The 'Dealing with Drought: Adapting to a Changing Climate' Workshops

A Report for the Colorado Water Conservation Board

Prepared by the University of Colorado, Boulder &
National Oceanic and Atmospheric Administration
Western Water Assessment

K. Averyt, J. Lukas, C. Alvord, J. Barsugli, N. Doesken

The 'Dealing with Drought: Adapting to a Changing Climate' Workshops
A Report for the Colorado Water Conservation Board

Executive Summary

The Western Water Assessment (WWA), in conjunction with the Colorado Water Conservation Board (CWCB), presented the "Dealing with Drought–Adapting to a Changing Climate" workshop series during October 2009 in three locations around Colorado: Castle Rock, Glenwood Springs, and Durango. These workshops built on themes and information from both the *Climate Change in Colorado Report* and the October 2008 Colorado Governor's Conference on Managing Drought and Climate Risk. The WWA, CWCB, and the National Integrated Drought Information System (NIDIS), along with the Colorado State University Colorado Climate Center (CCC) and the Mountain Studies Institute sponsored this series of workshops. The 80 participants represented diverse sectors and interests affected by drought and climate, including water resource management, agriculture, land-use planning, forest & range management, watershed protection, environmental organizations, and tourism & recreation. About half of the participants represented the water management sector (Figure 2). Collectively, the participants' decision-making affects natural resources in every river basin in Colorado.

The primary objectives of these workshops were to improve the climate literacy of the participants, provide input into the ongoing update of the state Drought plan, document participants' understanding of climate change in Colorado, and address concerns and questions among this group of stakeholders about climate change. The workshop objectives were achieved through pre- and post-workshop evaluations, instructional presentations, breakout discussions, and the distribution of climate and drought information in printed form. Analysis of the workshop evaluations and notes from breakout sessions and discussions yielded the following information:

Participants expressed an understanding that climate is changing and will affect Colorado in the pre-workshop surveys and in discussions during the workshop; however, they are unclear about the role climate information plays in decision-making (Figure 4). In all three workshops, the participants, as a group, were able to replicate the diverse list of climate change impacts that scientists have also identified as possibilities. However, most participants indicated that they did not know where to find climate information, they did not know what information they needed, or they did not know how to use it.

The suite of responses to pre-workshop evaluation questions indicates a lack of understanding of at least some of the fundamentals of climate. It is worth further work to determine whether incomplete understanding of the fundamentals of climate inhibits action by the decision-makers attending the workshops.

Comparison of the pre- and post-workshop evaluation responses suggest that the participants value climate information specific to Colorado but do not know where to find these resources. In the pre-workshop evaluation, those who indicated that they use climate information in decision-making primarily access that information from federal or state-supported sources (Table 7). A follow-up question on specific sources found that only the National Weather Service and the NOAA Climate Prediction Center resources were consulted regularly by a majority of participants (Table 8).

The climate literacy of participants improved after the workshop (Table 4). Perhaps related to the improvement in the climate literacy scores, 85% of participants indicated in the post-workshop evaluation that they would be "somewhat more likely" or "more likely" to use climate information to inform resource management and planning after having participated in the workshop; 15% said they would not change their use of climate information compared with before the meeting.

The greatest increase in perceived utility of climate information for planning purposes was for ENSO information and precipitation forecasts (Table 6). Although some participants indicated that they would be more likely to use reservoir storage and inflow information after the workshop, the post-workshop increase in

participants' attitudes about the usefulness of these climate indicators was less than what was indicated for other observations and forecasts.

When asked to identify major challenges posed by climate change, participants most frequently identified those issues that will require cross-sector collaboration and planning (Table 11). The challenges presented by drought identified by workshop participants also tended involve cross-sector issues, and successful adaptation efforts developed during the 2000s drought tended to involve enhanced trans-boundary communication. Cooperation across sectors was identified as both a positive outcome of the 2000's drought, but was also highlighted as a hurdle to properly dealing with challenges. In general, positive examples tended to involve local collaboration, while hurdles tended to involve difficulties at the state and federal levels.

After the workshop, 59% of participants believed that they did not have all the climate information necessary to make a well-informed planning decision. Even so, there was an increased likelihood that participants will use climate information in decision-making, (85% after the workshops vs. 65% before). Given that participants found many of the tools, products, and information resources presented during the workshop useful (Table 8), it is likely that they will be using these particular resources in the future.

The details of these observations and results are discussed further in the document. An appendix of participant lists and workshop agendas is also included. For information about evaluation results or survey question, please contact wwa@noaa.gov. The full set of presentations and materials provided at the workshops are available at: http://wwa.colorado.edu/climate_change/drought09.html.

Background

Periodic drought is part of life in Colorado and the western United States. Mitigating the impacts of drought is a goal of the Colorado Drought Mitigation and Response Plan ("Drought Plan"). The state's Drought Plan, however, does not remove the responsibility from local water providers to plan for drought. The first statewide Drought Plan dates to 1981. The most recent revision to this plan was issued in 2002, with "Updated Information" added in 2007. The 2007 update indicates the need to educate stakeholders about drought:

> "The state will plan to work with U.S. government agencies such as Western Water Assessment, the Regional Integrated Sciences and Assessments program in the Rocky Mountain region, to provide scientific knowledge to public and private water providers and stakeholders to anticipate, track, assess, and respond to drought threats at regional and local levels."

This document also explicitly states the need to consider drought planning as a part of the adaptation strategy to climate change:

> "Increased awareness and attention to climate change and the associated potential impacts to state water supplies as a result of predicted changes warrants further analysis and proactive adaptive planning strategies … efforts should be made to focus on vulnerabilities and building increased resiliency to climatic extremes such as drought."

The state Drought Plan is undergoing a comprehensive revision that is scheduled to be complete in 2010. Drought is also prominent in the Colorado Climate Action Plan that was released by Governor Ritter in November 2007. This plan calls for the development of a Water Adaptation Plan that includes "comprehensive drought planning" and "information exchange and education."

The Report *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation* ("*Colorado Climate Report*"), commissioned by CWCB and prepared by WWA in 2008, was presented at the Colorado Governor's Conference on Managing Drought and Climate Risk. It provides a summary of the state of the science on the physical aspects of climate change, including temperature, precipitation, and runoff. The scientific studies cited in the Colorado Climate Report indicate that by mid-century, climate change may lead to significant changes in Colorado's water resources, with earlier snowmelt and runoff, potentially less annual water supply, and an increased risk of a "compact call" on the Colorado River. These findings, in conjunction with the prospect of longer, more intense droughts provide increased motivation for drought planning at the regional and local level. Clearly, the state has expressed a need to deliver scientific information about drought and climate change to stakeholders, while also learning more about stakeholder requirements for climate adaptation planning.

This "Dealing with Drought" workshop series addressed the need to incorporate drought planning across affected sectors and provided an educational and discussion-oriented setting designed to improve individual and stakeholder knowledge and understanding of climate science and drought. Improving climate science knowledge provides a common ground to advance discussion among affected sectors and identify cross-sector challenges. Doing so helps identify climate information needed to aid and encourage informed decision-making processes.

Workshop Objectives

The workshop objectives were threefold: improve climate literacy of participants, provide input into state planning efforts regarding drought and climate change, and document participant understanding and concerns with regard to climate change in Colorado. Secondary objectives outlined below helped focus the primary objectives.

Objective 1: **Improve climate literacy of participants and communicate information about climate in Colorado (based on the results of the *Colorado Climate Report*).** Secondary objectives included: introduce and reinforce the basics of climate change and climate variability to stakeholders in both a local and a global context; and make climate a more salient issue with Colorado stakeholders by presenting information from the *Colorado Climate Report*.

Objective 2: **Provide input into the development of the updated state Drought Plan and the water adaptation-planning component of the Colorado Climate Action Plan by identifying impacts of drought and climate change on resources.** Secondary objectives included: gather and synthesize information from stakeholders that will inform drought planning and climate adaptation strategies in Colorado.

Objective 3: **Document participant understanding and address concerns about climate change in Colorado.** Secondary objectives included: enable stakeholders to identify impacts and vulnerabilities to climate variability, drought, and future climate change.

Workshop Description

The one-day workshops consisted of three elements. *Instructional sessions* gave participants the opportunity to learn more about Colorado's climate and climate variability, the history of past drought in Colorado, scenarios for future climate change, and implications of climate change for water and other resources. In *breakout discussion sessions*, participants discussed the impacts of the 2000s drought, the information or resources would help them adapt to future droughts, and the potential impacts from a changing (warming) climate that were of greatest concern. Input from these discussion sessions will inform the revision of the state Drought Plan, as well as the forthcoming Climate Change in Colorado Impacts Report; the prelude to identifying a state adaptation plan as part of the Colorado Climate Action Plan. *Participant evaluations* prior to and after the workshops assessed climate literacy and use of climate information.

Instructional Sessions

The workshops consisted of seven instructional presentations given by WWA and CCC team members, with contributing presentations from CWCB, Colorado Springs Utilities, and the Colorado River Water Conservation District (CRWCD). The "climate curriculum" covered in instructional presentations (Table 1) followed a logical progression, with each presentation building on the information in previous ones.

Table 1. Instructional Sessions and Breakout Sessions (in order of their presentation in the workshops).

Session	Content
Fundamentals of global and Colorado climate	Introduction to the basics of global and Colorado climate, including the geographic and seasonal distribution of temperatures precipitation in the state, and the physical, geographical, and meteorological reasons behind the observations
Colorado climate variability and trends	Introduction to the basics of climate variability on a global scale and for Colorado with an emphasis on geographic and seasonal distribution of temperatures and precipitation, other factors affecting variability (topography, elevation); and variability in the context of climate change
Drought (including paleoclimate)	Discussion of the definition of drought and indices used to monitor drought, observed records of droughts and the evidence from tree rings for extended dry and wet periods in Colorado before the historical period and their causes.

Session	Content
Breakout: Lessons Learned from Drought	Within breakout groups, participants identify their experience with the 2000's drought, focusing on the exceptional drought year of 2002, including impacts by sector, with an emphasis on impact to short- and long-term decision-making, and resulting change in practices
Overview of the revision of the State Drought Plan Update	Introduction to the ongoing update of the state Drought Plan, including new sections of the plan, workshop contribution/input, and applications to sector decision-making
Scenarios of climate change in Colorado	Based on the Climate Change in Colorado report, mid-century temperature and precipitation projections, attribution of climate change, and explanation of climate models and applications to decision-making. Preceded by brief group breakout activity on climate projections.
Breakout: Impacts and Vulnerabilities to climate change	Within breakout groups, participants identify potential impacts of climate change and vulnerabilities for their sectors, distinguishing and ranking the top 5 challenges facing Colorado
Climate Change Impacts on Water and Related Resources	Physical impacts and resulting impacts to regional water supplies, and other resources and economic activities, based on the climate scenarios presented (temperatures & precipitation projections)
Web Resources for Climate and Drought Information	Overview of key climate and drought information resources on the Web, from a variety of state and federal entities, and their potential uses and applications

Breakout Groups & Discussion

During the breakout discussions held at each workshop, the participants were split into assigned groups of 4 to 6 people. The groupings were assigned so as to diversify sector representation within each breakout group with the intent of expanding discussion.

The first breakout session addressed the impacts of the 2000s drought (2002 in particular) and the information and the strategies used to monitor, mitigate, and adapt to those impacts that led to better preparedness in their sectors. The second breakout session asked participants to identify potential impacts of climate change and vulnerabilities for their sectors, building on information in prior instructional presentations. A brief breakout activity was added for the Glenwood and Durango workshops, which asked participants to make their own projections of future temperature and precipitation out to 2050 for Colorado. The observed temperature and precipitation record (1900–2009) for Colorado was provided to participants as a visual aid to help guide projections. This activity was intended to capture individual perceptions of future temperature and precipitation projections and to in turn correct any misrepresentations. More details about the breakout sessions are found in the Workshop Results portion of this report.

Workshop Materials & Handouts

The workshop materials provided recent and relevant climate and drought information, tools, and resources, covering global and Colorado climate basics as well as tools and products aimed at providing specific user applications. They were selected to both reinforce and complement information given during the workshop sessions, so as to improve participant climate literacy and create an additional resource for participants to incorporate climate information in decision-making. The workshop resource book comprised three sections: (1) information about the workshop sponsors and the National Drought Mitigation Center, (2) articles and resource sheets describing different climate and drought tools, products, and information sources, and how to use them, and (3) the Frequently Asked Questions (FAQ) section from the 2007 Intergovernmental Panel on Climate Change (IPCC), Working Group I: The Physical

Science Basis of Climate Change Report. In addition to the workshop resource book, participants were given supplemental materials, most importantly the *Climate Change in Colorado* Report on which the workshops were based. The contents of the resource book and the supplemental materials are provided in Table 2.

Table 2. Resource Book Contents & Supplemental Materials.

Resource Book Contents

Information Sheets:

Western Water Assessment (WWA)

Colorado Water Conservation Board (CWCB) Drought Planning

National Integrated Drought Information System (NIDIS)

National Drought Mitigation Center (NDMC)

Drought Products and Tools - from the National Drought Mitigation Center (NDMC):

Spotting Drought Before It's Too Late

Products of the NDMC

The US Drought Monitor Map

Checklist of Drought Impacts

Frequently Asked Questions about Climate and Climate Change - IPCC 2007 Working Group I

Drought and Climate Products and Tools - Feature Articles and Focus Pages from the WWA Intermountain West Climate Summary:

Improve Your Climate Vocabulary! (April 2005)

NIDIS Drought Portal (January 2008)

Drought Indices (July 2007)

New NWS Western Water Supply Forecast Services (May 2007)

Monthly and Annual State of the Climate Reports from NCDC (September 2008)

Introduction to the Drought Impact Reporter (October 2005)

The CPC's U.S. Temperature and Precipitation Trend Maps (March 2009)

CPC Soil Moisture Products (July 2007)

The US Hazards Assessment (September 2007)

A Look at Two of the Climate Change Science Program's Latest Products (September 2008)

The Colorado Climate Center (April 2007)

An Overview of NOAA's Colorado River Basin Forecast Center (May 2005)

New and Improved NRCS Snow and Water Supply Forecast Products (March 2006)

NWS Introduces New Local Climate Products (May 2006)

NIDIS Remote Sensing Workshop (April 2008)

Supplemental Materials

Climate Change in Colorado Report (WWA, CWCB)

Selected Web Resources for Colorado Drought and Climate Information (2-page handout)

Global Climate Change Impacts in the United States Report: (20-page Highlights Brochure (handed out at Castle Rock and Glenwood Springs workshops)

Climate Literacy--The Essential Principles of Climate Sciences (Brochure)

Participant Invitations

The Colorado Water Conservation Board sent out the initial workshop announcement to two e-mail lists: participants in the October 2008 Governor's Conference, and municipal water providers who deliver 2000 acre-feet of water or more annually. The announcement was also sent to the Colorado Municipal League to disseminate to their membership through e-mails and newsletters. The announcement was distributed further by WWA (particularly for the Glenwood Springs workshop), and by the Mountain Studies Institute and the Water Information Program (for Durango). Also, recipients of the initial announcement were asked to forward the information to other interested parties.

People responding to the announcement were directed to a webpage at WWA to request registration. These registration requests were screened by WWA staff to ensure that workshop participants were in the targeted sectors and would be able both benefit from the information presented and provide useful input to the state Drought Plan. As it turned out, all those requesting registration met these criteria, and no interested party was denied participation. The few cases in which requestors were not immediately

registered were the result of multiple requestors from the same organization, and so they were put on a wait list until the organizers determined that an adequately diverse set of organizations could be accommodated.

Pre- and Post-Workshop Evaluation

The intent of the pre- and post- workshop evaluations was twofold: (1) to identify the saliency and use of climate information in decision-making by sector; and (2) to evaluate the climate literacy of the participants, both individually and by sector. The pre- and post-workshop evaluation asked participants to identify the sector they represent and their use of climate information in decision-making. They were also asked to identify the climate indicators and resources they were currently using and familiar with. The second component of the evaluation addressed the climate literacy of participants, with specific questions aimed to test knowledge of climate concepts. The climate concepts tested included global and Colorado climate fundamentals, regional drought indicators and contributors, and climate variability and change. The climate literacy questions were framed in a way to evaluate common misconceptions surrounding climate, particularly climate change implications for Colorado, in order to identify gaps in understanding.

The pre-workshop evaluation results helped guide workshop presentations and discussion so they could better address participant gaps in understanding, and knowledge and familiarity with available climate information. The post-workshop evaluation provided information on changes in both the participants' climate literacy and their familiarity with climate information and products.

The comparison of pre-and post workshop evaluation results provided the basis to evaluate the workshops' effectiveness in communicating climate and drought information, as well as information to improve future climate literacy exercises and evaluations. By comparing the responses to the same questions in the pre- and post-workshop evaluations, specific weaknesses in understanding of climate concepts were identified. Performance on the climate literacy questions was also cross-analyzed by various participant variables including sector, workshop location, and location and use of climate information in decision-making.

Before the workshop, registered participants were invited to participate in a pre-workshop evaluation online. The post-workshop evaluation was handed out in hardcopy form at the conclusion of the workshop and was available online for participants who were unable to complete the evaluation at the workshop. Of the 80 total participants, 70% completed at least a portion of the pre-workshop evaluation, and 61% responded to the post-workshop evaluation (Table 3).

Table 3. Workshop Participants and Evaluation Respondents.

	Total Participants	Pre-Workshop Evaluation	Post-Workshop Evaluation
Castle Rock	30	18 (12)	16 (16)
Glenwood Springs	20	15 (10)	14 (14)
Durango	30	23 (15)	19 (19)

Numbers in parenthesis indicate the number of participants who completed the entire evaluation.

Workshop Results:
Participant Demographics

Workshop participants were asked to self-identify with one of eight sector categories in the pre- and post-workshop evaluation. Figure 1 shows the demographic breakdown by sector of those responding to both the pre-workshop and post-workshop evaluations. The similarity of the two distributions implies that the pre- and post- respondents represent two similar populations, meaning that the pre-workshop and post-workshop evaluation results can be meaningfully compared.

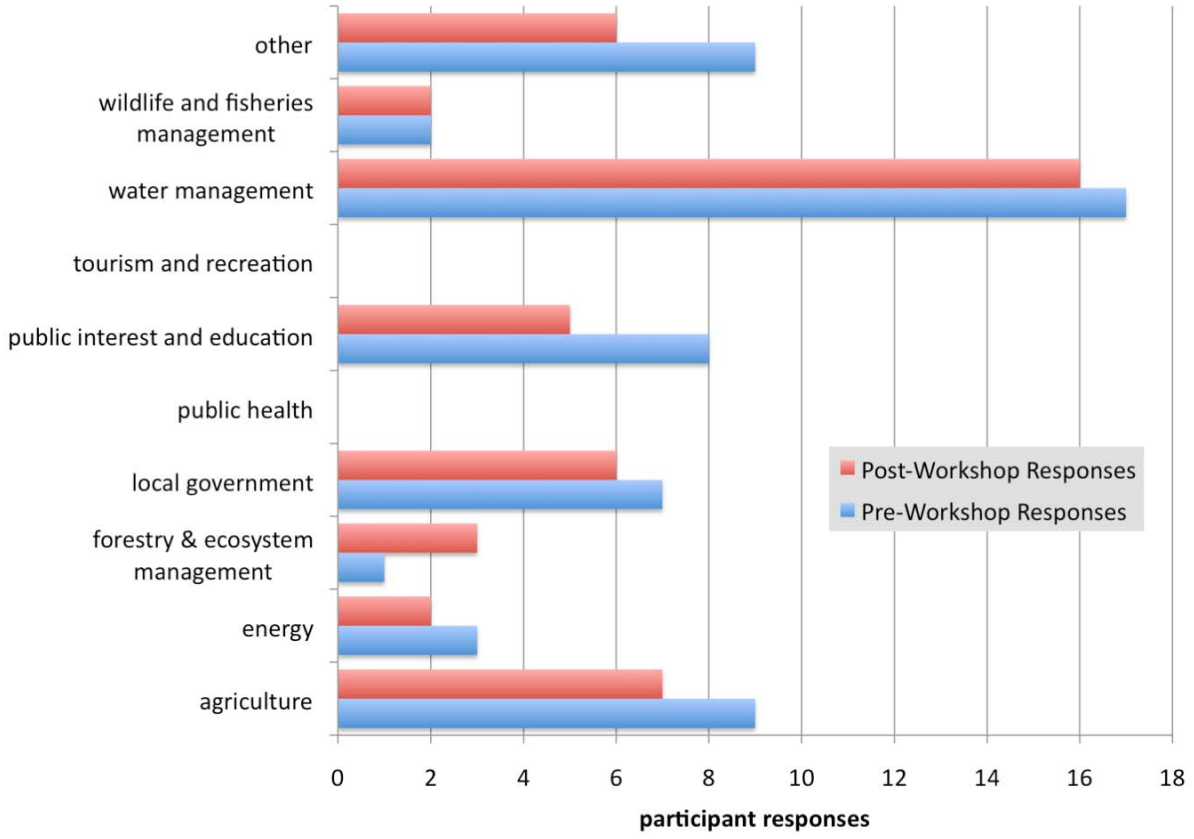


Figure 1. Sectors (self-identified) Represented by Participants Completing the Pre- and Post-workshop Evaluations.

In comparison, Figure 2 shows the sector representation of all 80 participants as identified by job title and organizational affiliation provided at registration. This group therefore includes those who did not respond to one or both evaluations. The similarity between the distribution of identified sectors in figures 1 and 2 suggests that the evaluation results are a stratified sample of the total population of participants in attendance at the three workshops.

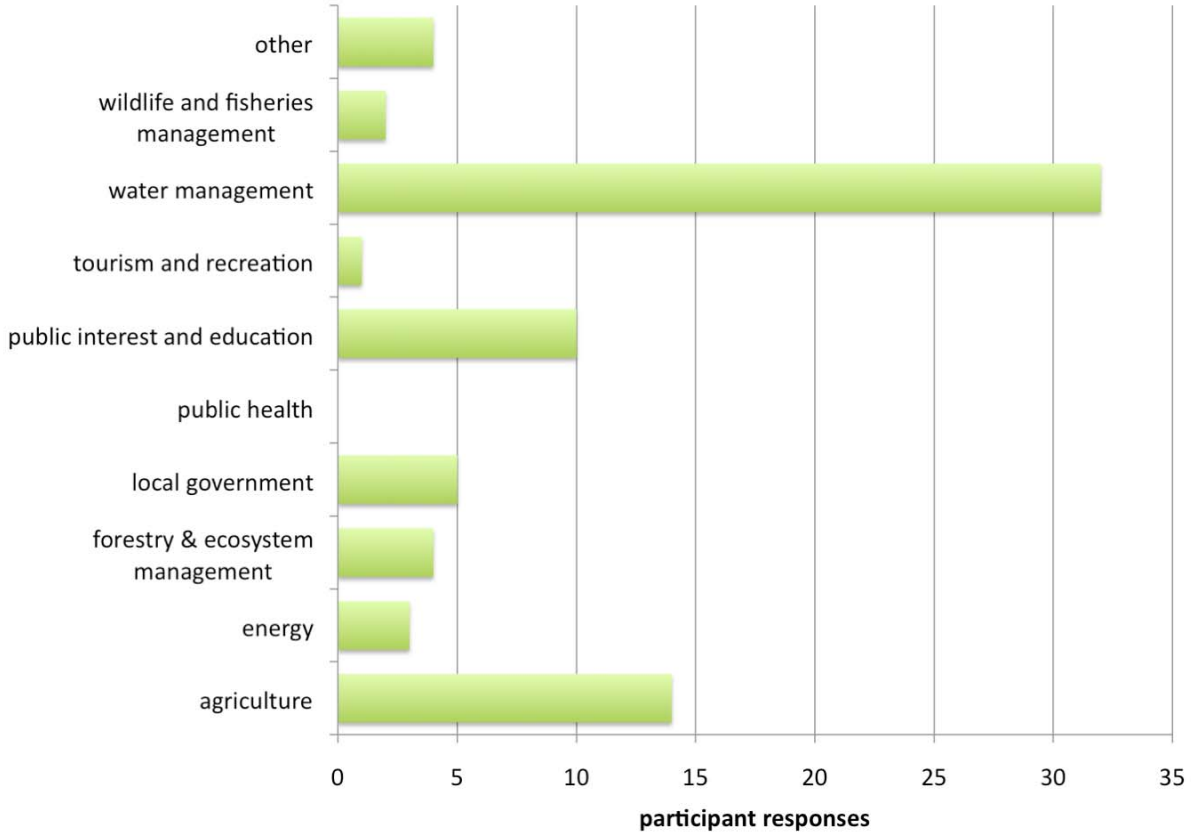


Figure 2. Sectors Represented by all Participants. *Category is based on job title and organizational affiliation provided at registration.*

Overall, the sector that was best represented by the workshop participants was water management, followed by agriculture, "other", public interest and education, local government, energy, wildlife and fishery management, and forestry and ecosystems management, in that order. Because participants were asked to identify only one sector, we were not able to identify participants who identified with multiple sectors.

As as a whole, the participants' decision-making affects natural resources in every river basin in the state (Figure 3).

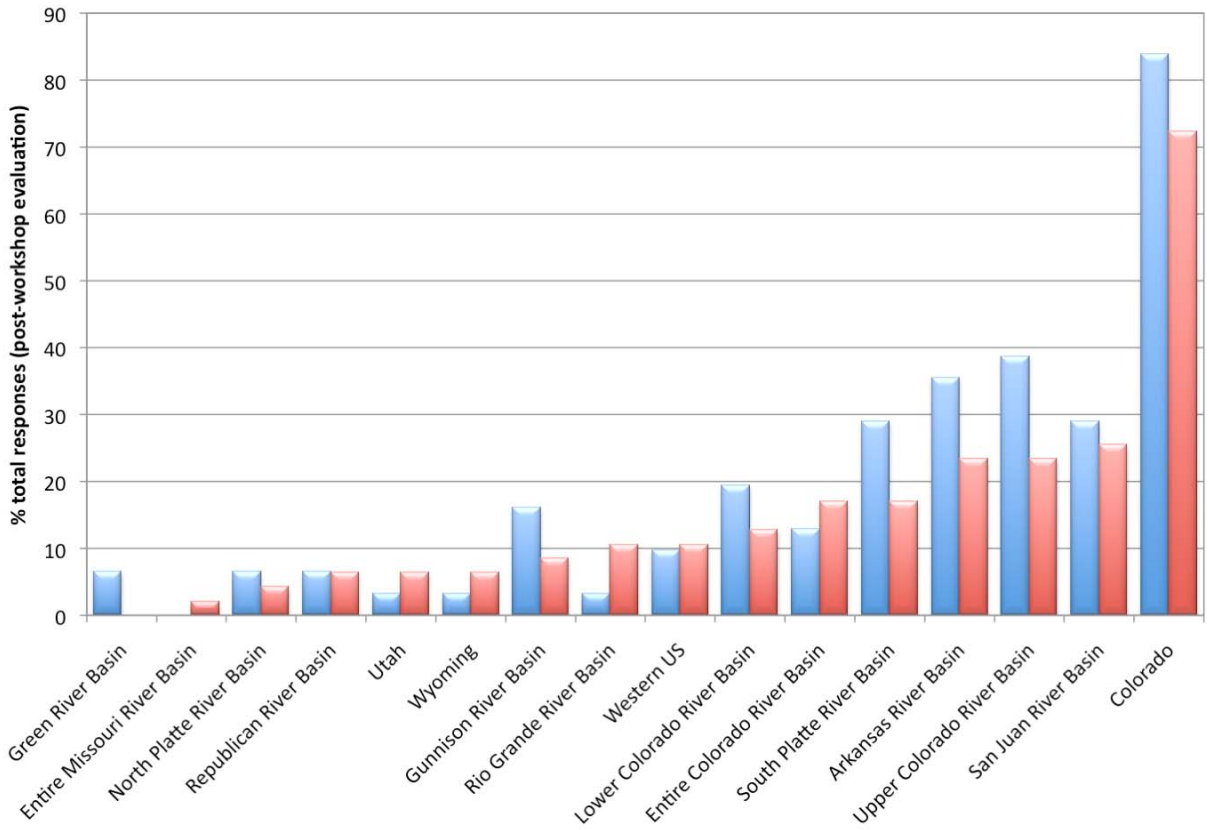


Figure 3. Regions Affected by Decision-Making of Participants. *Results are from both the pre- (blue) and post-workshop (red) evaluations. Note that participants were allowed to select multiple answers to this question.*

Workshop Results:
Understanding Climate Science and the Use of Climate Information in Decision-Making

The suite of responses to the pre-workshop evaluation questions about the use of climate information in decision-making supports the need for instruction on the fundamentals of climate variability and change, and available resources and information to support informed decision-making.

Participants were asked before the workshop whether they currently use climate information to inform resource management decisions and planning. Most (65%) chose "Yes", yet 90% of these respondents indicated that they do not have all the climate information they need to make a well-informed decision. Those indicating "No" (35%) were asked why they did not use climate information. The most common response was "Don't know what information I need" (Figure 4). The number of respondents who indicated that they do not believe climate information is relevant to their decisions and planning suggests a lack of understanding about the connection between climate and their sector.

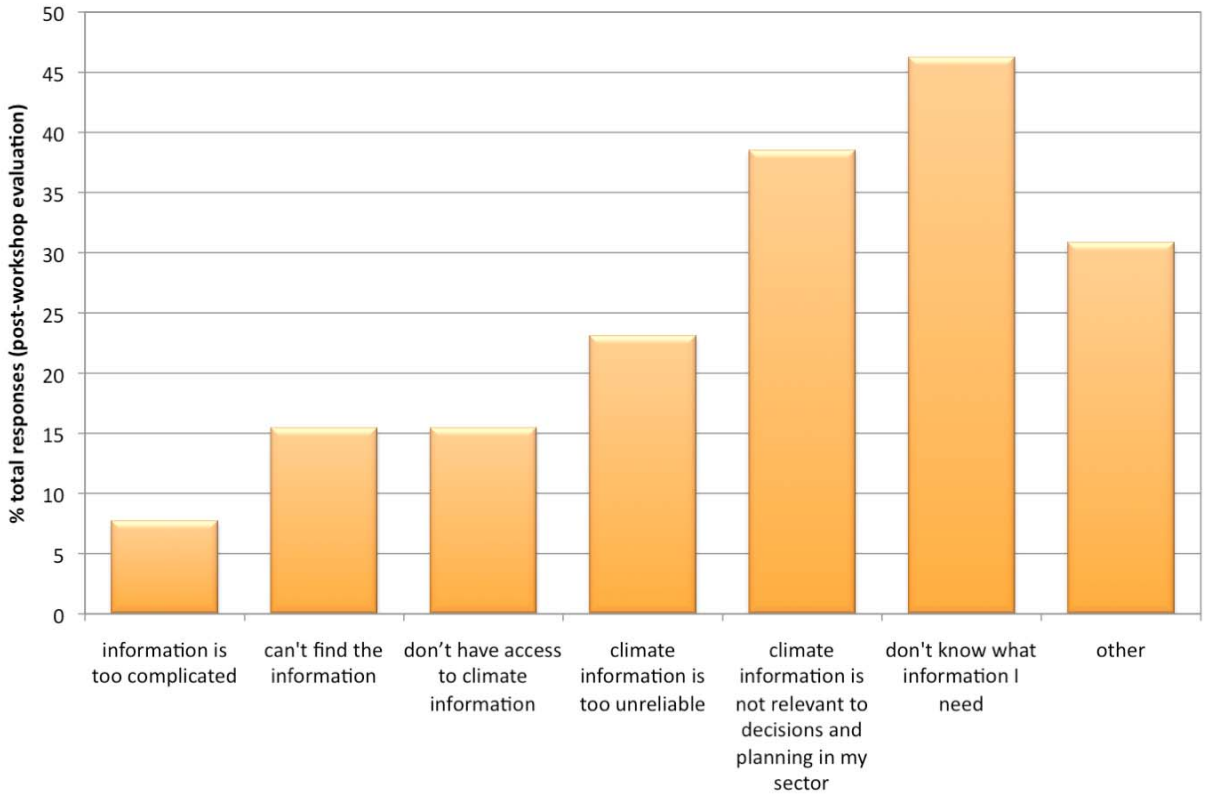


Figure 4. Reasons Indicated for Not Using Climate Information to Inform Decisions and Planning. *Results are from pre-workshop evaluation.*

Participants were asked questions about fundamental climate and drought concepts both before and after the workshop. Table 4 lists the concept being tested and the percentage of correct responses to each question in the pre- and post-workshop evaluation. For all but three questions, scores improved. For the questions where improvement was not observed, scores were virtually the same, indicating a need to improve the components of the workshop focused on these concepts. On average, scores

improved by 14 points (from 63% correct to 77%). For four concepts, the increase exceeded 30 points, indicating widely held misperceptions that were successfully addressed during the workshop. These included the following misperceptions about climate:

- The recent decline in global average temperatures means that climate change is no longer occurring.
- Precipitation in Colorado has declined.
- Climate change will result in less frequent heavy precipitation events, more frequent hurricanes, and more frequent El Nino events.
- There will be major declines in Colorado's high elevation snowpack (>8000 ft) by 2025.

Table 4 shows that participant understanding of fundamental climate concepts improved overall.

Table 4. Comparison of Pre- and Post-Workshop Climate Literacy Scores.

Concept	BEFORE	AFTER
Scientific Process	71	75
Weather and Climate	79	82
Controls on Climate	46	62
Climate Variability	39	39
Greenhouse Effect	78	95
Historical Global Temperature Trends	**98**	**93**
Anthropogenic Climate Change	71	85
Recent Global Temperature Trends	49	76
Emissions and Concentrations	95	100
Climate in Colorado and the West	88	98
Regional versus Global Climate Change	**95**	**93**
El Nino	73	81
Colorado Climate Observations	23	74
El Nino and Colorado	21	36
Paleoclimate	92	98
Drought in Colorado	62	72
Climate Models	71	83
Global Climate Projections	21	62
Colorado Climate Projections	32	63

Numbers represent the % of respondents answering with the correct answer. Instances where scores declined are in bold; highlighted boxes indicate greater than 30-point improvement.

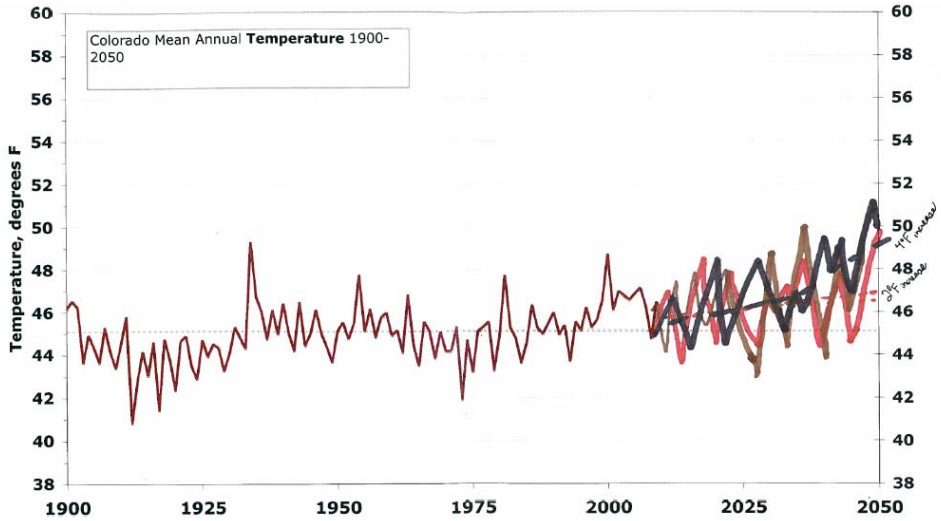
The connection between understanding of climate science and the use of climate information is highlighted by comparison of the pre- and post-workshop evaluation. The results show that the climate literacy of participants improved after the workshop, as did the intention to use climate information to inform decisions and planning. 85% of participants indicated in the post-workshop evaluation that they would be "somewhat more likely" or "more likely" to use climate information to inform resource management and planning after having participated in the workshop; 15% said they would not change their use of climate information compared to before the meeting. Although it is unclear if the latter set of respondents include those who will continue to *not* use climate information, the post-workshop evaluation suggests that more people will use climate information in decision-making than the 65% who indicated they used climate information prior to the workshop.

Temperature and Precipitation in 2050

At two of the workshops, an exercise was implemented to determine in more detail participant (mis)perceptions about climate projections for Colorado. This exercise was added in order to counter some problems noted in the afternoon session at the Castle Rock workshop, including our perception of decreased enthusiasm among the participants. The exercise also was intended to refocus the attention of the participants from the past climate (the discussion of the 2000s drought in the morning session) to projections of future climate.

In the exercise, each breakout group was presented with a graph showing historical annual-average temperature and precipitation in Colorado. Each individual in the group was then asked to draw a line on each graph indicating how each parameter would evolve from present out to 2050. Prior to this exercise, no climate projections had been presented during the workshop. Subsequently, participants were presented with ensembles of climate model projections of temperature and precipitation for Colorado, at which time they were asked to show their graphs to the whole group. The facilitator commented on salient features of the graphs, including trend, variability (or lack thereof), and the "ensemble" concept.

Results varied across groups and workshops. At the workshop in Glenwood Springs, no participant estimate of temperature exceeded the minimum temperature increase projected by climate models. In Durango, participant estimates were more consistent with model projections. Most participants indicated that temperature would increase, and that precipitation would remain highly variable, and in some cases, decrease (Figure 5).



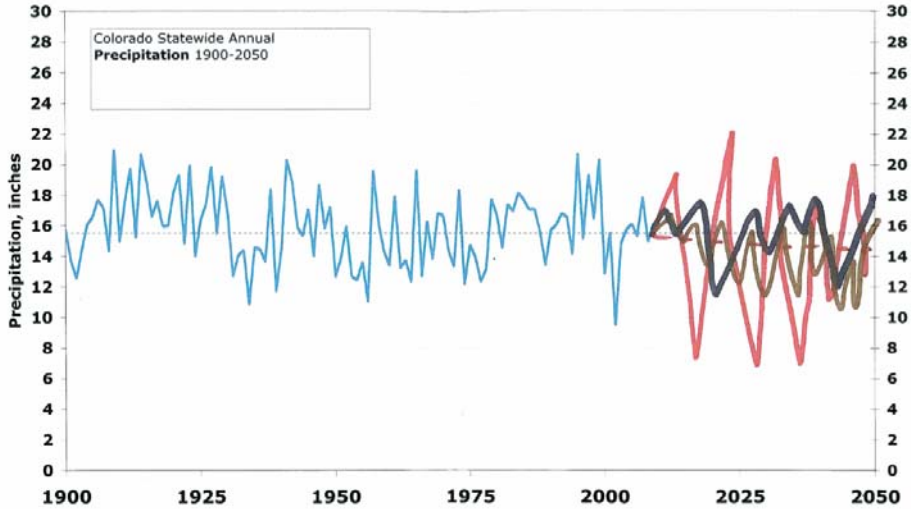


Figure 5. Example of Participant Graphs Created During the 2050 Projection Exercise in Durango.

Workshop Results:
Climate & Drought Indicators and Tools

Prior to the workshop, participants were asked to indicate which climate observations and forecasts they consult to help guide decisions. Each climate-related indicator or forecast listed in Tables 5 and 6 was then introduced during the course of the workshop. At the end of each workshop, participants were asked to indicate whether they were more likely than before to consult a given indicator. Table 5 shows participant use of observational data before the workshop (left columns), compared with the likelihood of a participant to use the same information after the workshop (far right column). The same information as it applies to seasonal forecasts is shown in Table 6.

It is clear that most participants consulted several observations and forecasts of climate indicators prior to the workshop, but with varying frequency. Temperature and precipitation observations and forecasts were consulted the most frequently. Participants were largely unaware of the utility of the observed ENSO signal as a climate indicator. After completing the workshop, between 30% and 73% of the participants indicated they would be more likely to use each indicator. The greatest increase in perceived utility was for ENSO and precipitation forecasts. Although some participants indicated they would be more likely to use reservoir storage and inflow information after the workshop, the post-workshop increase in participants' attitudes about the utility of these indicators was less than for other observations and forecasts.

Table 5. Participant Use of Current Conditions to Help Guide Decisions.

	Not familiar with this indicator	Heard of this indicator, but never use it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly	Depends on the Application		Post-workshop: % more likely to use indicator
Observed Precipitation Amounts	0% (0)	3.0% (1)	6.1% (2)	18.2% (6)	21.2% (7)	6.1% (2)	**27.3% (9)**	18.2% (6)		**43.2%**
Observed Temperature Observations	0% (0)	3.0% (1)	6.1% (2)	18.2% (6)	15.2% (5)	9.1% (3)	**27.3% (9)**	21.2% (7)		**40.5%**
Observed Streamflow Amount	0% (0)	14.7% (5)	14.7% (5)	11.8% (4)	11.8% (4)	**20.6% (7)**	14.7% (5)	11.8% (4)		**43.2%**
Observed Reservoir Storage	2.9% (1)	11.4% (4)	14.3% (5)	**20.0% (7)**	8.6% (3)	14.3% (5)	14.3% (5)	14.3% (5)		**29.7%**
Observed Reservoir Inflow Amounts	8.8% (3)	**26.5% (9)**	5.9% (2)	17.6% (6)	5.9% (2)	8.8% (3)	17.6% (6)	8.8% (3)		**29.7%**
Observed soil moisture levels	6.3% (2)	**25.0% (8)**	9.4% (3)	6.3% (2)	**25.0% (8)**	3.1% (1)	6.3% (2)	18.8% (6)		**43.2%**
Observed Snow Water Equivalent (SWE) Levels	0% (0)	11.8% (4)	11.8% (4)	**26.5% (9)**	11.8% (4)	8.8% (3)	14.7% (5)	14.7% (5)		**37.8%**
Observed Snowpack Amounts	0% (0)	8.6% (3)	11.4% (4)	**28.6% (10)**	8.6% (3)	8.6% (3)	20.0% (7)	14.3% (5)		**40.5%**
Observed Evapotranspiration (ET)	5.9% (2)	**26.5% (9)**	8.8% (3)	8.8% (3)	**26.5% (9)**	5.9% (2)	2.9% (1)	14.7% (5)		**37.8%**
Observed ENSO signal	**51.5% (17)**	15.2% (5)	3.0% (1)	12.1% (4)	9.1% (3)	3.0% (1)	0.0% (0)	6.1% (2)		**73.0%**

Boxes highlighted in yellow indicate the most frequent temporal scale used by participants for each climate indicator listed. Boxes highlighted in orange indicate the largest percentage of participants who took the post-workshop survey that are now more likely to use the listed indicator after attending the workshop.

Table 6. Participant Use of Seasonal Forecasts to Help Guide Decisions.

	Not familiar with this indicator	Heard of this indicator, but never use it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly	Depends on the Application		Post-workshop: % more likely to use indicator
Precipitation Forecasts	0.0% (0)	14.7% (5)	8.8% (3)	14.7% (5)	11.8% (4)	11.8% (4)	**20.6% (7)**	17.6% (6)		**55.0%**
Temperature Forecasts	0.0% (0)	11.8% (4)	8.8% (3)	11.8% (4)	14.7% (5)	6.9% (2)	**23.5% (8)**	**23.5% (8)**		**47.5%**
Streamflow Forecasts	2.9% (1)	14.7% (5)	14.7% (5)	11.8% (4)	14.7% (5)	**20.6% (7)**	5.9% (2)	14.7% (5)		**45.0%**
Reservoir Storage Forecasts	2.9% (1)	**20.6% (7)**	14.7% (5)	**20.6% (7)**	14.7% (5)	5.9% (2)	8.8% (3)	11.8% (4)		**30.0%**
Reservoir Inflow Forecasts	11.8% (4)	**20.6% (7)**	11.8% (4)	17.6% (6)	11.8% (4)	8.8% (3)	8.8% (3)	8.8% (3)		**15.0%**
Snow Water Equivalent (SWE) Projections	5.9% (2)	8.8% (3)	11.8% (4)	**32.4% (11)**	8.8% (3)	14.7% (5)	5.9% (2)	11.8% (4)		**45.0%**
ENSO Forecast	**54.3% (19)**	14.3% (5)	2.9% (1)	8.6% (3)	8.6% (3)	2.9% (1)	2.9% (1)	5.7% (2)		**65.0%**

Boxes highlighted in yellow indicate the most frequent temporal scale used by participants for each climate indicator listed. Boxes highlighted in orange indicate the largest percentage of participants who took the post-workshop survey that are now more likely to use the listed indicator after attending the workshop.

Workshop Results:
Climate & Drought Information Resources

A key component of the evaluation was to survey the extent to which climate and drought resources are accessible to and useful for participants. Participants were asked in the pre-workshop evaluation where they access climate information, and about their familiarity with particular resources, tools, and products designed for climate end-users.

Those who indicated before the workshop that they do use climate information in decision-making primarily access information from Federal- or state-supported sources, as opposed to popular media, to inform their decisions (Table 7). A follow-up question on specific sources found that only the National Weather Service and NOAA Climate Prediction Center resources were consulted by a majority of participants (Table 8). During the workshop, a broad suite of climate information resources were presented, and in the post-workshop evaluation, at least some to most of the participants indicated that they were now more likely to use each of the resources (right column, Table 8). Of particular note is that even though not all the information resources in Table 8 were introduced during the meeting, participants still indicated they would be more likely to use almost all of the resources after the workshop.

Table 7. Sources Used by Participants to Access Climate Information in Order to Inform Decision-Making.

	1 Frequently	2	3	4	5	6	7 Never
TV	6.9% (2)	3.4% (1)	3.4% (1)	3.4% (1)	10.3% (3)	10.3% (3)	**62.1% (18)**
Newspaper	11.5% (3)	0.0% (0)	0.0% (0)	7.7% (2)	11.5% (3)	**57.7% (15)**	11.5% (3)
Magazine or Popular Journal	0.0% (0)	7.7% (2)	0.0% (0)	7.7% (2)	**57.7% (15)**	7.7% (2)	19.2% (5)
Scientific journals	3.4% (1)	10.3% (3)	17.2% (5)	**51.7% (15)**	10.3% (3)	3.4% (1)	3.4% (1)
Federal or state supported web sites, data portals, or publications	**61.3% (19)**	19.4% (6)	3.2% (1)	9.7% (3)	6.5% (2)	0.0% (0)	0.0% (0)
University web sites, data portals, publications, or products	14.3% (4)	**42.9% (12)**	**32.1% (9)**	0.0% (0)	3.6% (1)	3.6% (1)	3.6% (1)
Non-governmental organization (NGO) web sites, data portals, or publications	13.8% (4)	13.8% (4)	**41.4% (12)**	**17.2% (5)**	3.4% (1)	6.9% (2)	3.4% (1)

The median (50%) of responses is highlighted in yellow.

Comparison of the pre- and post-workshop evaluation responses suggests that the participants value region-specific climate information but did not know where to find these resources. This is particularly evident in participant choices about resources they are more likely to use having completed the workshop: the National Integrated Drought Information System (NIDIS) portal, the Colorado Climate Center Website, and the Western Water Assessment Intermountain West Climate Summary.

Table 8. Participant Familiarity with Climate Information Sources.

	Never heard of it	Heard of this indicator, but never use it	Looked at it, but never used it	Consult Yearly	Consult Seasonally	Consult Monthly	Consult Weekly	Consult More than Weekly		**Post-Workshop: % indicating more likely to use resource**
NOAA Climate Prediction Center Forecasts	10.0% (4)	15.0% (6)	17.5% (7)	2.5% (1)	**20.0% (8)**	**20.0% (8)**	5.0% (2)	10.0% (4)		**48.8%**
NOAA River Basin Forecast Center	**23.7% (9)**	13.2% (5)	21.1% (8)	5.3% (2)	10.5% (4)	10.5% (4)	7.9% (3)	7.9% (3)		**41.5%**
NOAA, ESRL Southwest Experimental Precipitation Forecasts (K.Wolter)	**47.2% (17)**	19.4% (7)	11.1% (4)	0.0% (0)	2.85% (1)	19.4% (7)	0.0% (0)	0.0% (0)		**24.4%**
National Weather Service Forecasts (NWS)	2.6% (1)	7.7% (3)	7.7% (3)	0.0% (0)	7.7% (3)	**28.2% (11)**	23.1% (9)	23.1% (9)		**22.0%**
Colorado Climate Center Website	**28.2% (11)**	15.4% (6)	12.8% (5)	7.7% (3)	17.9% (7)	12.8% (5)	2.6% (1)	2.6% (1)		**56.1%**
Utah Climate Center	**45.7% (16)**	40.0% (14)	5.7% (2)	2.9% (1)	5.7% (2)	0.0% (0)	0.0% (0)	0.0% (0)		**4.9%**
Wyoming Water Resources Data Center	**52.9% (18)**	38.2% (13)	5.9% (2)	0.0% (0)	2.9% (1)	0.0% (0)	0.0% (0)	0.0% (0)		**0.0%**
National Integrated Drought Information System Portal	**36.8% (14)**	21.1% (8)	10.5% (4)	0.0% (0)	15.8% (6)	10.5% (4)	5.3% (2)	0.0% (0)		**75.6%**
Western Water Assessment Intermountain West Climate Summary	**38.5% (15)**	20.5% (8)	2.6% (1)	7.7% (3)	12.8% (5)	15.4% (6)	0.0% (0)	2.6% (1)		**48.8%**
Western Regional Climate Center (WRCC)	**40.5% (15)**	27.0% (10)	8.1% (3)	2.7% (1)	10.8% (4)	5.4% (2)	5.4% (2)	0.0% (0)		**46.3%**
High Plains Regional Climate Center (HPRCC)	**59.5% (22)**	24.3% (9)	10.8% (4)	2.7% (1)	2.7% (1)	0.0% (0)	0.0% (0)	0.0% (0)		**12.2%**
National Drought Mitigation Center (NDMC)	**45.9% (17)**	27.0% (10)	10.8% (4)	2.7% (1)	10.8% (4)	2.7% (1)	0.0% (0)	0.0% (0)		**31.7%**

The most frequent response field is highlighted in yellow.

Although participants indicated an increased likelihood of using climate information in decision-making post-workshop (85% vs. 65%), and found many of the tools, products, and information resources useful (Table 8), 59% of participants still believed that they did not have all the climate information necessary to make a well-informed planning decision. Further information about informational needs is included in the following sections (e.g. Table 10).

Workshop Results:
Lessons Learned from the 2000s Drought

The first breakout session at each workshop was a discussion focused on the lessons learned from the 2000s drought. This session was designed to elicit what those directly impacted by the drought experienced, the positive and negative outcomes and responses, and what information would have decreased participant vulnerability to drought impacts.

The breakout groups were asked to address the following questions: "What were the challenges posed by the 2000s drought? What went right and what went wrong?" Table 9 is a compilation of the breakout responses to these questions from all three workshops. The sectors impacted by each challenge are indicated with the blue Xs. Workshop facilitators estimate that approximately 50% of the participants were in Colorado in 2002 and experienced the drought firsthand in a managerial capacity.

The challenges presented by drought tended to cross sector boundaries, and successful adaptation efforts developed to address these challenges tended to involve cross-sector communication. Cooperation across sectors was identified as both a positive outcome of the drought, but was also highlighted as a major hurdle to dealing with the challenges posed by drought. In general, workshop facilitators noted that positive collaborations tended to be on local scales, while hurdles tended to be at the state and federal levels.

Table 9. Challenges Posed by the 2000s Drought, and Consequent Changes and Adaptations.

	Education & Outreach	**Agriculture**	**Municipal and Industrial Water Management**	**Energy**	**Tourism & Recreation**	**Ecosystems & Forestry**	**Safety & Public Health**	Castle Rock	Glenwood Springs	Durango
Impact to water quality tied to low streamflows			X					X	X	X
Impact to fisheries and aquatic hatches			X			X		X	X	X
Use of alternate, back-up water supply source			X			X		X	X	X
Economic impacts tied to negative media coverage stemming from Governor's response to drought	X				X			X	X	X
Increased incentive and pressure for trans-basin diversions	X	X	X					X	X	X
Reactionary management of natural resources during early stages of drought period	X	X	X			X	X	X	X	X
Increased water conservation efforts	X		X	X		X		X	X	X
Increase in public education/awareness concerning drought and water use	X			X				X	X	X
Increased cooperation across basins	X		X					X	X	X
Perception of water scarcity and corresponding vulnerabilities; intrinsic and economic value of water changed	X		X					X	X	X
Change in demand hardening: development of			X					X	X	X

	Education & Outreach	Agriculture	Municipal and Industrial Water Management	Energy	Tourism & Recreation	Ecosystems & Forestry	Safety & Public Health	Castle Rock	Glenwood Springs	Durango
"worst case scenario" planning										
Water right calls, injury to junior right holders	X	X	X		X	X		X	X	
Lack of cross-agency communication and collaboration	X		X			X		X	X	
Expectation from East Slope to supplement water shortages from West Slope sources	X		X					X	X	
Development of the II77 Process: Interbasin Compact Committee	X	X	X		X	X		X	X	
Development or expansion of drought contingency plans	X		X					X	X	
Impact to groundwater supplies, aquifers and wells; slow recharge rates		X	X					X		X
Increased utilization of climate & drought indicators and resources in water supply planning			X					X		
Increased incentive and pressure to build additional storage	X		X					X		
Increasing or change to water rate structures, especially in municipal areas	X		X	X				X		
Inconsistent watering restrictions across Front Range	X		X					X		
Landscape & planting restrictions	X	X	X					X		
Direct and indirect physical impacts tied to fire: loss or evacuation of homes, sediment loading, flooding, poor air quality, soil erosion	X		X		X	X	X		X	X
Diversification of agriculture techniques: less water intensive crops, increased dryland irrigating		X							X	X
Livestock mortality tied to dry vegetation, prolonged evacuation		X				X			X	X
Increase in streamflow temperatures					X	X			X	X
Drying of rangelands, grazing stress		X				X			X	X
Impact to water reliant recreation industries; i.e. whitewater rafting, fly-fishing, ski industry					X				X	X
Lower agriculture yields tied to crop stress and/or senior water right calls		X	X			X			X	X
Diversification of tourism industries: increased incentive to develop drought resilient economies: rock-climbing, four-wheeling, hiking, mountain biking	X				X				X	X
Increase in tree, forest stress						X			X	X
Conflict over instream flows	X		X		X	X			X	

	Education & Outreach	Agriculture	Municipal and Industrial Water Management	Energy	Tourism & Recreation	Ecosystems & Forestry	Safety & Public Health	Castle Rock	Glenwood Springs	Durango
Inconsistent information concerning resident evacuations, state recreational closures, road closures							X		X	
Insufficient time/communication to coordinate livestock evacuations		X					X		X	
Pre-determined flow regimes: inflexible water management and allocation structure on the Colorado River		X	X		X	X			X	
Development of shortage sharing agreements	X	X	X		X	X			X	
Immediate allocation of state funding to fight/mitigate fire and related drought impacts		X			X	X	X		X	
Wells ran dry; drove the need to haul water		X	X							X
Loss of riparian biodiversity						X				X
Development of new businesses related to fuel clearance, drought mitigation on property				X		X				X
Impact to aesthetic beauty/desirability of mountain communities	X				X					X
Increased public health resources tied to fire, air quality	X						X			X

After discussing what happened during the drought, participants were asked to identify what information, planning strategies, or government assistance would have helped them to better cope with the challenges. These needs tended to fall within four categories: climate, drought, and impact information; education, outreach, and communication; socioeconomic; and management (Table 10).

Table 10. Needs Identified by Participants for Dealing with Challenges Posed by Drought.

Climate, Drought, and Impact Information

- Multi-scale climate forecasts: 6, 12, 24, 48-month forecasts
- Aquifer status and health assessments
- Better moisture content and evaporative rate observations & monitoring
- Information on how to protect stressed trees from infestations, further drying
- Assessment of changing land use, grazing operations
- Agriculture and irrigation recommendations concerning when/what/where to plant in below average years
- Large-scale ecosystem impact assessments
- Better understanding of causation, behavior of pine beetle & other infestations
- Assessment of groundwater supplies (wells, aquifers) and recharge rates
- Increased well monitoring and risk assessment during times of shortage
- Early warning for multiple climate and hydrologic indicators. i.e. snowmelt timing, rate of runoff
- Cater forecasts to sector needs, specifically different temporal scales
- Better characterization of demand patterns and behavior
- Address uncertainty in seasonal forecasts, and climate projections
- Increased monitoring of regional wells
- Better interpretation of climate information; improve utility of information

Management

- Better appropriation of reserved grazing allotments
- Fire response: formulate response for sediment loading
- Currently it is very difficult to adapt, a reactionary approach: early warning needed
- Agriculture diversification: less water intensive crops, improved crop management approaches
- Increased water conservation
- Early fire warning and evacuation preparedness
- Further development & coordination of drought contingency plans
- Better identification and development of a drought indicator catalogue
- Longer planning horizons in drought and water management
- Need to streamline decision-making, especially with regards to issuing water restrictions
- Use of climate scenarios & corresponding exceedence projections in seasonal water supply management: 1-3 month outlook
- Drought preparedness & advanced early warning
- Historic firm yield estimates based on average water supply scenario are no longer viable: need to reassess critical yield approaches

"There is a need for a state-driven effort to encourage coordinated management between water providers & basins"

(Water Manager, Castle Rock Workshop)

Socio-Economic: Recommendations for the State

- Better economic diversification of local communities reliant upon tourism dollars
- Sharing of drought consequences across regions and basins
- Assessment of the interplay between municipal growth, drought, and firm yield
- Streamline bureaucracy at state level to shorten drought management response time
- Centralized message and information source concerning communication of drought conditions
- State-driven effort to encourage coordinated management between water providers & basins
- Assessment of before and after drought event: lessons learned
- Information on how to mitigate drought stress by sector and region
- Drought impacts to demographics, migration patterns, willingness and desirability to live in different areas

Education, Outreach, & Communication

- Increase need for public education: water conservation & scarcity, ecosystem impacts, drought
- Public awareness regarding fuel management, insect infestations around property, camping, recreational areas
- Increased communication of current drought conditions to general public and stakeholder groups
- Better communication of available climate and drought information, products and data to stakeholder groups
- Increased climate education for individuals & agencies in applicable fields; i.e. natural resource managers, state representative, policy and legal spheres
- Maintain saliency and importance of drought management & water conservation amongst the public

"Did the 2002 drought last long enough? How would drought response and public awareness be impacted if it were longer?"

(Forest Manager, Glenwood Springs Workshop)

Workshop Result:
Participant Concerns about Climate Change in Colorado

In the second half of the workshop, participants were asked to identify the most serious challenges that climate change would pose to different sectors across Colorado. Prior to the exercise, future projections of temperature and precipitation for Colorado were presented along with the consequent hydrologic changes (e.g., snowpack, runoff, evapotranspiration). Participants were then asked to consider the potential consequences of these climatic and hydrologic changes for sectors across the state: agriculture, municipal & industrial water management, energy, tourism & recreation, ecosystems & forestry, and safety & public health. These are the sectors that WWA and CWCB have identified as targets for Phase II of the *Climate Change in Colorado* Report, which will focus on climate impacts and vulnerabilities.

The list of potential climate impacts identified by participants is shown in Table 11. At all workshops, the most frequent challenges identified were those necessitating cross-sector collaboration and planning efforts.

In all three workshops, the participants, as a group, were able to essentially replicate the diverse list of climate change impacts that scientists have also identified as potential impacts of and vulnerabilities to climate change. Initially, we had anticipated a need to correct misperceptions by participants about climate change impacts, but there was no need as the group was able to accurately articulate impacts.

Table 11. What will be the Most Difficult and Important Challenges Climate Change will pose for Colorado in the Future?

	Education & Outreach	**Agriculture**	**Municipal & Industrial Water Management**	**Energy**	**Tourism & Recreation**	**Ecosystems & Forestry**	**Safety & Public Heath**	Castle Rock	Glenwood Springs	Durango
Uncertain future of tourist industries and economies					X			X	X	X
Increasing public health impacts tied to water and air quality, disease, and invasive species							X	X	X	X
Increasing energy demands				X				X	X	X
Long-term water availability as primary water management objective			X					X	X	X
Increasing number of water administration/management entities to accommodate increasing demand and conflict		X	X					X	X	X
Longer growing season		X						X	X	X
Increasing pressure on current water management/legal structure such as the Colorado Compact, *prior appropriation doctrine*, federally reserved water rights		X	X	X	X	X	X	X	X	X
Increased conflict between M&I and instream flow rights, whitewater parks, recreation, endangered species (specifically Black Canyon on the Gunnison River)		X			X	X		X	X	X
Increase in invasive species						X		X	X	X

	Education & Outreach	Agriculture	Municipal & Industrial Water Management	Energy	Tourism & Recreation	Ecosystems & Forestry	Safety & Public Heath	Castle Rock	Glenwood Springs	Durango
Increase in streamflow temperatures and resulting impacts to fisheries, riparian ecosystems					X	X		X	X	X
Premature snowmelt and resulting surface water supply vulnerabilities			X				X	X	X	X
Increasing water quality issues		X	X	X		X	X	X	X	X
Increasing water resource conflict and competition		X	X	X	X	X	X	X	X	X
Increasing water right transfers from agriculture to M&I		X	X					X	X	X
Likely increase in water availability for M&I			X					X	X	
Increased conflict across and between sectors		X	X	X	X	X	X	X	X	
Negative impact to reservoir storage			X					X		X
Increase in evapotranspiration, decrease in soil moisture levels		X						X		
Sedimentation load changes from multiple sources (wildfire reduces soil-H2O capacity)		X	X				X	X		
Increase in GHG emissions								X		
Increase in frequency of extreme climate events		X	X	X	X	X	X	X		
Increase in ecological instability						X		X		
Water shed degradation						X		X		
Cost associated with planning strategies to accommodate changes in climate		X	X	X	X	X	X	X		
Increasing risk to firm yields		X	X					X		
Impact to drinking water availability							X	X		
Stress on carrying capacities of ecosystems, endangered species, agriculture and ranching operations		X				X			X	X
Change in agriculture practices including less water-intensive crops, irrigation techniques		X							X	X
Increase in water rate structures and pricing			X						X	X
Increased need for public education campaigns concerning water conservation		X	X	X	X	X	X		X	X
Impact to overall image & perception of CO and willingness to live					X				X	X
Impact to inter/intra-state demographic make-up, migration patterns			X						X	X
Increased need to utilize water supplies for renewable energy development including hydroelectric, solar cooling processes		X	X	X					X	X
Increased incentive to invest in renewable energy supplies				X					X	X
Change in water treatment strategies			X						X	X

	Education & Outreach	Agriculture	Municipal & Industrial Water Management	Energy	Tourism & Recreation	Ecosystems & Forestry	Safety & Public Heath	Castle Rock	Glenwood Springs	Durango
Changes in winter recreation, specifically shorter ski season					X				X	X
Increasing consumptive use and decrease in return flows		X	X	X	X	X	X		X	X
Changes in trans-basin diversion strategies for the Front Range: increase in West slope vs. East slope conflicts			X						X	X
Riparian impacts: wetlands, fisheries, game species: impacts to habitat					X	X			X	X
Increase in sharing of climate change impacts and consequences		X	X	X	X	X	X		X	
Increase in citizen commitment to mitigating climate change impacts	X								X	
Increased need for public education campaigns concerning climate change, impacts, and adaptation strategies	X								X	
Increased incentive to invest in hydroelectric energy supplies				X					X	
Reduction in native flows						X			X	
Loss of biodiversity, specifically aquatic due to changes in runoff timing, warming temperatures						X		X	X	X
Broader water use implications: source of water for growth (M&I) uncertain		X	X					X	X	
Changing regimes for agriculture and ranching practices		X							X	X
Increase need to define energy production: hydrologic fracturing, coal fire plants-future of these industries is uncertain				X					X	
Migration of tropical diseases and species such as African bees							X			X
Longer fire season and resulting impacts: changes in forest composition, large-scale die-offs of lodge pole pine, increase in fire mitigation costs, impact to tourism industry, public health								X	X	X
Shorter time-span for growing irrigated crops as a result of earlier snowmelt: increase need for irrigation in agriculture practices		X								X
Impacts to sectors tied to degree of flexibility/adaptability in decision-making capacities		X	X	X	X	X				X
Need for increased water banking and storage to balance out supply and demand			X							X
Economic and demographic projections will be less certain: less reliability of the past to use as barometer for the future	X									X

Workshop Results:
Impacts to Water Resources Tied to Observed Drought and Projected Changes in Climate

One objective of the workshop was to identify impacts of both climate and drought as a step toward recognizing water supply vulnerabilities in the state. An ancillary objective of the workshop was to present drought in the context of climate variability and change, and to identify participant characterization of impacts related to drought and climate change. A compilation of participant characterization of impacts to water supplies tied to drought and/or climate is listed in Table 12. This is not a quantification of participant identification of impact to water supplies, rather is a summary of overarching trends in discussion related to drought and climate change in breakout sessions.

The frequency in the occurrence of X's in the climate change category coupled with the absence of X's in the drought category suggests that participants perception of impacts on water supplies is not always associated with strictly drought events; but rather that the extent of observed or expected impacts on water supplies are associated with long-term changes in climate. Table 10 (above) provides a list of recommendations for responding to and mitigating water-related vulnerabilities identified here.

Table 12: Compilation of Impacts from the 2000s Drought and/or Climate Change.

	Observed from the 2000's2000s Drought	Associated with Climate Change
Impacts to Physical Processes: Hydrologic & Ecosystem/Riparian Health		
Impact to water quality tied to low streamflows	X	X
Loss of biodiversity, specifically impact to fisheries and aquatic hatches	X	X
Increase in tree, forest stress	X	
Impact to groundwater supplies, aquifers and wells; slow recharge rates	X	
Increase in stream temperatures	X	X
Impact to streamflow amount: reduction in native flows; decreased return flows		X
Increased flooding tied to forest fire impacts	X	X
Increase in invasive species	X	X
Premature snowmelt	X	X
Increase in evapotranspiration, decrease in soil moisture levels		X
Sedimentation load changes from multiple sources (wildfire reduces soil-H2O capacity)	X	X
Increase in ecological instability: Stress on carrying capacities of ecosystems, endangered species, agriculture and ranching operations		X
Water shed degradation		X
Riparian impacts: wetlands, fisheries, game species: impacts to habitat	X	X
Water Management/Regulation & Legal Impacts		
Pre-determined flow regimes: inflexible water management and allocation structure on Colorado River	X	
Further development of shortage sharing agreements	X	X
Increasing pressure on current water management/legal structure: Colorado Compact, prior appropriation doctrine, federally reserved water rights		X
Increased conflict between M&I and instream flow rights: whitewater parks, recreation, endangered species (i.e. Black Canyon on the Gunnison River)	X	X
Impact to reservoir storage: less reliability		X
Increasing water right transfers from agriculture to M&I		X

	Observed from the 2000's2000s Drought	Associated with Climate Change
Increased conflict and competition across and between sectors		X
Landscape/planting restrictions	X	
Increase in planning across sectors to accommodate change in climate will be expensive		X
Increasing risk to firm yields		X
Impact to drinking water availability		X
Increase in water rate structures, pricing	X	X
Increased public education campaigns concerning water conservation	X	X
Change in water treatment strategies		X
Broader water use implications: source of water for growth (M&I) uncertain		X
Increased water banking and storage to balance out supply and demand		X
Long-term water availability as primary water management objective		X
Increasing number of water administration/management entities to accommodate increasing demand and conflict		X
Changes in trans-basin diversion strategies for the Front Range: increase in west slope vs. east slope conflicts		X
Water Dependent Industries: Energy, Agriculture & Tourism		
Energy		
Increased need to utilize water supplies for renewable energy development; i.e. hydroelectric, solar cooling processes		X
Increased incentive to invest in renewable energy supplies		X
Increased incentive to invest in hydroelectric energy supplies		X
Agriculture		
Drying of rangelands, grazing stress	X	X
Lower agriculture yields tied to crop stress and/or senior water right calls	X	X
Change in agriculture practices: less water-intensive crops, irrigation techniques		X
Changing regimes for agriculture and ranching practices		X
Longer growing season		X
Shorter time-span for growing irrigated crops as a result of earlier snowmelt: increase need for irrigation in agriculture practices		X
Diversification of agriculture techniques: less water intensive crops, increased dryland irrigating	X	X
Insufficient time/communication to coordinate livestock evacuations	X	
Outdoor Tourism & Recreation, Desirability		
Diversification of tourism industries: increased incentive to develop drought resilient economies: rock-climbing, four-wheeling, hiking, mountain biking	X	X
Impact to tourist economy: unsure of future		X
Changes in traditional recreation seasons: shorter ski and rafting season, longer hiking, mountain-biking season		X

Appendix: Meeting Participant Lists

Castle Rock Participant List

Name	Affiliation	Email
Bauers, Curt	South Adams Co. Water and Sanitation Dist.	cbauers@sacwsd.org
Basdekas, Leon	Colorado Springs Utilities	lbasdekas@csu.org
Belanger, Laura	Headwaters Corporation	belangerl@headwaterscorp.com
Bell, Janet	Jefferson County Conservation District	jrb10095@comcast.net
Binard, Debrah	Parks and Recreation, City of Denver	debrah.binard@denvergov.org
Bouvette, Tracy	Great Western Institute	tbouvette@tde.com
Brislawn, Jeff	AMEC Earth and Environmental	jeff.brislawn@amec.com
Droesch, Pam	South Adams Co. Water and Sanitation Dist.	pdroesch@sacwsd.org
Fanning, Paul	Board of Water Works of Pueblo	pfanning@pueblowater.org
Feinglas, Stu	City of Westminster	sfeinglas@cityofwestminster.us
Gillon, Kara	Defenders of Wildlife	kgillon@defenders.org
Griffin, Carol	Grand Valley State University	griffinc@gvsu.edu
Iturreria, Julio	Arapahoe County Planning Division	jiturreria@co.arapahoe.co.us
Kuhn, Eric	Colorado River District	ekuhn@crwcd.org
Leffler, Richard	Town of Frederick	rleffler@frederickco.gov
Ludwig, Scott	US Forest Service	saludwig@fs.fed.us
Lusk, Kevin	Colorado Springs Utilities	klusk@csu.org
Messner, Erin	Aurora Water	emessner@auroragov.org
Moss, SeEtta	Arkansas Basin Roundtable	seettam@gmail.com
Murrell, Tim	Douglas County	tmurrell@douglas.co.us
Newmark, Robin	National Renewable Energy Laboratory	robin.newmark@nrel.gov
Rodriguez, Alfredo	Aurora Water	drodrigu@auroragov.org
Schreiner, Tom	Colorado Division of Wildlife	tom.schreiner@state.co.us
Thorvaldson, Jennifer	Colorado State University	thorvy@lamar.colostate.edu
Peppler, Courtney	AMEC Earth and Environmental	courtney.peppler@amec.com
Staton, Kurt	US Forest Service	kstaton@fs.fed.us
Weaver, Berten	Clear Creek County	bweaver@co.clear-creek.co.us
Winner, Jay	Lower Arkansas Valley Water Cons. Dist.	cquezada@centurytel.net
Winter, Scott	Colorado Springs Utilities	swinter@csu.org
Woodall, Scott	US Forest Service	swoodall@fs.fed.us
Presenters and Facilitators		
Alvord, Christina	Western Water Assessment	christina.alvord@noaa.gov
Averyt, Krisein	Western Water Assessment	kristen.averyt@noaa.gov
Barsugli, Joe	University of Colorado - CIRES	Joseph.barsugli@noaa.gov
Doesken, Nolan	CSU - Colorado Climate Center	nolan@atmos.colostate.edu
Hutchins-Cabibi, Taryn	Colorado Water Conservation Board	taryn.hutchins-cabibi@state.co.us
Lukas, Jeff	Western Water Assessment	lukas@colorado.edu
McNutt, Chad	NOAA - NIDIS	chad.mcnutt@noaa.gov

Glenwood Springs Participant List

Name	Affiliation	Email
Earnst, Harley	Colorado Ass'n of Conservation Districts	jhe_farm@yahoo.com
Gilmore, Andrew	Bureau of Reclamation	agilmore@usbr.gov
Goodenow, Greg	Bureau of Reclamation	ggoodenow@usbr.gov
Graf, David	CO Division of Wildlife	david.graf@state.co.us
Luke, Dixie	Gunnison Basin Roundtable	dluke6265@juno.com
Jensen, Darlene	Colorado Ass'n of Conservation Districts	darlene@cacd.us
Kanzer, Dave	Colorado River District	dkanzer@crwcd.org
Knight, Erik	Bureau of Reclamation	eknight@usbr.gov
Lewis, Dylan	Sunlight Mountain Resort ski area	dylan@sunlightmtn.com
McBride, Kevin	Upper Yampa Water Conservancy District	kmcbride@upperyampawater.com
Merritt, David	Colorado River District	davidhmerritt@aol.com
Peterson, Kim	City of Aspen	kim.peterson@ci.aspen.co.us
Piergrossi, Monica	Western Voices Public Affairs Inc	monica.westernvoices@gmail.com
Pokrandt, Jim	Colorado River District	jpokrandt@crwcd.org
Reich, Denis	CSU Extension	Denis.Reich@Colostate.edu
Rettig, Mel	Mesa Conservation District	mmrettig@bigdoghsi.com
Roberts, Gary	Town of Breckenridge	garyr@townofbreckenridge.com
Rose, Susan	CSU Extension Tri River Area	susan.rose@colostate.edu
Shaw, Jim	ZeoponiX, Inc	jim@zeoponix.com
Sundstrom, Greg	Colorado State Forest Service	gsund@lamar.colostate.edu

Presenters and Facilitators

Alvord, Christina	Western Water Assessment	christina.alvord@noaa.gov
Averyt, Kristen	Western Water Assessment	kristen.averyt@noaa.gov
Barsugli, Joe	University of Colorado - CIRES	Joseph.barsugli@noaa.gov
Doesken, Nolan	CSU - Colorado Climate Center	nolan@atmos.colostate.edu
Gangwer, Kristin	University of Colorado	kristin.gangwer@colorado.edu
Hutchins-Cabibi, Taryn	Colorado Water Conservation Board	taryn.hutchins-cabibi@state.co.us
Lukas, Jeff	Western Water Assessment	lukas@colorado.edu

Durango Participant List

Name		Affiliation	Email
Ernie	Amos	San Juan Conservancy Board	ccranch1@verizon.net
Michael	Barber	Animas Watershed Partnership	VISTA@ecosphere-services.com
Ken	Beegles	Animas-La Plata Board Member	headwaters@animas.net
Robert	Blair	Mountain Studies Institute	blair_r@fortlewis.edu
Brooke	Chidrey	Dolores River Dialogue	bechildrey21@gmail.com
Jim	Dyer	SW Marketing Network	jadyer@frontier.net
Deanna	Collins	League of Women Voters, La Plata Co.	dcdurango@msn.com
Michael	Costello	Mountain Studies Institute	michael.cost@hotmail.com
Ken	Curtis	Dolores Water Conservancy District	kcurtis@frontier.net
Katrina	Dahlman	Western Hardrock Watershed Team	co@hardrockteam.org
Mat	DeGraaf	Pagosa Area Water and Sanitation District	mat@pawsd.org
Kalen	Elliott	Florida Canal	kalenelliott@hotmail.com
Steve	Fearn	Southwestern Water Conservation District	janem@southwesternwater.org
Jodi	Foran	League of Women Voters, Montezuma Co.	jodi@foran.net
Kimberly	Herb	Cork Tree Consulting	kherb@corktreeconsulting.com
Katherine	Holgate	Southern Ute Indian Tribe	kholgate@southern-ute.nsn.us
Aaron	Kimple	Mountain Studies Institute	kimple_a@fortlewis.edu
Bruce	Kowalski	Mountain Studies Institute	kowalski@ftitel.net
David	McCart	Blue Mountain Gardens	garlic@fone.net
Cara	MacMillan	USFS/BLM	caramacmillan@fs.fed.us
Estella	Moore	B.U.G.S. Consulting/Watershed LLC	Estella@bugsconsulting.com
Kelly	Palmer	San Juan Public Lands Center	kapalmer@fs.fed.us
Denise	Rue-Pastin	Water Information Program	denise@waterinfo.org
John	Taylor	Southwestern Water Conservation Dist.	janem@southwesternwater.org
Aileen	Tracy	Four Corners Office for Resource Efficiency	aileen@fourcore.org
Karen	Wessels	Pagosa Area Water and Sanitation District	marie@pawsd.org
Jan	Van West	Ridgway-Ouray Community Council	arcticwild@gmail.com
Rein	Van West	Ridgway-Ouray Community Council	arcticwild@gmail.com
Bruce	Whitehead	Southwestern Water Conservation District	brucew@southwesternwater.org
Presenters and Facilitators			
Christina	Alvord	Western Water Assessment	christina.alvord@noaa.gov
Joe	Barsugli	University of Colorado - CIRES	Joseph.barsugli@noaa.gov
Taryn	Hutchins-Cabibi	Colorado Water Conservation Board	taryn.hutchins-cabibi@state.co.us
Jeff	Lukas	Western Water Assessment	lukas@colorado.edu
Koren	Nydick	Mountain Studies Institute	nydick_k@fortlewis.edu
Imtiaz	Rangwala	Western Water Assessment	imtiaz.rangwala@noaa.gov

Appendix: Workshop Agendas

AGENDA
***Dealing with Drought – Adapting to a Changing Climate* workshop**
Douglas County Fairgrounds Events Center
Castle Rock, CO
Tuesday, October 13, 2009

9:00 - Welcome from Jack Hilbert, Douglas County Commissioner
Workshop Introduction
Pre-workshop survey – summary of results
9:30 - Fundamentals of global and Colorado climate
§ *Introduction to the basics of climate, with an emphasis on Colorado's climate, including the distribution of temperature and precipitation in the state*
10:05 - Colorado climate variability and trends
§ *Variability is a fact of life in Colorado; where does the year-to-year variation come from? What trends are seen in observed climate in Colorado?*

10:40 – Break

10:50 - Drought in Colorado – from observed and paleo
§ *Discussion of the observed record of droughts and the evidence from tree rings for extended dry and wet periods in the state's past.*
11:30 – Breakout/discussion sessions on drought
§ *Using information presented in the morning sessions, discuss past impacts of drought (e.g., 2000s drought); information and strategies used to monitor/adapt/mitigate;*
information that would have been useful
12:15 – Overview of the revision of State Drought Plan
- Jeff Brislawn, AMEC Earth & Environmental

12:30 - LUNCH

1:20 - Scenarios of climate change in Colorado
§ *Based on the* Climate Change in Colorado *report, we present scenarios of how Colorado's climate might be different by mid-century, and the global and local reasons this may happen.*
2:00 - Breakout/discussion session on climate change impacts, vulnerability
§ *Using information presented during the day, participants identify potential impacts of climate change and vulnerabilities for their sectors and activities*

2:30 - Climate change impacts on water and related resources
§ *Using information from the* Climate Change in Colorado *report and recent research articles, we will highlight some of the potential implications for water and related resources in the state to discuss and reinforce issues identified in the breakout groups.*
3:00 - Brief Discussion Session on Impacts
§ *After hearing the information presented in the previous session, revisit the list of potential climate change impacts*

3:15 – Break

3:30 - Web resources for climate and drought information
§ *Introduction to resources at the Colorado Climate Center, the NIDIS drought.gov portal, and others*
4:00 – The use of climate information to support water planning at Colo. Springs Utilities
- Leon Basdekas, Colorado Springs Utilities
4:15 – Wrap-up discussion session on future climate change/drought and information needs
§ *How can what was learned and discussed today best be reflected in planning for and adapting to the future? What additional information and resources are needed?*
4:45 – Post-workshop survey
5:00 – End

AGENDA

Dealing with Drought – Adapting to Climate Change
Glenwood Springs Community Center
Glenwood Springs, CO
Friday, October 16, 2009

9:30 - Welcome and Workshop Introduction
Pre-workshop survey – summary of results
9:45 - Fundamentals of global and Colorado climate
▪ *Introduction to the basics of climate, with an emphasis on Colorado's climate, including the distribution of temperature and precipitation in the state*
10:30 - Colorado climate variability and trends
▪ *Variability is a fact of life in Colorado; where does the year-to-year variation come from? What trends are seen in observed climate in Colorado?*

11:00 – Break

11:10 - Drought in Colorado – from observed and paleo records
▪ *Discussion of the observed record of droughts and the evidence from tree rings for extended dry and wet periods in the state's past.*
11:50 – Breakout/discussion sessions on drought
▪ *Using information presented in the morning sessions, discuss past impacts of drought (e.g., 2000s drought); information and strategies used to monitor/adapt/mitigate; information that would have been useful*

12:30 - LUNCH

Reporting from drought breakout groups
Overview of the revision of State Drought Plan
Taryn Hutchins-Cabibi, Colorado Water Conservation Board
1:20 - Scenarios of climate change in Colorado
▪ *Based on the* Climate Change in Colorado *report, we present scenarios of how Colorado's climate might be different by mid-century, and the global and local reasons this may happen.*
2:10 – Climate change impacts on the water cycle
Using information from the Climate Change in Colorado *report and recent research articles, we will describe the projections for climate-driven changes to the water cycle*
2:25 - Breakout/discussion session on climate change impacts and vulnerability
▪ *Using information presented during the day, participants identify potential impacts of climate change and vulnerabilities for their sectors and activities, and try to prioritize the most important impacts.*
3:00 – Group discussion session on climate change impacts
▪ *Compile the breakout lists of potential climate change impacts. Are there ones that were missed? Would you change the priorities, given what you heard from other groups?*

3:25 – Break

3:35 - Web resources for climate and drought information
▪ *Introduction to resources at the Colorado Climate Center, the NIDIS drought.gov portal, and others*
4:00 – The use of climate information to support water planning at Colorado River District
Dave Kanzer, Colorado River District
4:10 – Wrap-up discussion session on future climate change/drought and information needs
▪ *How can what was learned and discussed today best be reflected in planning for and adapting to the future? What additional information and resources are needed?*

Post-workshop survey
4:30 - End

AGENDA

Dealing with Drought – Adapting to Climate Change
Durango Public Library
Durango, CO
Thursday, October 22, 2009

9:00 - Welcome and Workshop Introduction
Pre-workshop survey – summary of results
9:20 - Fundamentals of global and Colorado climate
▪ *Introduction to the basics of climate, with an emphasis on Colorado's climate, including the distribution of temperature and precipitation in the state*
10:05 - Colorado climate variability and trends
▪ *Variability is a fact of life in Colorado; where does the year-to-year variation come from? What trends are seen in observed climate in Colorado?*

10:40 – Break

10:50 - Drought in Colorado – from observed and paleo records
▪ *Discussion of the observed record of droughts and the evidence from tree rings for extended dry and wet periods in the state's past.*
11:30 – Breakout/discussion sessions on drought
▪ *Using information presented in the morning sessions, discuss past impacts of drought (e.g., 2000s drought); information and strategies used to monitor/adapt/mitigate; information that would have been useful*

12:15 - LUNCH

Reporting from drought breakout groups
Overview of the revision of State Drought Plan
Taryn Hutchins-Cabibi, Colorado Water Conservation Board

1:00 - Scenarios of climate change in Colorado
▪ *Based on the* Climate Change in Colorado *report, we present scenarios of how Colorado's climate might be different by mid-century, and the global and local reasons this may happen.*
Using information from the Climate Change in Colorado *report and recent research articles, we will describe the projections for climate-driven changes to the water cycle*
2:10 - Breakout/discussion session on climate change impacts and vulnerability
▪ *Using information presented during the day, participants identify potential impacts of climate change and vulnerabilities for their sectors and activities, and try to prioritize the most important impacts.*
2:40 – Group discussion session on climate change impacts
▪ *Compile the breakout lists of potential climate change impacts. Are there ones that were missed? Would you change the priorities, given what you heard from other groups?*

3:00 – Break

3:15 - Web resources for climate and drought information
▪ *Introduction to resources at the Colorado Climate Center, the NIDIS drought.gov portal, and others. What resources have participants found to be useful?*
3:50 – Wrap-up discussion session on future climate change/drought and information needs
▪ *How can what was learned and discussed today best be reflected in planning for and adapting to the future? What additional information and resources are needed?*

Post-workshop survey
4:30 - End