrology (WH), Ecosystems (E), Land Cover (LC), Water Quality (WQ), Consumptive Use on Irrigated Lands (CU), and Sedimentation and River Hydraulics (SRH) (continued)			
4.09 (*LC*) Understanding how climate and/or carbon dioxide changes should impact land cover communities that control natural evapotranspiration and soil erosion potential.	Medium	Low	Reclamation 2007, CCAWWG 2008
4.10 (*WQ*) Understanding how water quality characteristics depend on climatic variables and how dependencies may evolve in a changing climate.	High	High	
4.11 (*CU*) Understanding how climate and carbon dioxide changes should impact plant physiology, how impacts vary with crop type, and how impacts affect irrigation demand.	Medium	Medium	CCAWWG 2008
4.12 (*SRH*) Understanding how climate and/or land cover changes will change watershed sediment yield, changes in sediment constituency, and the resulting impacts on water resources.	Medium	Medium	
4.13 (*SRH*) Understanding how climate, land cover, and/or sedimentation changes will affect river and reservoir ice-event potential.	Medium	Low	
Step 5 – Assess Socioeconomic and Institutional Response			
5.01 Understanding how socioeconomic factors may affect flood risk reduction and reservoir regulation objectives in a changing climate (e.g., flood protection values, land management).	Medium	High	CCAWWG 2008
5.02 Understanding how socioeconomic factors may affect water and power delivery reliability, water allocations, as well as decisions on source of supply under a changing climate (e.g., groundwater pumping versus surface water diversion).	High	High	CCAWWG 2008

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Table ES-1. Summary of gaps and relation to other needs assessments (continued)

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 5 – Assess Socioeconomic and Institutional Response (continued)			
5.03 Understanding how institutional realities currently control socioeconomic responses to climate variability and could control socioeconomic responses under a changing climate.	Medium	Low	
Step 6 – Assess System Risks and Evaluate Alternatives			
6.01 Guidance on how to conduct an adaptation evaluation that efficiently explores and ranks strategy options, potentially using optimization techniques.	High	High	CCAWWG 2008
6.02 Guidance on how to portray realistic operator "learning" in evaluations supporting planning for climate change adaptation.	Low	Low	CCAWWG 2008
6.03 Guidance on how to assess the effect of planning proposals on climate.	Low	Medium	CCAWWG 2008
Step 7 – Assess and Characterize Uncertainties			
7.01 Uncertainty information on global climate projections data, including uncertainties about climate system science, portrayal in climate models, emissions scenario development, and simulation methods.	High	High	CCAWWG 2008
7.02 Uncertainty information on regional climate projections data, including uncertainties from choice of bias-correction and spatial downscaling methods.	High	High	CCAWWG 2008
7.03 Uncertainty in planning results stemming from method choices on how to use transient characteristics of climate projections in planning scenarios.	Medium	Medium	CCAWWG 2008
7.04 For each response analysis on a natural system, uncertainty information on system science and associated ways of portraying this science in a system model and the observations used to customize a model for a specific system.	Medium	High	CCAWWG 2008

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Table ES-1. Summary of gaps and relation to other needs assessments (continued)

Technical Planning Steps and Associated Gaps in Tools and Information	Priority Ranking[1]		Other Assessments Having Related Discussion
	Reclamation/ USACE	All Respondents	
Step 7 – Assess and Characterize Uncertainties (continued)			
7.05 For each response analysis on a socio-economic system, uncertainty information on system science and associated ways of portraying this science in a system model and the observations used to customize a model for a specific system.	High	Medium	CCAWWG 2008
Step 8 – Communicating Results and Uncertainties to Decisionmakers			
8.01 Guidance on strengths and weaknesses of various methods for communicating results and uncertainties affected by using climate projection information.	High	High	CCAWWG 2008
8.02 Guidance on how to make decisions given the uncertainties introduced by considering climate projection information.	High	High	

[1] Color shading indicates priority rating on research to address gaps: low (yellow), medium (light orange), and high (dark orange).

Gaps are more fully discussed in section 2.4, and the priority ratings received during the perspective gathering process is discussed in section 3.0 (e.g., inviting prioritization of research to address gaps, inviting general comments, and inviting suggestions on missing gaps). A complete record of perspectives received, including relative priority assignments, are included in appendices B–D.

The relative priority ratings assigned to each of the gaps listed in table ES-1 were also averaged across the gaps associated with each Technical Step (also known as Gap Category) to derive a relative priority that could be associated for each Technical Step. These results are shown in table ES-2.

Table ES-2. Prioritization of research to support each gap category

Technical Step	Gap Category (Technical Step)	Average Priority Rankings[1]	
		USACE/ Reclamation	All Respondents Combined
1	Summarize Relevant Literature	1.5	1.5
2	Obtaining Climate Change Information	2.5	2.4
3	Make Decisions About How To Use the Climate Change Information	3.0	2.7
4	Assess Natural Systems Response	3.0	1.9
5	Assess Socioeconomic and Institutional Response	2.5	2.3
6	Assess System Risks and Evaluate Alternatives	1.5	2.0
7	Assess and Characterize Uncertainties	2.0	2.6
8	Communicating Results and Uncertainties to Decisionmakers	3.0	3.0

[1] Low = 1, Medium = 2, High = 3.

In terms of summary messages heard, Reclamation and the USACE indicate relatively greater concern for the following three Technical Steps:

- Step 3: Make Decisions About How to Use the Climate Change Information
- Step 4: Assess Natural System Responses
- Step 8: Communicating Results and Uncertainties to Decisionmakers

This compares favorably to the perspectives of water managers from all respondents combined with agreement that both Steps 3 and Step 8 deserve the greatest concern. However, all respondents combined indicate a greater concern for Step 7: Assess and Characterize Uncertainties.

The remaining steps received relatively lower priority. Review of gap-specific summaries (section 3.3) suggests that much of this lower prioritization stems from perception that a relatively greater understanding currently exists in these step areas compared to those that

were given higher priority and does not necessarily indicate they are not as important as those assigned a high priority.

Lastly, a number of commenting entities provided letter responses, some of which highlighted themes that were largely absent in the draft version of this report. Those letter responses are provided in appendix D. Two notable themes were:

- **Monitoring and Data Collection**: Need for supporting current data collection networks and understanding their adequacy to support water management in a changing climate.

- **Making Decisions Under Uncertainty**: Need for understanding the relative merits of various tools/concepts (e.g., adaptive management, robustness, resilience, flexibility) to support water management and development under a changing climate, and also understanding the compatibility of these tools/concepts with current influences on management (e.g., legislation, appropriations, policy).

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