Bear River Climate Change Adaptation Workshop Summary

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Salt Lake City, Utah

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Executive Summary

The Nature Conservancy (TNC) convened a two-day climate adaptation workshop for the Bear River Basin on May 26 and 27, 2010, in Salt Lake City, Utah. The goal of the workshop was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for adaptation action. Thirty-nine participants representing 20 public agencies, private organizations, and academic institutions attended the workshop.

The objectives of the workshop were to:
1. Provide information about the observed and projected effects of climate change in the Bear River Basin.
2. Introduce a framework for landscape-scale climate change adaptation planning for application to the Bear River Basin and other important conservation areas.
3. Assess the impacts of climate change on high-priority species and ecosystems.
4. Identify strategic actions to reduce the adverse impacts of climate change.
5. Identify opportunities for ongoing learning and collaboration for climate adaptation in the Bear River Basin.

Over the course of two days, managers, scientists and conservation practitioners identified adaptation strategies under two climate change scenarios for two conservation features: Bear River wetlands and the Bonneville cutthroat trout.

Key outcomes of the workshop were:
1. A shared understanding of the current and potential future effects of climate change, through development of conceptual models, on Bear River wetlands and Bonneville cutthroat trout.
2. A set of strategic actions that can be implemented to promote resilience and realignment of Bear River wetlands and Bonneville cutthroat trout in the face of climate change.
3. A discussion of opportunities to implement the identified strategic actions.
4. A list of research and monitoring needs for climate adaptation in the Bear River Basin for Bonneville cutthroat trout and oxbow wetlands.
5. Recognition among participants of the urgent need to take action to prepare for a changing climate.

By the end of the workshop, the participants identified a set of priority strategic actions for the each of the two conservation features, and discussed opportunities for implementation. These features and actions were:

Bonneville Cutthroat Trout (BCT)

- Reduce or remove competing non-native fish species (e.g., brown trout and rainbow trout), especially in headwaters.
- Maintain and create cool water refugia by preserving existing refugia, restoring habitat, providing connectivity among cooler reaches, and accessing cool water in deep water areas behind dams.
- Improve riparian and aquatic habitat through grazing management.
- Expand the distribution of BCT by identifying and strategically restoring former habitat: expand and improve headwater stream habitat, and reintroduce BCT and other native species to reaches from which they have been extirpated.
- Eliminate dispersal barriers in priority reaches by taking these steps: 1) inventorying barriers, 2) selectively removing physical barriers; and, 3) increasing seasonal water flows.

Bear River Oxbow Wetlands

- Create legal/financial incentives that would provide adequate water for wetlands.
- Restore and maintain healthy uplands in order to increase water retention and recharge that will benefit wetlands.
- Establish a land trust that can promote, hold and manage valley bottom conservation easements.
- Implement land use planning tools that help conserve wetlands.
- Educate the public about the value of wetlands and the agricultural community about wetland conservation incentive programs.

Many of the strategic actions are focused on private land and emphasize the use of existing land management planning and regulation approaches, including zoning and ordinances. The group agreed that the purpose of such intervention is not to hold the line – that is, to maintain wetlands and the Bonneville cutthroat trout in their current condition – but to *increase* the health and distribution of these conservation targets in order to increase their resilience in the face of climate change and the existing threats that it will exacerbate.

The participants provided additional observations to facilitate strategy implementation:

1) Strategy identification was viewed as an important first step in addressing the potential effects of climate change on species and systems of the Bear River. While there may be mostly "nothing new"[1] in these strategies, climate change was seen as aggravating the "usual suspects" and may help us prioritize where we apply resiliency-creating actions, e.g., choosing to work in those places that are most threatened and therefore need immediate attention, and/or conserving places that have the best chance of retaining quality wetlands and habitat for Bonneville cutthroat trout.

2) It is import to understand and acknowledge uncertainty while acting to manage risk and head off the most adverse climate change impacts. If decisions are robust and flexible they can be adjusted as we learn more about climate change in the future.

3) It will be necessary to take action across jurisdictional lines, working together to prepare for climate change whose consequences will likely be full of surprises, lasting, and extensive.

4) There is a need for institutional and political leadership and technical support.

The experts noted that this two-day session represents the beginning (rather than the end) of a long-term process for understanding and responding to the challenge of climate adaptation for the species, habitats and ecosystems of the Bear River Basin. The group emphasized in its closing discussion that the workshop was a good starting point for climate adaptation, but that more time, thought and energy will be required to build consensus for – and begin implementing – resilience-building strategies.

Specifically, the group wanted to explore the Main and Alternate climate change scenarios in more depth. They wanted deeper discussion, and more testing, of projected climate change effects on natural resources of the Bear River Basin. They called out the need to reexamine and refine the strategic actions developed in brainstorming sessions during the workshop's second day. They called upon stakeholders to make deeper commitments to research and – especially – to system-wide monitoring to determine the effects of climate change and effects of adaptation strategies. And they recognized the need to raise funds and rally managers around a shared program of work.

The group also observed that the Bear River Basin presents many good opportunities for conservation of the BCT and other conservation features through basinwide strategic planning. A large and strong partnership is already in place, there is much scientific information already available, funds are available from a number of different public and private sources, and using The Nature Conservancy's Conservation Action Planning methodology, a Bear River Conservation Action Plan has been developed.

The ecological changes that could occur under the climate change scenarios presented at the workshop will likely require more extensive and intensive management intervention

[1] It was pointed out by a participant that "it is innovative if we haven't yet implemented the idea."

than the suite of strategies identified at the workshop. Participants expressed the desire for continued collaboration across jurisdictional boundaries to plan for species and ecosystem adaptation to climate change in the Bear River Basin. This work of refining and implementing the strategies identified at the workshop can be coordinated through the existing partnership created through the Bear River Conservation Action Plan.

The *Bear River Climate Change Adaptation Workshop* was the fourth in a series of four workshops organized by the Southwest Climate Change Initiative (SWCCI), a project of TNC and collaborators from the Wildlife Conservation Society, USDA Forest Service, University of Arizona's NOAA-funded Climate Assessment for the Southwest (CLIMAS), University of Washington, National Center for Atmospheric Research, and Western Water Assessment. The goal of the SWCCI is to provide information and tools for climate change adaptation planning and implementation to conservation practitioners in Arizona, Colorado, New Mexico and Utah. For SWCCI products, including the Bear River workshop presentations and participant notebook materials, see: http://www.nmconservation.org/projects/new_mexico_climate_change.

Introduction

The Nature Conservancy (TNC) in Utah, working with TNC-New Mexico, University of Arizona, and the Wildlife Conservation Society, convened a two-day workshop entitled *Bear River Climate Change Adaptation Workshop* on May 26 and 27 at Fort Douglas on the University of Utah campus in Salt Lake City, Utah (See Appendix 1 for the agenda). A total of 39 participants representing 20 public agencies, private organizations, and academic institutions participated (See Appendix 2 for a list of participants).

This workshop was the fourth in a series of four workshops organized by the Southwest Climate Change Initiative (SWCCI), a collaborative effort (with the above-listed partners) to provide information and tools for climate change adaptation planning and implementation for conservation practitioners in the Four Corners states: Arizona, Colorado, New Mexico and Utah.

Workshop Goal and Objectives

The workshop goal was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for strategy implementation.

The objectives of the workshop were to:

1. Provide information about the observed and projected effects of climate change in the Bear River Basin.
2. Introduce a framework for landscape-scale climate change adaptation planning for application to the Bear River Basin and other important conservation areas.
3. Assess the impacts of climate change on high-priority species and ecosystems.
4. Identify strategic actions to reduce the adverse impacts of climate change.
5. Identify opportunities for ongoing learning and collaboration for climate adaptation in the Bear River Basin.

Why the Bear River?

The Bear River travels 500 miles through Utah, Wyoming and Idaho. Vital to both human and natural communities, the Bear River provides critical wildlife habitat and serves as the largest water source for globally important habitats at the Great Salt Lake. Its importance has been recognized in several regional conservation assessments and plans.[2] Many partners came together in 2009 to produce the first biologically-driven cross-jurisdictional strategic plan for the three-state Bear River, the Bear River Conservation Action Plan (CAP). The CAP reinforced many activities that partners were already doing, highlighted areas for new activity and identified information gaps.

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[2] These plans include Noss, R., Wuerthner, G., Vance-Borland, K,, and Carroll, C. 2001. A Biological Conservation Assessment for the Utah-Wyoming Rocky Mountains Ecoregion: Report to the Nature Conservancy. Conservation Science, Inc. Jones. A., Catlin, J., 2004. Heart of the West. Wild Utah Project.

One of the major information gaps was climate change. Through the CAP development process, it was identified as a threat to the system, but more specific information was needed about what changes to temperature and moisture were likely and how such changes might affect the systems of interest. The SWCCI approach offered an opportunity to answer these questions and then incorporate the answers into the strategic plan.

Workshop Outcomes

Over the course of two days, participants worked through an interactive process to identify adaptation strategies under two climate change scenarios developed by Senior Scientist Linda Mearns of the National Center for Atmospheric Research and Research Scientist Joe Barsugli of University of Colorado's Western Water Assessment. Workshop outcomes include:

1. Review and interpretation of two climate change scenarios. Shared acknowledgement of uncertainties associated with projections, but recognition of the need to move forward.

2. Development of conceptual ecological models and long-term management objectives for two conservation features: Bear River oxbow wetlands and Bonneville cutthroat trout.

3. Shared understanding of the known current and potential future effects of climate change, through development of conceptual models, for Bear River oxbow wetlands and Bonneville cutthroat trout. Conceptual models illustrate the climate, ecological, physical, and social factors that affect conservation features.

4. Identification of management intervention points (ways that managers can influence the ecosystem) for climate adaptation. Documentation of the critical assumptions behind specific management actions using conceptual ecological models.

5. Identification of practical adaptation strategic actions that can be implemented to promote resiliency and realignment of Bear River oxbow wetlands and Bonneville cutthroat trout in the face of two climate scenarios.

6. Identification of barriers and opportunities to implementing strategic climate adaptation actions at a scale and pace sufficient to meet management objectives for the conservation features in the context of rapid climate change.

7. Statement of research and monitoring needs for informing climate adaptation strategies in the Bear River basin.

8. Recognition that more work is needed to identify "no-regrets" strategic actions to reduce the impacts predicted under the climate change scenarios. Assessment of

the ecological changes that could occur under the climate change scenarios will require more in-depth climate analyses.

9. Recognition that cross-jurisdictional collaboration is needed to refine workshop products and implement the actions.

10. Recognition that effective climate change adaptation will require a great deal of communication and collaboration among stakeholders and policy makers.

Background Information for Development of Adaptation Strategies

Introductory Remarks

The workshop began with a statement of the significance of the climate change challenge in the Southwest and the need for adaptation planning. It continued with a group discussion of why is it hard for organizations to move forward on planning for climate change.

Dave Livermore, Director of the Utah Field Office of the Nature Conservancy, welcomed the participants to the meeting.

Patrick McCarthy, director of the Southwest Climate Change Initiative (SWCCI), provided an overview of the SWCCI, a regional project whose goal is to build understanding of the effects of climate change on natural resources, and to encourage and inform climate adaptation planning at landscapes across the U.S. Southwest. In his introductory plenary talk, he reviewed the observed and projected effects of climate change on the biodiversity of the Southwest, using these findings to underscore the logic and urgency of taking action now to help natural systems cope with inevitable climate change.

Notes and slides from his presentation can be viewed or downloaded at http://nmconservation.org/downloads/data/bear_river_climate_change_adaptation_workshop/. Key points from the presentation include the following:

> *Climate stability and persistent ecosystems are no more.*
> Several years ago it became apparent to the conservation community that we are no longer working in a world where we can assume climate stability and persistent ecosystems. Hydrologists now say, for example, that "stationarity[3] is dead." The assemblages of species we have known as persistent, relatively stable, natural communities will disassemble and reassemble in new and unpredictable ways. In fact, climate change is already causing subtle change, like changes in timing of migrations or leaf-out, and dramatic and sometimes surprising change, such as widespread forest dieback, due to the crossing of temperature and moisture thresholds.

[3] The idea that natural systems fluctuate within an unchanging envelope of variability. (See Milly et al. 2008 for more on stationarity, climate change and water management).

We must avoid unmanageable climate change by reducing carbon emissions now
The community's first response to the emerging science of climate change has been to push for reductions in the emissions that may lead to what some of the world's most prominent ecologists and climatologists call "dangerous climate change." TNC and other conservation organizations have taken this on in earnest through efforts in Washington, state capitals, and internationally, to promote new policies that would establish emission reduction targets and controlling the global deforestation that causes 17% of GHG emissions.

We must manage unavoidable climate change by helping ecosystems adapt
Climate scientists are now in near-unanimous agreement that the Earth's climate has already been disrupted irrevocably, and that there will be significant warming, increases in the intensity and frequency of droughts, and other climatic changes in the coming decades (and even centuries) even if we dramatically reduce carbon emissions now. Thus the conservation community's fallback strategy—one that is looking increasingly necessary: to help ecosystems adapt by building resilience in the face of a rapidly changing climate.

Climate change is already well underway in the southwestern U.S.—more so than in other North America regions, outside the northernmost latitudes—and it is already affecting native plants, animals and habitats.

In The Nature Conservancy's analysis of climate change in the Southwest, which we began in 2007 in New Mexico and recently expanded to the Four Corners, we determined that:

- From 1960-2006 mean annual temperatures have risen several degrees Fahrenheit across the great majority of the region's land area.
- The timing of peak streamflow is on average a week earlier than in the mid-20th century and, in one site, peak runoff arrives on average 23 days earlier.
- Of 40 cases of species population changes we found in the scientific literature, most (28) involved population declines, including declines in endemic species and forest dieback; shifts in species distribution (elevation, latitude) comprised about 1/3 of these 40 cases.
- Climate change is pushing ecosystems across physiological thresholds, resulting in wholesale changes in species composition and vegetation cover. For example, a massive piñon pine dieback occurred on over 3 million acres of woodlands across the Four Corners during the 2002-2003 drought, with some sites suffering mortality rates of up to 94%. Scientists have linked this extensive dieback to climate change—specifically, to an anomalous combination of exceptionally warm summer temperatures and deep drought.

Though there remains some uncertainty about projected climate change effects, now is the time to figure out how to manage risk and minimize loss.
Governments, businesses and individuals have made an enormous investment – billions of dollars – in building an understanding the climate system, and this investment has paid off in greatly increased knowledge about global and regional patterns. Even though uncertainties remain, any action we take now to understand the local effects and to build resilience will help us, over time, become more effective in the face of ecological change that may be more rapid and extensive than any of us can now imagine.

We're all in this together.
Climate change does not respect ecological or jurisdictional boundaries. It changes the former and ignores the latter. Unlike some other threats to diversity, it is global and affects us all. To build resilience and reduce loss, we must act together, across political boundaries, to accelerate adaptation action.

The Southwest Climate Change Initiative is aiming for practical climate adaptation on the ground, at four focal landscapes.
TNC engaged the University of Arizona (Climate Assessment for the Southwest), Wildlife Conservation Society, USDA Forest Service, National Center for Atmospheric Research and Western Water Assessment to collaboratively design and carry out the SWCCI, which includes Arizona, Colorado, New Mexico and Utah and whose goal is to provide information and tools to conservation practitioners for climate adaptation in vulnerable landscapes. The initiative has three functions:

1. Prepare a **regional assessment of climate change exposure** that will identify the places where temperature, precipitation and moisture stress have changed, and will change, the most and the least, helping us set priorities for climate adaptation. We plan to complete an interim report in 2010.

2. Organize a series of **landscape workshops**, one in each of the Four Corners states, where conservationists can work together to identify science-based and practical adaptation strategies and can commit to implementing and testing these strategies for the benefit of nature and people at these sites.

   We've completed three workshops and are making the reports available through our web site. Follow-up adaptation work is underway at all three.

3. **Draw upon the four workshops** for data, tools and lessons that can be applied to some of the hundreds of other landscapes in the southwestern US that may be adversely affected by climate change.

There is more detail about the SWCCI in the one-pager in the workshop's participant notebook. More information is available at
http://nmconservation.org/projects/new_mexico_climate_change/

The measure of success: on-the-ground action to build ecological resilience
All of us in the SWCCI recognize that ultimate measure of success of this workshop will be the extent to which informed, collaborative action is taken by you and your organizations to build the resilience of the Bear River Basin in the face of ongoing climate change. Let's get started.

Gregg Garfin of the University of Arizona (UA) was the lead facilitator of the two-day workshop. Dr. Garfin is an expert in Southwest climatology, the UA's deputy director for science translation and outreach at the Institute of the Environment, and an investigator with the Climate Assessment for the Southwest (CLIMAS – a NOAA funded Regional Integrated Sciences and Assessments project [RISA]).

In his remarks, Garfin provided the rationale for the workshop and gave participants a chance to share their current concerns about climate change. Garfin asked participants to break out into small groups to identify barriers and uncertainties regarding climate change. Participant responses (Box 1) were diverse but consistent with the concerns participants have expressed at other Southwest Climate Change Initiative workshops. Some responses, particularly with respect to public perceptions of climate change and the political and institutional zeitgeist in Utah, were unique to this workshop.

Box 1. What is the greatest barrier or uncertainty that Bear River Basin scientists, planners and managers face in moving forward on planning for climate change?

Institutional and public attitudes toward climate change and uncertainty

- The private sector is risk averse and does not tolerate uncertainty well;
- Uncertainty leads to lack of support for making planning changes;
- In Utah, the prevalent attitude toward climate change is one of skepticism: agency and private sector denial of the results of climate change science and resistance to uncertainty results in constraints on data collection and even data use.

Policy and political will

- There is a lack of policy experimentation and innovation, political will to change, and a lack of resources for change. As one participant put it, “It is like trying to turn a ship with a feather.”

Key constituencies are lacking

- The agricultural sector, a key water user, is not represented at this meeting.

Basic and applied science

- Inadequate characterization of resilience: What does it mean…across different organizations?
- There is a lack of key data.
- Inadequate information on the combined and interacting effects of climate change and other factors: How will these play out?
- Inadequate knowledge of how climate change will affect ecosystems and ecosystem processes, and an inadequate ability to conceptualize change.
    - Inadequate information on ecosystem trajectories
- Lack of information on how climate change will affect individual species, hydrology, and Bear River water resources.

Management, decision, and risk science

- Lack of information on whether any of the proposed strategies for coping with climate change will work.
- Lack of information on whether current management methods will be appropriate for the future.

Key points from Garfin’s presentation included the following:

- The goal of the workshop is to get from continental level to landscape level climate change projections, in order to identify strategies to address impacts.
- Preliminary lessons learned from other landscape adaptation workshops, including those convened by the USDA-Forest Service: adaptive management approaches are likely to be successful; managers need to lead the development of adaptation strategies; work in partnerships and leverage multi-agency resources; science-management collaboration will increase the likelihood of success; involve the public; and confront uncertainty.
- This workshop is a starting place for understanding the Bear River Basin system and how climate affects the system, its hydrology, and its ecosystems.

Presentations: Climate Change in the Bear River Basin

Following this session, a series of introductory presentations were given by experts on the evidence for climate change and its ecological effects in and around the Bear River. These presentations provided background information for participants to apply during the adaptation planning exercise. Copies of these presentations can be downloaded from http://nmconservation.org/projects/new_mexico_climate_change/ .

Linda Mearns, director of the Weather and Climate Impacts Assessment Science Program and senior scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, presented projections of future Bear River Basin climate and scenarios for the workshop. Her presentation, titled *Future Regional Climate Change in the Bear River Basin: Concepts and Scenarios*, supplemented her May 10, 2010 webinar—*Overview of Regional Climate Change: The Known, the Unknown, and the Uncertain*, which focused on the science of the climate system, global climate projections, and sources of uncertainties. (A copy of the webinar presentation can be obtained from Joan Degiorgio at jdegiorgio@tnc.org.)

Key points from Dr. Mearns' workshop presentation include the following:

- Three key challenges to making realistic projections of future climate conditions are (1) the varied topography of the Bear River Basin, (2) the lack of adequate modern climate records in order to accurately understand fine details of the climate of the Basin, and (3) the relatively low resolution of climate models.
- The climate change projections for North America, from the IPCC (Intergovernmental Panel on Climate Change) are based on a moderate greenhouse gas emissions scenario – A1B: business as usual greenhouse gas emissions, no increase in globalization of sustainable practices, with global population increasing until the 2060s. These projections are based on 21 models, with typical geographic resolution of around 150 miles per side of a grid cell.
    - IPCC North American projections suggest that annual average precipitation will decrease in the Southwest U.S. (67% probability), and that snow depth (67% probability) and snow season length (90% probability) will decrease in North America.
    - There is much uncertainty regarding future precipitation in the Bear River Basin region.
- The scenarios that Dr. Mearns created for the Bear River Basin use regional climate model downscaling (so-called "dynamical downscaling") to bring climate projections down to a resolution of about 30 miles per side of a grid cell. (These projections were culled from NARCCAP, the North American Regional Climate Change Assessment Program). The special projections and scenarios for this workshop are based on a medium-high greenhouse gas emissions scenario – A2: close to business as usual emissions, with assumptions of no greenhouse gas mitigation and large increases in global population.

- The scenarios were based on models falling within the middle of the range of all model projections, between the 25th and 75th percentile of model estimates.
    - Scenario development focused especially on the winter and summer seasons.
- Detailed annual and seasonal temperature, precipitation and hydrologic projections for the workshop can be found in Appendix 3. A summary can be found on page 16.
- Year-to-year variability will continue to be an important aspect of the future climate; thus, there may be multi-year decreases in temperature in the future, even as temperatures continue to increase during the course of many decades during the 21st century.
- **Do we need to eliminate uncertainty to respond to climate change? No, it is better to cope with current uncertainties, by making decisions that are robust and flexible that can be adjusted as we learn more about climate change in the future**.

Joe Barsugli, Research Scientist at the Cooperative Institute for Research in the Environmental Sciences (CIRES) at the University of Colorado, Boulder, and the NOAA Western Water Assessment RISA gave a presentation entitled *Hydrologic Projections for the Bear River Basin.* (Dr. Barsugli acknowledged Alan Hamlet [University of Washington], Jeff Deems [Western Water Assessment], Kevin Werner [NOAA Colorado Basin River Forecast Center], and Eve Davies [PacifiCorp] for their insights).

Key points from his presentation include the following:

- Hydrologic modeling used the climate scenarios developed by Dr. Mearns, as input. Barsugli modeled flows in tributaries, including the Bear River headwaters (northeastern Utah), the Smith Fork (southwestern Wyoming), and the Logan River (Utah). Precipitation over this region varies from more than 45 in./yr. in the Logan River headwaters, to less than 15 in./yr. in the valleys.
- Dr. Barsugli noted that temperature increases impact the entire water cycle, including the fraction of winter precipitation received as snow, the overall snowpack, the timing of runoff, evapotranspiration, drought severity, groundwater recharge, plant water use, stream temperatures, and water demand.
- He cautioned that models give ballpark estimates of the direction and magnitude of hydrologic change, and how processes are affected. He used the VIC (Variable Infiltration Capacity) model from the University of Washington.[4] VIC calculates changes in the energy balance at the surface, and its impacts on vegetation canopy, soils, and streams – in 5 elevation bands. He noted that wetlands are not explicitly modeled by VIC.
    - He demonstrated that the long term averages were well modeled, that there is great variability in the historic hydrology of the Bear River Basin, and

[4] There are many references to this model at this website: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Documentation/References.shtml

that the model overestimates flows, due to lack of input information about consumptive water uses.
    - He mentioned that he used the "delta method" to conduct sensitivity analyses of Bear River Basin hydrology. The delta method applies average changes in temperature and precipitation as inputs, and models the changes in hydrology.
    - He also reiterated that the stream flow and climate observation networks for the Bear River Basin, especially at high altitudes, are inadequate for modeling current streamflows.
- In general, the hydrologic projections show
    - Shifts in streamflow timing, with more future winter runoff events and fewer future spring runoff events, due to earlier snowmelt runoff – about 1 month earlier in both scenarios by mid-century.
    - There are slight compensating changes in hydrology, depending on the scenario:
        - The main scenario (#1) shows increased winter precipitation, but decreased spring precipitation; thus, much earlier runoff.
        - The alternative scenario (#2) shows increased spring precipitation, but decreased winter precipitation; thus somewhat earlier runoff.
    - All projections show decreased annual runoff. Lower elevation sites experience more pronounced reductions in average snowpack.
- Dr. Barsugli noted that the timing of agricultural irrigation demands will be an important intervening factor to compensate for changes in hydrology and the timing of runoff. Demand is a function of temperature, as well as precipitation.
- See Appendix 4 for details of the hydrologic scenarios developed by Dr. Barsugli for the Bear River Basin.

Summary of Climate Scenarios for the Bear River Basin

To guide the workshop discussions of the impacts of climate change and potential adaptation strategies, Dr. Mearns (NCAR), developed two climate change scenarios in collaboration with Dr. Barsugli (CU), who developed two scenarios of hydrological change. Scenarios for the development of adaptation strategies at this workshop are for 2040-2060. The scenarios are based on the IPCC SRES Emissions Scenario-A2 (medium-high emissions). The hydrologic scenarios are consistent with the climate change scenarios. The hydrologic modeling output is based on "natural flows," unaltered by diversions and reservoir storage. The two climate scenarios are summarized below.

Main Scenario (Scenario #1)

Climate
Annual temperature: +3.5°C (+6.3°F)
Annual precipitation: +1.6%

Season	Precipitation %	Temperature °C	Temperature °F
Winter	+13	+2.5	+4.5
Spring	-6	+3.5	+6.3
Summer	-15	+4.5	+8.1
Fall	0	+3.5	+6.3

Hydrology

Parameter	Impacts
Runoff Amount	5-18% decrease in annual runoff
Snowpack Accumulation and Melt	later fall accumulation 10-15% lower peak accumulation earlier spring melt – 2-4 weeks
Runoff Timing	earlier by 1-3 weeks
Summer Flows Winter Flows	low flows -10% high flows -25% 30-50% increase, due to more rain events

Alternate Scenario (Scenario #2)

Climate
Annual temperature: +2.7°C (+4.9°F)
Annual precipitation: -3%

Season	Precipitation %	Temperature °C	Temperature °F
Winter	-5	+2.7	+4.9
Spring	+10	+2.0	+3.6
Summer	-20	+3.0	+5.4
Fall	+3	+3.0	+5.4

Hydrology

Parameter	Impacts
Runoff Amount	5-13% decrease in annual runoff
Snowpack Accumulation and Melt	later fall accumulation 15-10% lower peak accumulation earlier spring melt – 2-4 weeks
Runoff Timing	earlier by 1-2 weeks
Summer Flows Winter Flows	low flows -15% high flows -50% 30-50% increase, due to more rain events

See the Reference section for information sources and the Workshop Participant Notebook materials for more details at the following link (see downloads section): http://nmconservation.org/projects/new_mexico_climate_change/.

Dr. Frederic H. Wagner, Emeritus Professor, Department of Wildland Resources, Utah State University, gave a presentation titled *Overview of Ecological Consequences of Climate Change in the West.*

Key points from his presentation included the following:

By examining ecological consequences in the relatively recent past, we may get a qualitative sense of the direction of future consequences of climate change. Climate change effects can be grouped into three major categories: Single Species Effects, Community/Ecosystem Effects, and Changing Western Hydrology.

Single Species Effects (Responses of Individual Species)
A growing body of literature has focused on responses of individual species to climate change. The three major types of changes are: range extensions, changing phenology, and population changes. For example:

- ***Range extensions*** Red foxes have been moving northward into the range of the arctic fox, driving arctic foxes farther northward or locally extirpating them on account of the greater competitiveness of red foxes.
- ***Phenology (seasonal) changes – such as plant flowering, bird nesting*** Dr. David Inouye, of the Rocky Mountain Biological Laboratory and the University of Maryland, has catalogued changes in the timing of various phenological phenomena in the West. He has determined over about four decades of research that robins now begin nesting about two weeks earlier, and yellow-bellied marmots emerge from hibernation about one month earlier than previously.
- ***Population changes*** Re-inventory of 25 populations of pikas in Nevada found that pika populations have disappeared from 8 lower-elevation mountain ranges. Pika populations have in general been moving upward in elevation, but they

cannot move high enough in such lower ranges and thus are disappearing from those places.

Community/Ecosystem Effects

Species exist in webs of interactions with each other. For example, a key species interaction influenced by climate change may be a changing timberline and sage grouse. That is, the relative aridity of western U.S. mountain ranges creates a lower timberline driven by precipitation. As rising temperatures drive increased evapotranspiration, precipitation may or may not be adequate to compensate for the moisture loss. If precipitation is inadequate, then lower timberlines may move upward in elevation. If precipitation is adequate to compensate, then lower timberlines could move downward in elevation, even out into adjacent valleys where trees species may invade sagebrush ecosystems, altering habitat for obligate animals, such as sage-grouse.

Changing Western Hydrology

There are many signs that western hydrology is changing. For example:

- Analysis of 926 Natural Resources Conservation Service snow sampling (SNOTEL) sites back to the 1950s showed declines in April 1st snow water content in 72% of the sites.
- Analyses of April-through-July stream flows as a fraction of the water-year total show that peak runoff periods are occurring about two to three weeks earlier in many western streams, thus prolonging the low-flow period following peak runoff. Thus, the proportion of total flow occurring in spring is decreasing; hydrographs are "flattening out."
- Water temperatures in western streams are warmer at lower elevations and colder at higher elevations, with aquatic fauna sorted according to this gradient. As rising air temperatures cause the zone of warmer water temperatures to expand to upstream reaches, the warmer-water fauna would also migrate upstream, thus "pinching" cold-water fauna at the upper ends of some streams. As a result, native cold-water species such as cutthroat trout could disappear from streams in lower-elevation mountain ranges.
- Dr. Phaedra Budy of Utah State University notes that water temperature changes (increases) in streams may have other effects. Populations of introduced brown trout may move farther upstream, posing additional problems for native cutthroat trout. Also, whirling disease is limited by lower temperatures, but as water temperatures rise, outbreaks of whirling disease may become more likely. Dr. Budy listed three potential strategies for adaptation of cutthroat trout to climate change: more fencing of streams to limit access and damage by cattle, planting of woody vegetation in riparian zones to provide shading and thus cooler local water temperatures, and removal of non-native brown trout.

Introduction to Adaptation Planning

Molly Cross, climate change ecologist and adaptation coordinator with the Wildlife Conservation Society (WCS), provided an overview of climate change adaptation concepts and approaches, including a new adaptation planning framework in her presentation, *Place-based Climate Change Planning: Overcoming the Paralysis of Uncertainty*.

Key points included:

- There are many challenges to incorporating climate change into natural resource management, including how to make broad understanding of impacts applicable to specific systems, how to deal with the uncertainty and complexity of climate change, how to know where to begin planning for the impacts of climate change, and how to determine what it is we're trying to manage for in a time of change (e.g., should we be focused on resisting change or allowing responses and transitions to happen). The lack of specific direction on how to adjust management decisions in light of climate change is causing *uncertainty paralysis*, preventing managers from taking action in the near term.

- The Wildlife Conservation Society, the Center for Large Landscape Conservation, and the National Center for Ecological Analysis and Synthesis convened a working group of scientists and managers from multiple institutions and agencies to develop the Adaptation for Conservation Targets (ACT) Framework designed to translate general recommendations on climate change adaptation strategies into practical, specific actions for a given landscape, set of species, or ecosystems using a transparent and participatory process (Cross et al. *in review*). This framework was modified slightly for the purposes of this workshop, to include components of TNC's conservation action planning methodology for addressing climate change (TNC 2009).

- The ACT Framework has been applied at climate change adaptation workshops in the Jemez Mountains, New Mexico (Enquist et al. 2009), the Gunnison Basin, Colorado (Neely et al. 2010), the Four Forest Restoration Initiative area near Flagstaff, Arizona (Smith et al. 2010) and at a workshop organized by WCS and the U.S. Fish and Wildlife Service on adaptation planning for grizzly bears and wolverine in the Northern U.S. Rockies (contact mcross@wcs.org for details). The TNC climate and conservation action planning methodology has been applied to 20 sites across the globe at a workshop held in Utah in September 2009. (See The Nature Conservancy's Climate Adaptation workspace on ConserveOnline for more information).

Implementation of the Adaptation Planning Framework

The climate change adaptation framework is designed for collaborative application in a given landscape by a multidisciplinary group of managers, conservation practitioners and scientists, and includes the following steps:

1. Select feature targeted for conservation (e.g., species, ecological processes, or ecosystems) and specify an explicit, measurable management objective for that feature.
2. Build a conceptual model that illustrates the climatic, physical, ecological, and socio-economic drivers that affect the selected feature.
3. Assess impacts of plausible future climate scenarios:
    a. Use the conceptual model to assess climate change impacts (i.e., develop hypotheses of change) by examining how specific changes in climate variables might directly or indirectly influence the selected feature, for each scenario of future climate conditions being considered.
    b. Consider how human responses to climate change (e.g., solar and wind power development, geothermal exploration, construction of dams for increased water storage, etc.) may influence the selected feature.
    c. Assess the likely impact of climate change relative to other known impacts or threats, and identify which climate-induced impacts are most critical to address to achieve the stated management objective.
4. Identify potential strategic actions in light of climate change:
    a. Identify intervention points—those places in the system that we can influence through management and conservation actions.
    b. Brainstorm potential strategic actions that can be taken at those intervention points to achieve the stated objective under each climate scenario.
    c. Determine whether the management objective or the selection of the feature needs to be revisited: Does climate change fundamentally change the landscape? Do the management objectives for that feature need to change? Will the feature even be found in the same location in the future? Does our view of the landscape and boundaries need to change?
5. Evaluate feasibility of potential strategic actions and prioritize according to factors such as: cost; social and political feasibility; potential for positive effects or risk of unintended negative consequences for other features or objectives; and robustness to uncertainty in future climate.
6. Develop action plan outlining priority strategic actions to be implemented.
7. Implement action plan.
8. Monitor and evaluate action effectiveness and progress toward objectives—adjust or reevaluate actions if needed to address system changes or ineffective actions.

For the purposes of this workshop, breakout groups focused on completing the first five steps of the *planning phase* (left-hand side of Figure 1). Workshop facilitators divided the or the Bonneville cutthroat trout.

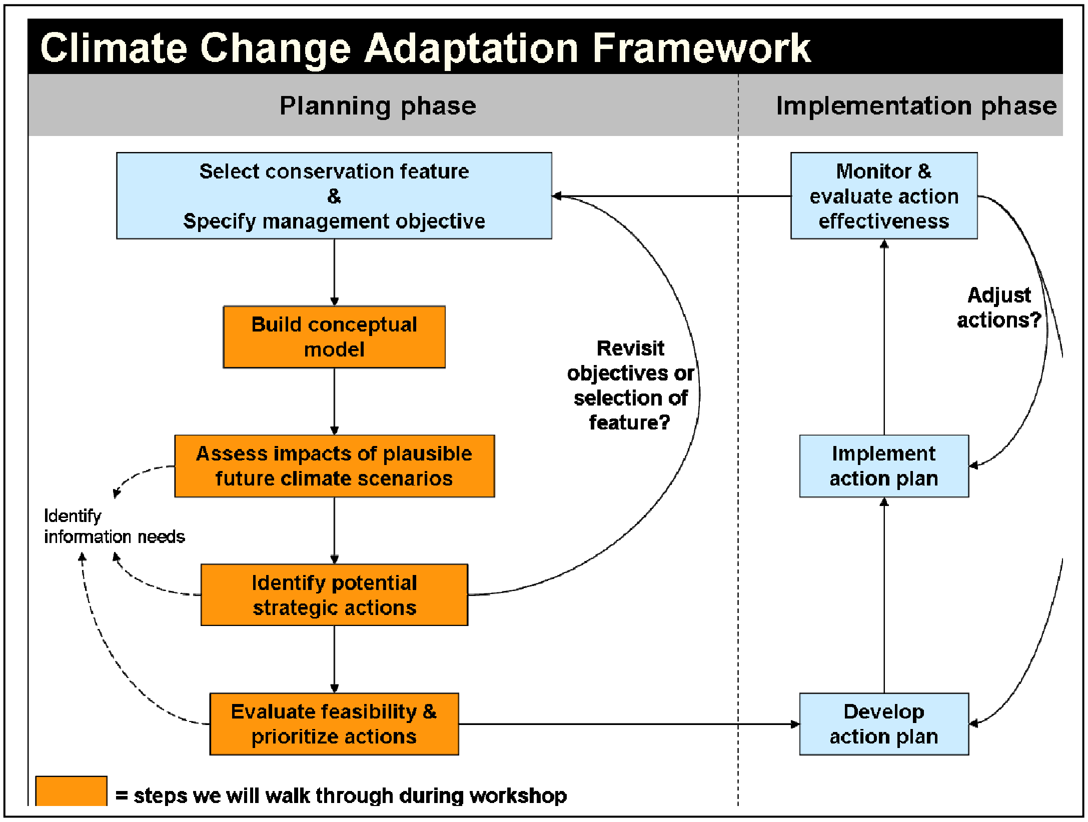


Figure 1. An iterative climate change adaptation framework for natural resource management and conservation (adapted from Cross et al. *in review* and TNC 2009). The left side represents the adaptation planning phase; the right side represents the implementation phase.

The workshop was then divided into two groups to develop adaptation strategies for the Bear River wetlands and Bonneville cutthroat trout, using the introductory material (above) as a guide.

Climate Change Adaptation Strategies for Bonneville Cutthroat Trout

Facilitated by Patrick McCarthy of The Nature Conservancy and Gregg Garfin of the University of Arizona, the Bonneville cutthroat trout (BCT) breakout group included thirteen participants with a broad range of experience in aquatic ecology, fish biology and management, and other natural science and management disciplines, representing many of the public agencies that are responsible for BCT management:

- Barry Baker – The Nature Conservancy in Utah
- Phillip Baigas – Wyoming Department of Game and Fish

- Joe Barsugli – National Oceanic and Atmospheric Administration and Western Water Assessment
- Jim Catlin – Wild Utah Project
- Danielle Chi – USDA Forest Service
- Chris Cline – US Fish and Wildlife Service
- Zac Covington – Bear River Association of Governments
- Paul Cowley – USDA Forest Service
- Eve Davies – PacifiCorp
- Joan Degiorgio – The Nature Conservancy in Utah
- Deb Freeling – USDA Forest Service
- Cassie Melon – Utah Division of Wildlife Resources
- Sharon Vaughn – US Fish and Wildlife Service

Erika Rowland of the Wildlife Conservation Society took notes of the discussion highlights.

The BCT break-out group used the process laid out in the *Adaptation for Conservation Targets* framework that was described earlier in the workshop by Molly Cross (Figure 1). The group's charge was to complete the following in two half-day sessions:

- Define a specific, measurable, attainable and time-bound management objective for the BCT.
- Develop a conceptual model for the BCT and its habitat.
- Describe known or likely impacts of climate change under two alternative scenarios.
- Identify management intervention points: activities that might mitigate or reduce the negative effects of climate change on the BCT.
- Identify strategic actions that could help the BCT adapt to moderate and/or severe climate change.

Defining the Conservation Feature

The Bonneville cutthroat trout (*Oncorhynchus clarkii utah*) occupies roughly 35% of its historic range. Much of the remaining suitable habitat for BCT occurs in the Bear River watershed in Utah, Idaho, and Wyoming. The Bear River watershed supports the healthiest remaining migratory populations and comprises the last large river habitat still available to the subspecies. Bear River populations are unique in that they comprise resident and fluvial life forms. These alternative life history strategies have contributed to BCT resiliency in the face of non-native species invasions and marginal habitat quality. Unfortunately, irrigation diversions in the Bear River block upstream spawning migrations and kill downstream migrants in irrigation canals. Additionally, poor water quality and impaired riparian conditions have degraded aquatic habitats throughout the watershed. As a result, many historically important spawning tributaries and mainstem habitats are currently inaccessible or uninhabitable. BCT is the subject of an interagency Range-Wide Conservation Agreement and Strategy, which can be found at this link: http://wildlife.utah.gov/pdf/cacs7.pdf.

The BCT was chosen as a conservation feature for this workshop because of its special status in the Utah State Wildlife Action Plan, because the species is the focus of conservation attention through the licensing and mitigation of PacifiCorp hydropower facilities, and because of the unique status of the Bear River group of BCT populations: it is the only form of this subspecies able to persist in its native waters with introduced non-native trout. Finally, the BCT was selected because of its vulnerability to climate change. Recent thermal imaging studies show that most of the waters of the Bear River Basin, including nearly all of the mainstem, already exceed the fish's temperature tolerance threshold. Williams, et al. (2009) use climate change projections to show that the portions of the Bear River Basin are at high risk of increased summer temperature, increased winter flooding, and increased wildfire frequency, leading to exacerbated risk of BCT extirpation.

Management Objective

The group's charge in this portion of the breakout sessions was to establish a five- to ten-year management objective for the Bonneville cutthroat trout in the Bear River Basin. The purpose of setting an objective was to provide a foundation for determining whether and how climate change could compromise the participants' shared conservation objectives for the trout, for identifying climate change impacts, and for developing strategies for reducing these impacts. Another purpose of establishing an objective is to determine whether, in the face of ongoing and future climate change, it should be retained, revised or discarded.

After reviewing what is known of the status of BCT populations and habitat in the Bear River Basin and throughout its range, the group agreed to the following 5-10 year management objective for the BCT:

> *Maintain or expand the number of viable populations of the Bonneville cutthroat trout in the Bear River Basin. Achieve this by maintaining or restoring the following components of the trout's habitat, autecology and life history:*
>
> - *Connectivity between the mainstem and tributaries (reconnect diversions)*
> - *Flows in actual and potential habitat (restore natural flow regimes)*
> - *Habitat quality (channel morphology, riparian vegetation, etc.)*
> - *Genetic diversity and integrity*
> - *Aquatic community species composition and structure*
> - *Water quality (temperature, dissolved oxygen, etc.)(restore water quality regimes)*

The group spent considerable time learning from each other about the complexity and constraints inherent in the existing Bear River Basin water management system, which involves dams, diversions, barriers, water rights, irrigation agreements, and flow rules. The result has been permanent alteration in the natural flow regime, and breaks in connectivity between tributaries and mainstem. The Bear River is so thoroughly "plumbed," and the demands on water for irrigation and hydropower are so great, that there are significant constraints on restoration of the habitat and ecological processes that have been lost or altered over the past century.

In spite of these ongoing threats, and the emerging threat of rapid climate change, the participants agreed that there are – and will continue to be – good opportunities to work with private landowners and water users, public agencies, and PacifiCorp, owner and operator of the principal hydropower dams and reservoirs, to conserve the BCT. The Federal Energy Regulatory Authority (FERC) relicensing process for PacifiCorp hydropower operations created an Environmental Coordination Committee (ECC) that is responsible for the expenditure of an average of over $500,000 annually for BCT habitat improvement and species recovery. The ECC provides a forum and funds that could be used to anticipate and mitigate climate change effects through a strategic science-driven, consensus-based approach.

Conceptual Model

Participants began with a first-draft conceptual model of the Bonneville cutthroat trout and its habitat that was developed several weeks before the workshop by a small group of experienced biologists and managers, including three members of the BCT breakout group. This simple draft contained a small number of boxes and arrows representing habitat, biological agents, ecological processes, and climate parameters. Breakout group members revised this simple draft model by reorganizing it and adding new elements, including ten drivers associated with human management: dams, hydropower operations, wildfire exclusion, recreation, livestock grazing, dust deposition, agricultural irrigation, diversion (dewatering), and feedlot agriculture (See Appendix 9 for the "work-in-progress" draft model).

The final version of the conceptual model (Figure 2) centers on the quality and spatial distribution of two habitats that are critical to the fish's viability: the Bear River mainstem, which is intensively managed for hydropower and irrigated agriculture, and tributaries of the Bear River, where flow regimes and riparian plant communities are generally much less altered.

The group called out three elements of BCT viability: (a) genetic diversity and gene flow, (b) demography, or the number and spatial distribution of viable populations, and (c) connectivity, allowing for seasonal movement between mainstem and tributary habitats. With respect to the habitat itself, the group identified three critical elements: (1) hydrological or flow regime, (2) water quality regime and (3) physical habitat characteristics.

Completion of the conceptual model laid a foundation of shared knowledge and perspective for the next steps in the climate adaptation planning process: identification of observed and projected climate change impacts, and determination of potential management intervention points.

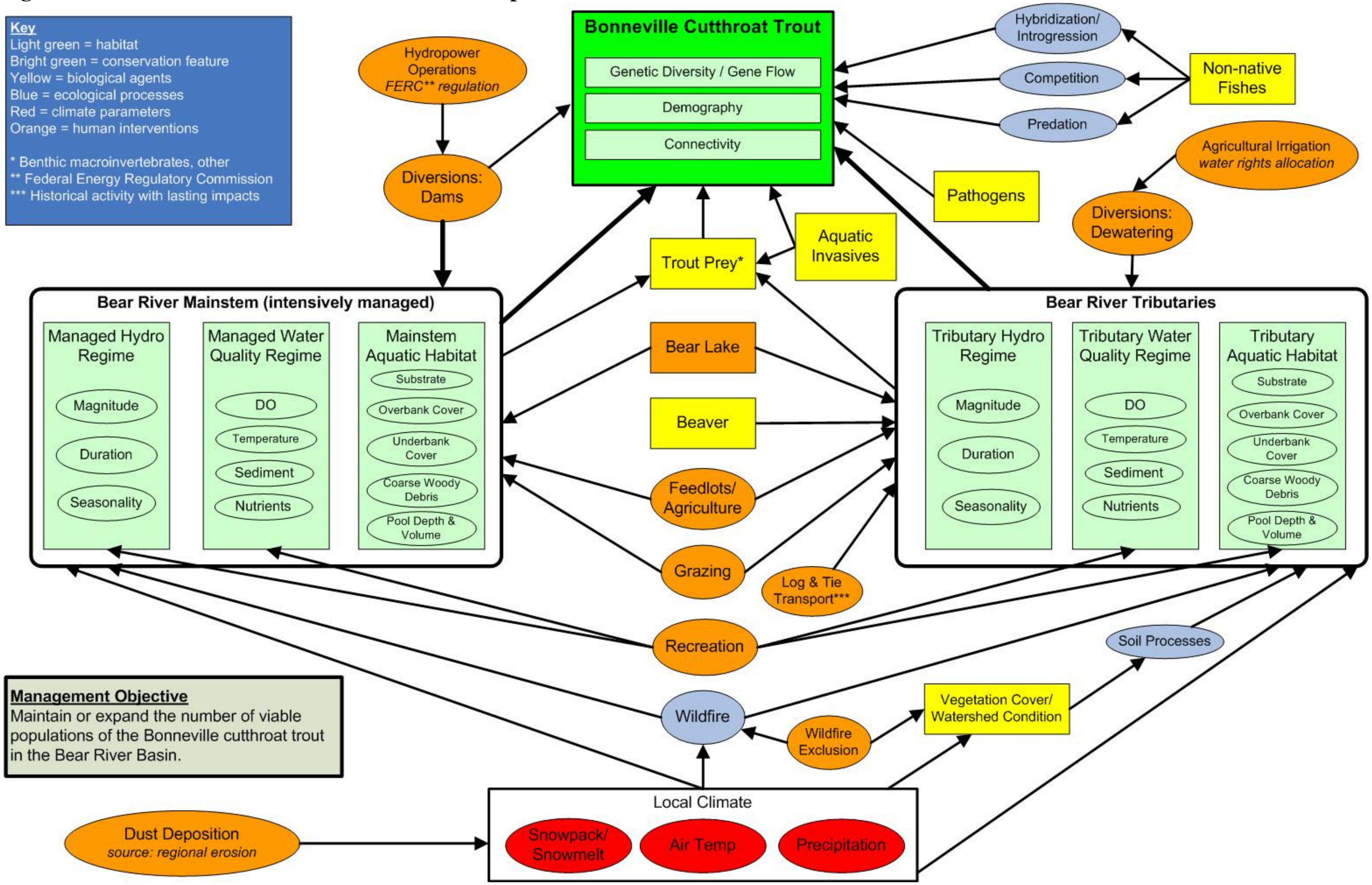
Climate Change Impacts Assessment

After completing the model, the group delved into whether and how the Main and Alternate climate change scenarios developed by Dr. Mearns and Dr. Barsugli could change the ecosystem that supports the BCT. The participants considered the Main Scenario first, using the relationships summarized in the conceptual model to identify known (already observed) and projected climate change impacts. Symbols indicating increase, decrease or change (+, - or Δ) were drawn directly onto the model so that participants could keep track of – and later summarize – the many anticipated interacting effects of climate change. The experts then proposed and discussed hypotheses of change whereby direct and indirect effects of changes in temperature and precipitation result in cascading ecosystem impacts and challenges to the achievement of the group's management objective for the BCT (see Appendix 5).

As one might expect, the group identified increased air temperatures, increased water temperatures, and resulting changes in hydrologic regime – especially changes in the timing, magnitude and duration of high and low flows – as the principal sources of climate change impacts to the BCT. However, the experts also identified several other potential climate change effects that are perhaps not as intuitively obvious. An example of such an indirect impact is increased sediment transport from tributary watersheds, leading to either direct fish mortality or additive physiological stress. Another subtle but perhaps very significant impact is increased dust deposition from the loss of soil crusts and vegetation cover from remote landscapes, a change that can be linked to climate change and poor watershed management. Research done in the central Rocky Mountains shows that increased dust deposition leads to earlier snowmelt and altered streamflow hydrology (Painter, et al. (2007).

The experts hypothesized that the climate change-driven ecological changes that pose the greatest threat to the BCT have to do with reductions in the already-small amount of stream habitat for the fish. These reductions could come in a number of forms: fewer

Figure 2. **The final Bonneville cutthroat trout conceptual model**



thermal winter refugia, due to the loss of ice bridges in small tributary streams; fewer stream reaches that do not exceed thermal tolerances in the warmest months; and dewatering of tributaries, due to increased irrigation demand from greater evapotranspiration and longer growing seasons.

The group identified several other potential impacts of, as yet, unknown probability and severity, but that might provide surprising and unwanted challenges to BCT managers. This category includes climate change-driven catastrophes such as uncharacteristically large winter floods due to rain-on-snow events, or ash flows from large and severe wildfires; earlier peak runoff and subsequent mismatches in the timing of spring flows with movement of fish upstream to spawn; and increased water temperatures favoring the spread of pathogens and non-native trout into BCT habitat.

With respect to the geographic distribution of climate change impacts, the group concluded that the direct effects of climate change on the river's mainstem would be buffered below Bear Lake because the river's flow is already so heavily controlled by diversions, dams and pumping.

The group's lengthy deliberations on the Main Scenario (#1) left no time for discussion of the Alternate Scenario (#2).

Management Intervention Points

After discussing the potential impacts of the two climate scenarios, the group examined the conceptual model (Figure 2) and identified sixteen management intervention points in the conceptual model where management actions could be taken to lessen the negative impacts of climate change and provide progress toward the management objective:

1. Vegetation and fire management
2. Grazing management, including:
    - Purchase/reduce animal unit months (AUMs)
    - Fencing
3. Riparian improvements/restoration, including beaver reintroduction
4. Fisheries management, including non-native fish control
5. Aquatic habitat management/restoration, including:
    - Removal or barriers
    - Increasing the number of trout refugia
    - Beaver reintroduction
6. Management of other non-native invasives (mussels, plants)
7. Pathogen control
    - Regulatory changes in pathogen policy – non-natives, movement of aquaculture fish (New Zealand mud snail)
8. Regional dust management
9. Watershed/snowpack management
10. Recreation management
11. Education and outreach – public awareness
12. Water quality regulation and management, including:

- Agricultural best management practices (BMPs
    - Effluent control
13. Water conservation policy, including the outreach and education required to bring it about.
14. Land and water protection on private lands, including:
    - Easements
    - Local ordinances, zoning, and other policy measures
    - Riparian buffers
    - Water right purchases and/or water banking

Strategic Actions for Climate Adaptation

The group then brainstormed strategic actions that might help the Bonneville cutthroat trout survive in the Bear River Basin in the warmer, drier climates of Scenario #1 (see Appendix 6) presents a list of these strategic actions, organized by hypothesis of change (that is, by potential climate change impact). We also noted, for each strategic action, the relevant management intervention point. This brainstorming session was intended to generate a diverse range of potential actions that could be considered; the resulting list is not exhaustive, nor does it necessarily represent participants' consensus on which actions *should* be implemented. Rather, it is an initial list of actions that might be considered, some of which may be more "outside-the-box" or controversial than others.

The group identified a wide-ranging and comprehensive list of strategies. The proposed strategies touched on eight of fourteen management intervention points, and ranged from strategic removal of physical barriers in headwater streams, to protecting BCT habitat through acquisition of water rights, to reforming zoning ordinances for creation of riparian buffers.

A quick scan of Appendix 6 might suggest that many strategies needed for climate change adaptation are already being undertaken, albeit at a smaller scale and slower pace than might be necessary to achieve ecological resilience in the face of climate change. Many of the suggested strategies involve conventional approaches to ecological protection and restoration, including progressive grazing management, non-native fish control, forest fuels management, and so on. But, in fact several new and creative ideas emerged from the discussion. First, the group recognized the need to conduct a landscape-scale strategic assessment of stream and riparian restoration needs and opportunities in the face of climate change. Some stream reaches simply may no longer be habitable by BCT in a regional climate that is several degrees warmer in summer. Other stream reaches might serve as cool-water refugia by virtue of their landscape position or protection status. The group posited that it makes sense to use climate change projections in combination with field data to identify the warmest and coolest reaches, and make conservation investments – for example, riparian fencing or barrier removal – accordingly.

Two provocative ideas for climate adaptation were proposed by the group, for consideration by Bear River stakeholders: assisted migration of more southerly populations of BCT into the Bear River Basin, and pumping cool water through a new pipeline from the center of Bear Lake to the Bear River mainstem to increase the amount of mainstem habitat for this cool-water species. The hypothesis underlying the former suggestion is that increasing genetic diversity in the Bear River BCT populations could increase their adaptability and chances of survival in a changing environment.

Several group members saw an opportunity for climate change adaptation in faster and more effective development and implementation of Total Maximum Daily Load (TMDL) limits for regulated streams of the Bear River Basin. TMDLs are set by state environmental quality agencies under the authority of the federal Clean Water Act. Expedited TMDLs could expedite aquatic and riparian habitat protection and restoration at a scale that is large enough to make a difference for the viability of the BCT.

As the discussion of strategic actions for climate adaptation drew to a close, the participants agreed that the list in Appendix 6 should be considered a first draft, subject to expansion and revision. Further discussion with scientists, managers and other stakeholders is needed to organize and confirm the strategic actions to be taken by the Bear River Basin's conservation organizations to conserve the BCT under rapid environmental change.

Research and Monitoring Needs

Many of the climate change effects identified in Appendix 5 and the strategies listed in Appendix 6 are based on hypotheses about the ecological effects of climate change, or about the effects of a given management intervention.. As with any conservation program, climate adaptation efforts in the basin will not succeed if they are not supported by empirical data that are consistent with the hypotheses that underpin them. Accordingly, the group identified the following research and monitoring questions and needs for the BCT and its ecosystem.

Hydrology and fluvial geomorphology

- Rain on snow – hydrologic process and modeling; how does it affect water storage, hydrograph, water budget?
- What does increased winter flow mean for channel geomorphology if rain on snow sends tributary ice packs downstream?
- What is the influence on base flows of timing of snow melt and spring shift from snow to rain events?
- What is the influence of frozen soil/snowpack versus rain events that infiltrate the soils (water storage in different components of system). How does this affect the overall water budget of the system and the riparian vegetation communities?
- Need hydrological modeling that integrates multiple alternate climate change scenarios.
- Need to identify relationship (sensitivity) between stream and air temperature and other climate parameters—as well as monitoring and analysis to capture variability.

BCT biology: demography, life history, phenology, genetics, and habitat requirements

- Need basic BCT research—e.g., spawning and feeding behavior, demographics, distribution in watershed—see existing Smith Fork and Thomas Fork studies—and need to coordinate interstate data sources.
- Will there be a phenological shift in food source/supply, and will there be a mismatch with earlier peak flow and BCT response/spawning?
- How does timing of runoff affect spawning and feeding?
- Need demography studies and monitoring.
- Need more comprehensive and integrated water quality and BCT population monitoring.
- What is resilient habitat? How can we identify and manage this habitat for BCT. Need metrics for identification/assessment of resilient habitat.
- Need to identify stream reaches that are near, at, above and below the thermal tolerance limit for the BCT, in order to guide restoration and reintroduction
- Need to determine adaptation of southern BCT populations to warmer temperatures and feasibility of assisted migration.
- To inform assisted migration of southern populations of BCT, need to analyze genetics and physiological tolerance of all BCT populations.
- What do we mean by a viable population? Need coordination between different groups on definition and metrics.

Watershed condition, vegetation cover, and fire/fuels management

- What shifts in terrestrial plant communities can we expect? What will be the effects on watershed condition?
- What will be the nature of terrestrial vegetation during the transition associated with rapid climate change—more cover, less cover? How will this affect erosion, sedimentation and water quality? What lessons can be drawn from the paleo-ecological record?
- What are the effects of alternative approaches to fire and fuels management in BCT watersheds? What are the potential impacts to BCT of changing fire regimes, including the possibility of larger and more severe forest fires?

Habitat

- Need to inventory springs and assess grazing impacts to guide the placement of exclusion fences.
- Need to identify key spawning reaches (e.g., using thermal imaging, state agency data).
- Need geographically comprehensive thermal imagery for consistent and continuous monitoring of water temperatures in reaches actually or potentially occupied by BCT.

- What is the role of beaver in maintaining refugia where BCT can persist during extreme disturbance events (e.g., major flooding after fire events that result in catastrophic stream sedimentation)?

Information management

- Need coordination between states (Idaho, Utah and Wyoming) on sharing of monitoring data and other information.

Revisiting the Management Objective

After identifying research and monitoring needs, the group revisited the management objective that it developed at the beginning of the break-out session in light of projected climate change impacts. The group decided that, even though a rapidly warming and drying regional climate presents a great challenge to conservation of the BCT, it will still be possible to expand the number of viable populations, and the objective should stand as written. It is important to emphasize that <u>the implications for BCT of the pace and scope of change projected by Drs. Mearns and Barsugli are daunting and severe, requiring a redoubling of efforts to build ecological resiliency in the Bear River Basin</u>.

Priority Adaptation Strategies

The facilitators asked the group to identify the strategies most likely to increase the viability of the BCT under the climate change scenarios described by Drs. Mearns and Barsugli. After a lengthy discussion, the group reached consensus on five priorities:

Table 1. High priority strategic actions identified by participants for reducing climate change impacts on Bonneville cutthroat trout in the Bear River Basin, and associated management intervention points

Intervention Point	High Priority Strategic Actions (Planning Horizon: 2040-2060)
Fisheries management: non-native species control	Reducing or removing stress-producing non-native fish species, especially in headwater tributaries (will also benefit the northern leatherside chub); inventory and prioritize key non-natives; cease the stocking of rainbow trout in occupied BCT habitat
Aquatic habitat management and restoration: removal of physical barriers to BCT movement	Address barriers: identify priority reaches; inventory barriers; increase water flows, remove physical barriers. (Barriers are being removed now in Upper and Middle Bear River, but this work needs to be accelerated, especially on Lower Bear.)
Aquatic habitat management: creation of cool-water refugia	Infrastructure changes to draw cooler water for BCT; create cool water pool in main stem; allow for migration to tributaries when main stem temperatures make reaches uninhabitable; pipeline to Bear Lake center, to draw cooler water; education and outreach to land owners regarding cool water refugia – deepen and enlarge refugia; restore habitat
Grazing management: reduce pressure on BCT habitat	Reduce impact of intensive grazing on BCT through: reduction of numbers through purchase of grazing rights; modification of allotment management plans; establishment of forage reserves; enforcement of existing standards and guidelines on federal (BLM; USDA-FS) lands; implementation of rest/rotation/re-growth systems; fencing springs; and excluding livestock damage from priority riparian and aquatic habitat.
Fisheries and aquatic habitat management; revegetation of habitat degraded by phreatophyte control	Identify and strategically restore potential habitat; Increase/improve headwater stream habitat; reintroduce trout and other species to reaches from which they have been extirpated.

Conclusions and Next Steps

The BCT group noted that the workshop represents the beginning (rather than the end) of a long-term process for understanding and responding to the challenge of climate adaptation for the species, habitats and ecosystems of the Bear River Basin. The group emphasized in its closing discussion that the two-day workshop was a good starting point for climate adaptation, but that more time, thought and energy will be required to build consensus for – and begin implementing – resilience-building strategies.

Specifically, the group wanted to explore the Main and Alternate climate change scenarios in more depth. They wanted deeper discussion, and more testing, of projected climate change effects on the BCT and its habitat. They called out the need to reexamine and refine the strategic actions developed in brainstorming sessions during the workshop's second day. They called upon stakeholders to make deeper commitments to research and – especially – to system-wide monitoring to determine the effects of climate change and effects of adaptation strategies. And they recognized the need to raise funds and rally managers around a shared program of work.

The group also observed that the Bear River Basin presents many good opportunities for conservation of the BCT and other conservation features through basinwide strategic planning. A large and strong partnership is already in place, there is much scientific information already available, funds are available from a number of different public and private sources, and using The Nature Conservancy's Conservation Action Planning methodology a Bear River Conservation Action Plan has been developed.

Climate Change Adaptation Strategies for the Bear River Wetlands

Facilitated by Molly Cross and David Gori (TNC), the Bear River wetlands breakout group included seventeen workshop participants with a broad range of experience in wetlands, hydrology, wildlife, water management, climatology and other natural science and management disciplines:

- Bob Barrett – US Fish and Wildlife Service
- Floyd Roadifer – Wyoming Department of Game and Fish
- Linda Mearns – National Center for Atmospheric Research
- Bryan Dixon – Bridgerland Audubon Society
- Bob Fotheringham – Cache County
- Landon Profazier – Bear River Association of Governments
- Toby Hooker – Utah State Geologic Survey
- Ann Neville – Inland Sea Shorebird Reserve manager (Kennecott)
- Joel Tuhy – The Nature Conservancy in Utah
- Kevin Werner – NOAA/NWS Colorado Basin River Forecast Center
- Russ Norvel – Utah Division of Wildlife Resources
- Sharon Vaughn – US Fish and Wildlife Service

- Sara O'Brien – Defenders of Wildlife
- Amy Defreese – US Fish and Wildlife Service
- Betsy Hermann – US Fish and Wildlife Service
- Wayne Padgette – Bureau of Land Management
- Temis Taylor – Utah State University

Chris Montague of The Nature Conservancy took notes of the discussion highlights.

The wetlands breakout group used the process laid out in the *Adaptation for Conservation Targets* framework that was described earlier in the workshop by Molly Cross. The group's charge was to complete the following in two half-day sessions:

- Define a specific, measurable, attainable and time-bound <u>management objective</u> for Bear River wetlands.
- Develop a wetlands <u>conceptual model</u>.
- Describe known or likely <u>impacts of climate change</u> under two alternative scenarios.
- Identify <u>management intervention points</u>: activities that might mitigate or reduce the negative effects of climate change on the wetlands.
- Identify <u>strategic actions</u> that could help the wetlands adapt to moderate and/or severe climate change.

Defining the Conservation Feature

A large portion of the region's wetlands occur in the Bear River Basin. These wetlands support a large number of and diversity of birds, including shorebirds, waterfowl and passerines. For example, five percent of the world's populations of white-faced ibis use these wetlands. While, in recognition of the wildlife importance of these areas, three national wildlife refuges have been established on the Bear River, most of the Bear River wetlands are in private ownership. Figure 3 identifies the extent of wetlands on the Bear River, as well as, Cokeville Meadows and Bear Lake National Wildlife Refuges. The third national wildlife refuge is found at the terminus of the Bear River, the Bear River Migratory Bird Refuge.

Participants identified several types of wetlands in the Bear River Basin, including seasonally flooded wetlands, abandoned oxbow wetlands, wetlands associated with managed water features (e.g., around Bear Lake and the Bear River Migratory Bird Refuge), wet meadows and marshes, high elevation tributary wetlands, wet riparian areas, and wetlands associated with springs. While each of these wetland types are important, the group voted to focus on just one type during the rest of the breakout discussions: **abandoned oxbow wetlands**. Figure 4 displays a typical section of oxbow wetlands in Cache County, Utah.

Figure 3. Bear River Basin wetlands

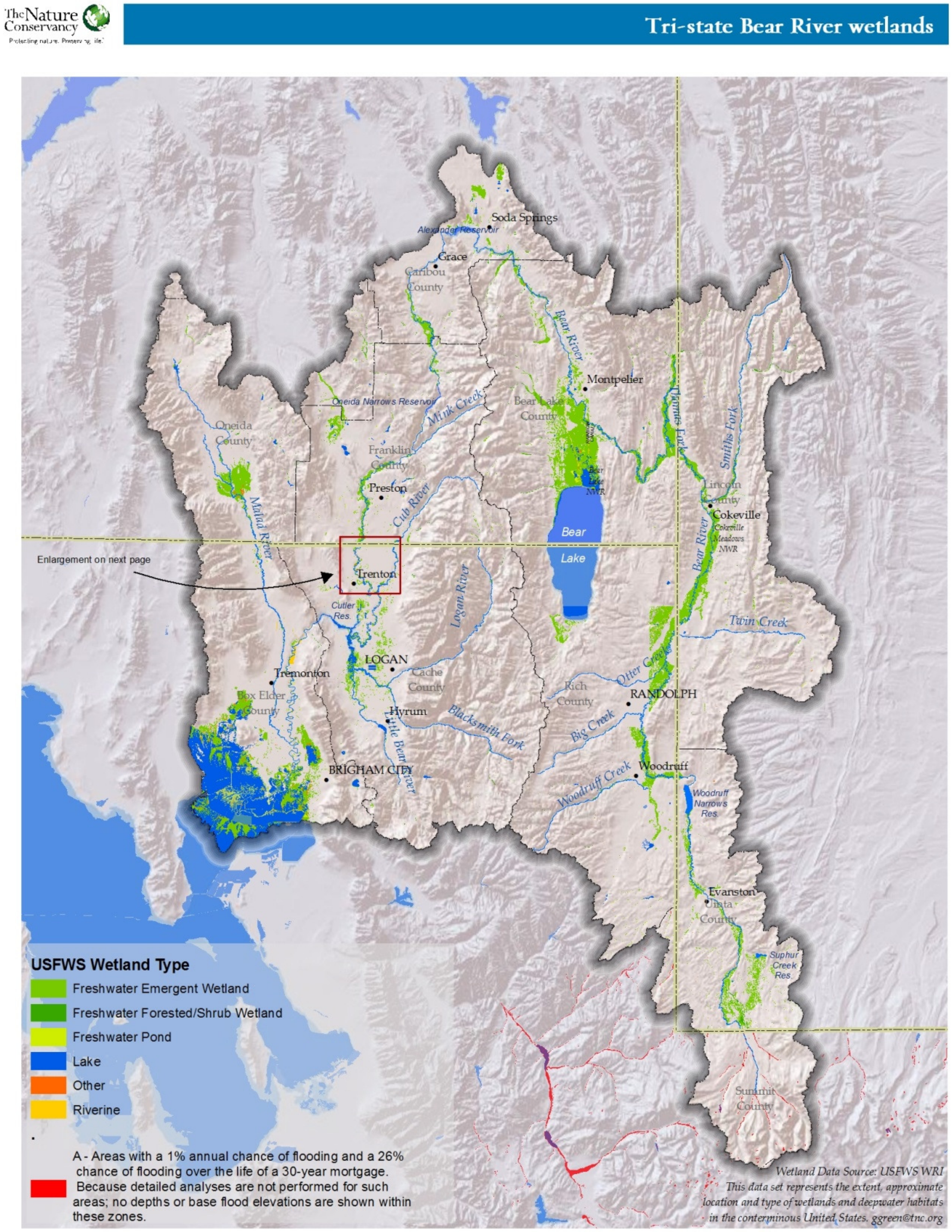
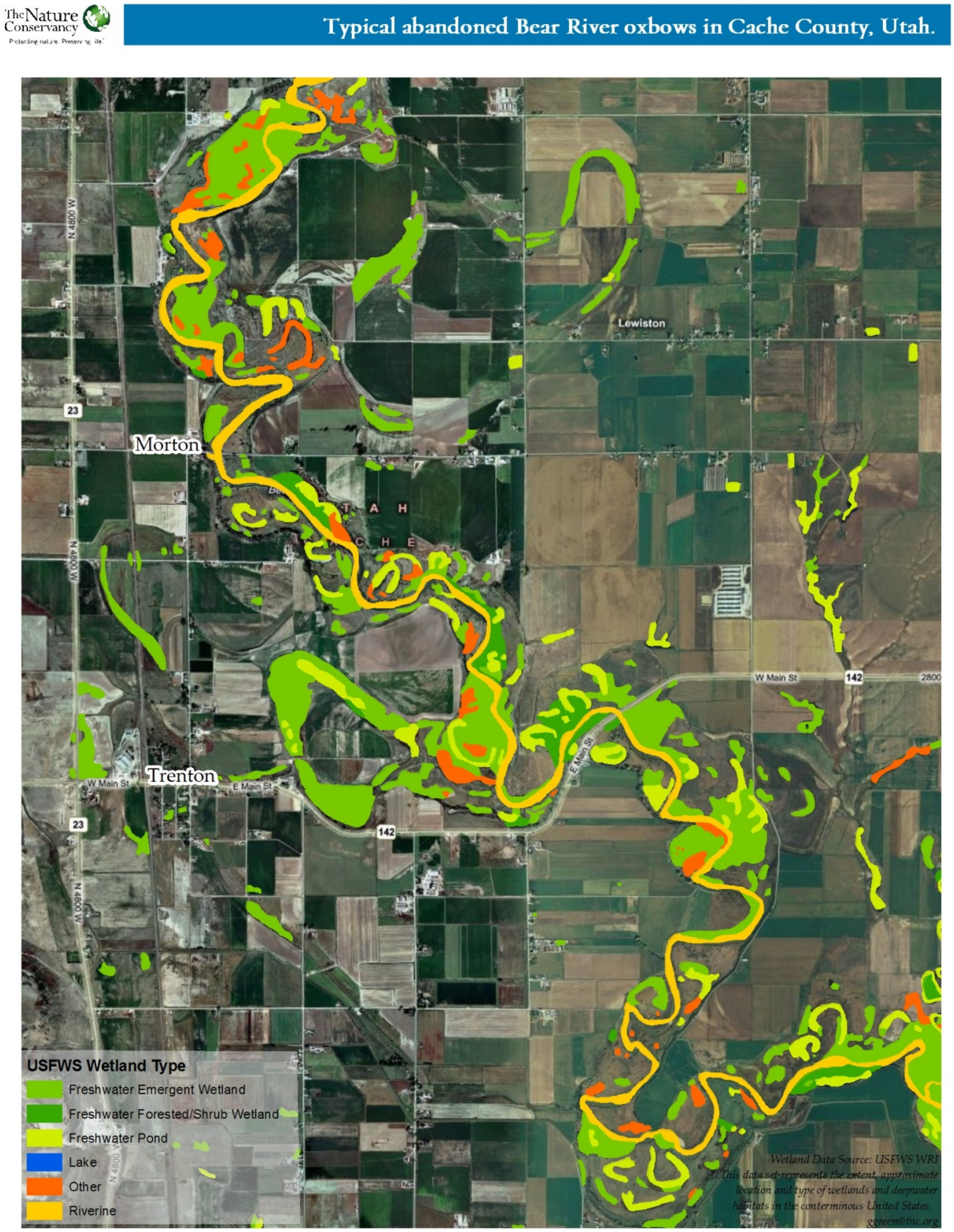


Figure 4. Cache Valley oxbow wetlands



Management Objective

The group's charge in this portion of the break-out sessions was to establish a five- to ten-year management objective for Bear River wetlands. The purpose of setting an objective was to provide a foundation for determining whether and how climate change could compromise the participants' shared conservation objectives for the wetlands, for identifying climate change impacts, and for developing strategies for reducing these impacts. Another purpose of establishing an objective is to determine whether, in the face of ongoing and future climate change, it should be retained, revised or discarded.

The group agreed to the following 5-10 year management objective for Bear River wetlands:

- *Maintain current wetland acreage and a diversity of wetland types*
- *Maintain and enhance wetlands to at least fair or good condition*
- *Maintain wetland functions including: bird and wildlife habitat, flood control, water storage, water infiltration, carbon and other nutrient sink, and connectivity for wildlife movement and ecological processes.*

Achieving all of these objectives in light of climate change will be predicated on maintaining and enhancing hydrology (in particular the quantity, quality and timing of water inputs). The group also discussed the need to have a dynamic concept of wetland condition and function based on future potential as climate changes.

Conceptual Model

Participants began with a first-draft conceptual wetlands model (Appendix 10) that was developed several weeks before the workshop by a small group of experienced biologists and managers. This simple draft contained a small number of boxes and arrows. The breakout group members revised this simple draft model to include important direct and indirect physical, ecological, climatic, social and economic drivers affecting abandoned oxbow wetlands in the Bear River Basin (Figure 5).

Completion of the conceptual model laid a foundation of shared knowledge and perspective for the next steps in the climate adaptation planning process: identification of observed and projected climate change impacts on the distribution and condition of wetlands in abandoned oxbows, and determination of potential management intervention points (see Appendix 7).

Climate Change Impacts Assessment

Under both climate scenarios, the group expects to see a decrease in the areal extent and a decline in the condition of abandoned oxbow wetlands in the Bear River Basin. For Scenario #1, the areal extent of abandoned oxbow wetlands will likely shrink due to the drying effect of decreased precipitation and streamflows in the spring and summer. Drier conditions are also expected to result in changes in wetland vegetation species composition and shifts from wetter to drier wetland types. While Scenario #2 will also result in drier conditions and a loss of wetland acreage, it is possible that the losses will be less dramatic than for Scenario #1 since an added pulse of moisture in the spring may somewhat buffer the effect of drier summers on plant productivity and water availability. However, changes in vegetation species composition and wetland type (from wetter to drier) may be even more pronounced under Scenario #2 because wetland plants are not adapted to a situation where they receive water in the spring but not in the summer. Participants discussed the fact that while migratory birds may encounter sufficiently productive plant communities in the spring under Scenario #2, the dry summers under both climate scenarios are likely to have a strong negative effect on fall migrations.

Participants also highlighted how changes in human land and water use in the Bear River watershed, due to background population growth rates as well as human responses to climate change, are likely to have a dramatic effect on abandoned oxbow wetlands. Population growth in the region is already a major threat to the abundance and condition of wetlands in the Bear River watershed. As soil conditions dry out under both climate change scenarios, the risk that land will be converted to urban developments will likely increase even further. In areas that continue to be used for agriculture, an extended growing season may shift agricultural practices from grazing to alfalfa and other crops that have higher irrigation requirements, and drier soils will enable larger areas to be tilled. In addition, more intensive agriculture, expanded use of fertilizers and urban development coupled with larger, flashier runoff events – predicted under both scenarios – will exacerbate water quality issues in oxbow wetlands. Humans will also be doing whatever they can to store dwindling river flows for human uses (e.g., irrigation and domestic or industrial use), by increasing the amount of water being stored in existing dams and reservoirs, and creating new impoundments. All of these human-related responses to climate change will likely lead to a decrease in water delivery to wetlands and a decrease in wetland acreage.

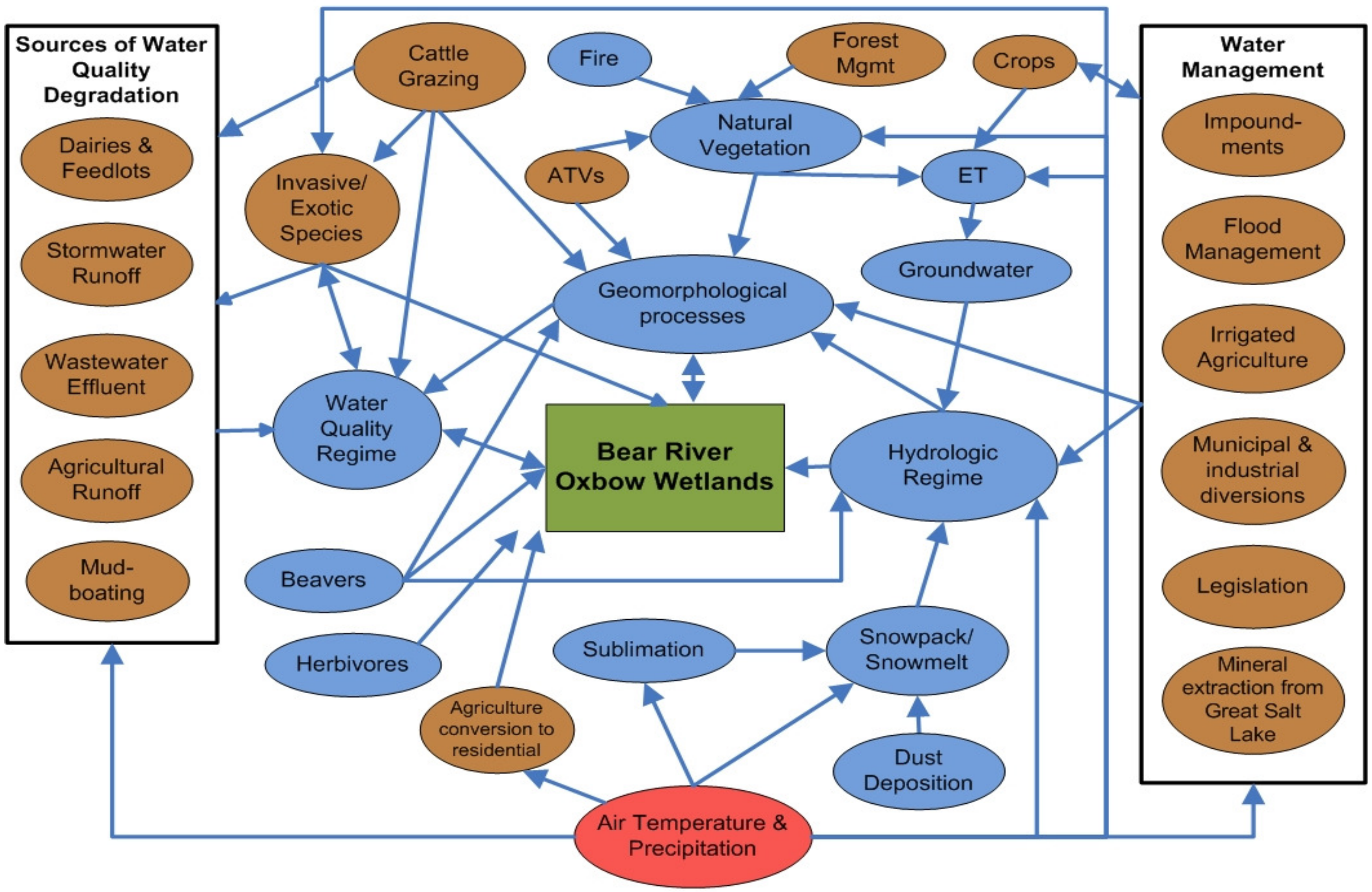
Management Intervention Points

After discussing the potential impacts of the two climate scenarios, the group examined the conceptual model (Figure 5) and identified intervention points in the conceptual model where management actions could be taken to lessen the negative impacts of climate change and provide progress toward achieving the management objective. The group identified management intervention points including land and water protection in the wetlands, and management of water flows, sources of water quality degradation (e.g., fertilizer use and runoff from agricultural and urban lands), land development and conversion, forests and upland vegetation, agricultural practices, beaver populations, grazing and browsing by herbivores, and invasive and exotic plants.

The group then brainstormed specific strategic adaptation actions that might be considered in association with each of these intervention points. This brainstorming session was intended to generate a diverse range of potential actions that could be considered; the resulting list (see Appendix 8) is not exhaustive, nor does it necessarily represent participants' consensus on which actions *should* be implemented. Rather, it is an initial list of actions that might be considered, some of which may be more "outside-the-box" or controversial than others.

Strategic adaptation actions generally related to one of several overarching strategies: maintaining and enhancing the availability of water for abandoned oxbow wetlands, protecting existing wetland areas, improving wetland condition, and facilitating changes in wetland species composition while minimizing invasion by invasive non-native species. Participants did not differentiate between actions that were appropriate under Climate Scenarios 1 and 2. Instead, they felt that all of the actions listed would be appropriate under both scenarios.

Figure 5. The final oxbow wetlands conceptual model



Priority Adaptation Strategies

After the broad brainstorming session, the group highlighted five high priority adaptation actions (Table 2 below) that address land and water protection, upland vegetation management, and education. These high priority actions were then shared with the larger workshop group during a full plenary report-back session.

Research and Monitoring Needs

Many of the climate change effects identified in Appendix 7 and the strategies listed in Appendix 8 are based on hypotheses about the ecological effects of climate change, or about the effects of a given management intervention.. As with any conservation program, climate adaptation efforts in the basin will not succeed if they are not supported by empirical data that are consistent with the hypotheses that underpin them. Accordingly, the group identified the following research and monitoring questions and needs for the abandoned oxbow wetlands.

- How vegetation composition and wetland function will change under various climate change scenarios?
- Quantitative study and modeling to better understand how conversion of forest vegetation to other types by wildfire affects watershed hydrological processes including evapotransporation, infiltration, runoff, recharge and water yields to Bear River, oxbow wetlands.
- Understand oxbow wetland hydrology under current and future climate, including the direct and indirect effects of beaver.
- Verify the assumptions laid out in our discussions and document evidence for making the changes we want to see happen.
- Research to define "in-wetland flows" (similar to in-stream flows). If we can define it, there's a better chance that we can protect it.
- Monitor ecosystem services, bird species, communities, invasives, etc., to get baseline data on wetlands. This will enable impact documentation for conservation and management actions, and improve understanding of how the system is changing (as a result of our actions, and as a result of climate change and other change).
- Research to better understand the values and ecosystem services that oxbow wetlands provide.

Table 2. High priority strategic actions identified by participants for reducing climate change impacts on oxbow wetlands in the Bear River Basin for two climate scenarios, and associated management intervention points

Observed & Projected Climate Change Impact (Hypotheses of Change)	Intervention Point	High Priority Strategic Actions (Planning Horizon: 2040-2060) *(note: these apply to both Scenarios 1 and 2)*
Hydrology: Decreased delivery of water to abandoned oxbow wetlands. (S1 & S2)	Water protection	• Establish water conservation laws that provide incentives for water conservation and changes in use (e.g., that provide financial incentives for users to leave some water in-stream).
	Upland vegetation management	• Restore and maintain healthy upland watershed vegetation communities to improve watershed function and increase water retention and recharge.
Land conversion: Increased risk of land development (conversion from agriculture to urban) in wetlands as they dry out. (S1 & S2)	Land protection	• Establish a Bear River land trust to hold easements, push for education about the benefit of easements, find funding, and manage some of the land. • Improved land use planning, such as through the creation of special area management plans.
All impacts	Education	• Education and marketing related to understanding and communicating the true value of wetlands (and the avoided cost of losing wetlands), and informing the agricultural community about wetland conservation incentive programs. Provides an incentive and motivation for caring about the loss of wetlands, and is necessary to encourage more dramatic changes in land use, policy, etc.

S1 = Scenario 1 (“Main”), S2 = Scenario 2 (“Alternate”)

Conclusions and Next Steps

Several participants noted that many of the strategic adaptation actions that were identified during discussions are similar to actions that also make sense under current climate conditions. On the one hand, this raises concerns that we have not yet thought of new, more "outside-the-box" actions that might be required to conserve oxbow wetlands as climate changes. On the other hand, participants also noted that some of the main impacts of climate change on wetlands in the region are to exacerbate all of the "usual suspects" (i.e., the current stressors and threats on the system). Therefore, by maximizing the viability of wetlands in the context of existing stressors through the kinds of actions that we already deem important for reducing threats, we are making the system more resilient to the effects of climate change. The group also noted that while the actions themselves may be similar to what is currently recommended or underway, there may be ways to prioritize *where* we apply those actions based on an understanding of how climate change may be influencing the system (e.g., those places that are most threatened and therefore need immediate attention, and/or places that have the best chance of retaining high quality wetlands in the future as climate changes). The discussion of climate change also alters the sense of priority or urgency surrounding actions that we already acknowledge as important.

Since the group only had time to consider the nuances of climate change impacts and adaptation strategies for abandoned oxbow wetlands, several participants mentioned that it would be interesting to examine how our discussions would differ if we were focused on other types of wetlands that are important in the Bear River watershed (e.g., seasonally flooded wetlands, wetlands associated with managed water features, wet meadows and marshes, high elevation tributary wetlands, wet riparian areas, and wetlands associated with springs).

Opportunities for Strategic Action Implementation

Discussion and Synthesis of Breakout Group Findings

The two breakout groups reconvened in plenary to present their management objectives and priority strategic actions for climate adaptation, as follows.

Bonneville cutthroat trout group – management objective

Maintain or expand the number of viable populations of the Bonneville cutthroat trout (BCT) in the Bear River Basin. Achieve this by maintaining or restoring the following components of the trout's habitat, autecology and life history:

- Connectivity between the mainstem and tributaries (reconnect diversions)
- Flows in actual and potential habitat (restore natural flow regimes)
- Habitat quality (channel morphology, riparian vegetation, etc.)

- Genetic diversity and integrity
- Aquatic community species composition and structure
- Water quality (temperature, dissolved oxygen, etc.)(restore water quality regimes)

Bonneville cutthroat trout group – priority strategic actions

- Reduce or remove competing non-native fish species (e.g., brown trout and rainbow trout), especially in headwaters.
- Eliminate dispersal barriers by identifying priority reaches; inventorying barriers; increasing seasonal water flows; and selectively removing physical barriers.
- Create cool water refugia by changing hard infrastructure (dams and diversions), preserving existing refugia, restoring habitat, and providing connectivity among cooler reaches.
- Improve riparian and aquatic habitat through grazing management.
- Expand the distribution of BCT, by identifying and strategically restoring former habitat: expand and improve headwater stream habitat, and reintroduce BCT and other native species to reaches from which they have been extirpated

After the BCT group presented their priority strategic actions, Joe Barsugli observed that, though it may seem as if the strategies are the same as the ones that conservationists are already pursuing, the priorities and urgency have changed. For example, the group assigned high priority to a strategy that might otherwise become an afterthought of the BCT recovery program: identification of river reaches for protection and restoration based on current and projected stream water temperatures, in relation to the thermal tolerance limits of BCT.

Wetlands group – management objectives

- No net loss of wetland acreage and maintain a diversity of wetland types.
- Maintain and enhance wetland functions in at least fair/good condition.
- Maintain wetland functions including: bird and wildlife habitat, flood control, water storage, water infiltration, carbon and other nutrient sink, and connectivity for wildlife movement and ecological processes.

Wetlands group – priority strategic actions

- Education – get the public, policy makers, agricultural stakeholders to care about and understand the value of wetlands and issues related to climate change.
- Land Trust Establishment – a land trust is needed to hold conservation easement and promote the use of easements.
- Land Use Planning – encourage public agencies to use planning tools, such as floodplain ordinances, transfer of development rights, and special area management plans, to protect wetlands.
- Land Management Planning – use planning to protect upland areas to enhance the infiltration and retention (“the sponge effect”) on those lands.

- Legislation – create laws that provide incentives for water conservation.

Review and synthesis of priority strategic actions for climate adaptation

Facilitator Gregg Garfin then guided the combined groups' review of all priority adaptation strategies identified by the two breakout groups. This exercise produced a set of priorities that, because of the small size of the group, must be considered preliminary and provisional: a foundation for more such work by a larger, more inclusive group. In fact, the participants recognized the need for more deliberation by a more broadly representative group over a longer time period. Development of a robust and feasible climate adaptation plan for the Bear River Basin calls for inclusion of more key decision-makers and integration of more scientific and technical information in a carefully designed process that will require more than the two days we devoted to this workshop.

However, the group made substantial progress, identifying several high-leverage cross-cutting actions for climate adaptation, including:

- Wetland and water banking
- Water policy reform
- Outreach and education
- Providing incentives for private landowners to engage in conservation practices on their lands

The participants noted that many of the strategic actions are focused on private land and emphasize the use of existing land management planning and regulation approaches, including zoning and ordinances. The group agreed that the purpose of such intervention is not to hold the line – that is, to maintain wetlands and the Bonneville cutthroat trout in their current condition – but to *increase* the health and distribution of these conservation targets in order to increase their resilience in the face of climate change and the existing threats that it will exacerbate.

Dr. Garfin then directed small groups of participants to evaluate these cross-cutting strategic actions, to identify barriers (e.g., high cost or insufficient political support) to implementing them, and to identify opportunities (e.g., agency mandates, funding sources, public interest, existing programs or projects) for overcoming these barriers. He also asked that they identify the agencies and individuals who need to lead or participate if these actions are to be successful. The participants' responses are documented in Table 3 below.

Table 3. Barriers and opportunities for implementation of priority cross-cutting strategic actions

Priority Cross-cutting Actions	***Barriers (cost, politics, social, cultural, uncertainty)***	***Opportunities (funding sources, policy, action)***	***Who Needs to be Involved (to make this successful)***
Water policy reform to allow for use of water for conservation *Need to change law such that (1) sale of water right will not trigger change in the priority date (seniority) of the right, (2) water can be leased from year to year, giving flexibility to water right holder to use leased water in case of need. Remove incentive to use every drop every year.*	• Formidable social and cultural resistance to legal reform. Skepticism about climate change and the need to act	• Making economic argument that it is cheaper to society to conserve water than to build new dams and pipelines to meet growing water demand. • Funding needed to hire policy specialists, lobbyists.	State engineer, conservationists (Western Resource Advocates), retired politicians, representatives of agricultural community, like-minded legislators, conservation districts, water conservancy districts, Bear River Commission (tri-state coordinating group), PacifiCorp, academic policy experts (University of Utah, Utah State University), governors, Utah Association of Counties, conservancy districts, EPA, state water quality departments, NRCS, US Fish and Wildlife Service, US Forest Service, tribes.
Riparian and aquatic restoration	• Funding: Some public funds require a private match. • Social/cultural: Convincing private land owners of benefits (need to come up with incentives, demonstrate benefits). • Institutional: Planning time involved can dissuade land owners from being involved. • Limited staffing and a lack of 'feet on the ground' limit conservation work.	• NRCS has good funding opportunities. • Addressing climate change issues in itself might provide opportunities for new federal funding. • Funding for ecosystem-based planning might bring funds and facilitate process. • Collaborative Forest Landscape Restoration Program coming on	Private landowners (primarily), public land managers (USFS, BLM), FWS, NRCS, Trout Unlimited, State water quality agencies, water users, state fish and wildlife agencies.

Priority Cross-cutting Actions	*Barriers (cost, politics, social, cultural, uncertainty)*	*Opportunities (funding sources, policy, action)*	*Who Needs to be Involved (to make this successful)*
	• Intra-agency conflicts or differing goals (e.g., game fish versus non-game fish). • NEPA requirements can be daunting. • Federal staff turnover can slow down projects.	board that will focus on large-scale projects that emphasize multiple partners.	
Education and Outreach: landowners and general public, working with early adopters to take risks and pilot changes in management.	• Education, outreach and incentives can be a turnoff in themselves? • Cultural barriers, such as "pioneer mentality" – that natural resources are meant for human dominion, rather than human stewardship – "Bryce Canyon is a hell of a place to lose a cow" • The phrase "Climate change" is a barrier • Must link education and economic incentives – without an economic "carrot" there is no incentive for action	• Crisis tends to bring people together to cooperate (at least in the short term). • Cultural opportunity: work with LDS Church on stewardship values related to the Plan for Deseret, and on values related to leaving resources for future generations • Use business and planning focus of dominant culture as a point of entry. • Focus on messages that emphasize win-win solutions rather than on politically polarizing messages. • Fishing and waterfowl hunting licenses as point of contact for environmental education • Partnership opportunities with federal initiatives, agencies, and entities that have a strong interest in communication of climate science for decision making: U.S. National Assessment of Climate Change Impacts, NOAA National Climate Service • Funding: Sin taxes; also – USDA-NIFA, NSF Informal Science Education, NOAA Climate Education	Early adopters in communities that may otherwise to be difficult to reach. Irrigation and canal companies. NRCD and cooperative extension. State wildlife agencies. Teacher's organizations. All NGOs operating on the river, including Trout Unlimited and Ducks Unlimited.

Priority Cross-cutting Actions	*Barriers (cost, politics, social, cultural, uncertainty)*	*Opportunities (funding sources, policy, action)*	*Who Needs to be Involved (to make this successful)*
Create land trust to do easements	• Finding people committed to leading. • Source of funds for easement work (ideally state or county money, but could also be private; also federal LWCF) • Takes time to build a land trust that works. • Unknown: landowners attitudes about easements; risks of land conversion. What are conversion hot spots?	• Bridgerland Audubon well-connected and respected; could spearhead effort to build land trust. • Funding: Farm Bill and other federal funds, including Wetland Reserve Program, NAWCA, LWCF. • Creation of joint positions between NRCS and Utah Division of Wildlife. • Could supplement NRCS capacity for Farm Bill project implementation by creating cost-share positions. • Desire to conserve local way of life among local residents. • Steering committee of like-minded organizations to provide seed money for land trust establishment. • Pulling together a land trust plan can attract resources.	Bridgerland Audubon, Bob Fotherington (Cache County), NRCS, Division of Wildlife, state wildlife agencies, TU, DU, local conservation districts, landowners, land managers, farming and ranching groups and associations, FWS, PacifiCorp, active land trusts. Engage foundations and individuals with capacity to donate funds.

Emerging Themes, Implementation and Next Steps

Joan Degiorgio (TNC) and Joel Tuhy (TNC) moderated a group discussion centered on three panelists' responses to the following questions:

1. How has this workshop changed how you think about your work?
2. Do one or more strategies jump out as ready for prime time?
3. How can we work together to implement the recommendations of the workshop?
4. What wasn't covered in the workshop that is essential?

The panelists' responses are paraphrased below.

How has this workshop changed how you think about your work?

Floyd Roadifer, Wyoming Game and Fish Department (FR):
Climate change adds more impetus for current landscape scale management ideas, initiatives. But we need more support for landscape-scale watershed management from our agency's Habitat Section. To be successful, we need to plan and act at a landscape scale, across state lines.

Betsy Herrman, U.S. Fish and Wildlife Service (BH):
It hasn't changed much because we are already doing a lot of the things outlined in the workshop. What I valued most about this workshop was its step-by-step process that takes you from overwhelm to targeted actions that will address the problem. I am the point person in my office to attend these climate change workshops, which are mostly just depressing. This one was different because there was a focus on the huge variety of things that we *can* do. There is a good diversity of folks here, and the workshop has been very encouraging and exciting. In the future FWS will be very reliant on our partnerships, figuring out how to work with others to build resilience.

Bryan Dixon, Bridgerland Audubon Society (BD)
The whole concept of partnership has emerged as even more important than before. TNC's strength is to pull together partners and we need to take advantage of that. We need to take the long view, but at the same time fight the daily battles. Recognize that it's going to take a long time to make climate adaptation happen. Also, the importance of outreach and education: we need to give a constant, steady message to the agricultural community and public officials year after year, because it's going to take many years for people to understand climate change and its implications. We need to develop a way to talk with people about climate change. The message needs to be morphed: global *weirding* (increasing frequency of extreme events, increasing climate variability) rather than global *warming*. "Would you rather be on the bus that's figured out how to deal with weirdness, or not?"

Do one or more strategies jump out as ready for prime time?

FR: First, conservation easements: They aren't a quick fix, but they are permanent. Conservation easements tie into a landscape conservation philosophy. Second, education and communication: Wyoming Game and Fish has education experts, and this work has to be done. We simply have to educate people about climate change so that we can move on and take adaptation action.

BH: Expansion of land trusts and conservation easements. There is a great need for energized small groups of individuals to pull partnerships together to take on the strategic actions we identified today.

Second, we must identify priority areas for wetland and aquatic restoration. This is something we can do immediately. Also, we need research on what we can do to minimize climate change impacts, and on where we should can most effectively do it. Finally, we can act right away to build monitoring programs that inform adaptive management as climate change trends become more apparent.

BD: Conservation easements can be established immediately and will do a lot for climate adaptation. Audubon, my organization, needs to help establish a land trust, now that they have seed money to do that. Also, outreach and education are critical, and we can work on them right away. Educating the agricultural community is critical: we need to present the climate change adaptation message in a way that isn't us vs. you. This community is open to understanding and learning; we just need to find ways to get the message to them. Education of public officials takes time, but they will change, especially in response to financial issues. Communicating about climate models and uncertainty is a particular challenge for education and outreach.

There is also a need for research: we don't know how the water and the wetlands work. We need to know more about the distribution of the Bonneville cutthroat trout. We need hydrologic research and monitoring. We also need research on water law so that we have a better understanding of how it works, whom it does and doesn't serve, and how and why we should change it.

How can we work together to implement the recommendations of the workshop?

FR: It would be good if this group could stay in touch. Also, we need to work together to narrow down and refine the strategies we developed today. We also need to simply pick a few strategies and start trying to implement them. I will help wherever I can with, for example, development of land trusts.

BH: Rely on each other and use partnerships (e.g., the new Landscape Conservation Cooperatives) to advance climate change adaptation. Leverage funds, use academia, U.S. Geological Survey, TNC and others to help manage our lands. Floyd's suggestion of keeping contact in this group is a good one. Joan's coordinating work is a good foundation for trying to do more together in the Bear River watershed.

BD: We need to keep this group together engaged. Above all, we need to communicate broadly (internally and externally) and frequently about climate change. We need a prepared presentation, with good graphics, about climate change, and other bits and tools that can assist with communication and outreach. Would like to see the group train others to give presentations and messages about climate change so that we can reach more people.

What wasn't covered in the workshop that was essential?

FR: It was a very good workshop. But it would have been good to have a couple of skeptics, "non-believers," to expand the dialogue. We need to find a way to have greater influence among decision-makers. Science and biology is fun and challenging but that's really the easy part. The political arena is much more challenging; we need to find a way to inform and influence policy.

BH: The workshop would have benefitted from more input and expertise in water resource management and water law: representatives from the state engineer office, and other state water rights experts. But overall this was a very well organized and informative workshop.

BD: We need to involve the power centers in Utah in this dialogue, including the agriculture community and real estate developers (can find common ground on wetland mitigation banking, transfer of development rights, floodplain management, and conservation easements). Need to get these communities understanding what we're talking about. Include the tourist industry -- not just skiing but bird-watching and other forms of wildlife viewing. Tie them in somehow to climate change and get them to help fund adaptation. Include water resource planners in the state of Utah. They are tied in with water rights and water users.

Participant Feedback on Workshop Process and Outcomes

Feedback on the workshop method (Adaptation for Conservation Targets)

Participant: Eve Davies' and Molly Cross' presentations were very helpful in helping us understand the adaptation planning process and the environmental context, respectively. It's critical that the steps in the workshop method be clearly explained up front. Also very important is to help participants develop a very clear understanding of complex conservation targets like the Bear River populations of the Bonneville cutthroat trout – *before* identifying climate change impacts and strategic actions.

Participant: There is a lot of basic common sense in this approach [*ed.: the Adaptation for Conservation Targets approach that this workshop employed*] that some of us have already been applying in our work. How do we set management objectives in the face of basic uncertainties, how do we address research questions? The workshop process leads to steps that go beyond what we can do today. There are additional steps that will unfold.

Participant: A question that has emerged for me during this workshop: How do these concepts get integrated into existing planning processes so that climate change adaptation planning isn't an add-on that stands alone?

Participant: The way the process was broken down helped us address climate change in stepwise fashion effectively. You could use this process with a lot of different things, *e.g.*, to assess impacts of a road construction project on a particular habitat. Good way to break down what would otherwise be an overwhelming task.

Participant: Developing a scaled-down version of this could be helpful, especially if time is limited.

Participant: Appreciate the effectiveness of the interdisciplinary approach used at the workshop. "It's a cool heuristic."

Participant: Simplifying the conceptual model might be useful at some point. The model could be impenetrable to those who weren't involved in developing it.

Participant: It's easy to be paralyzed by complexity, and the models became more and more complex. In the future, simplify models by eliminating superfluous elements.

Participant: Once people have learned this approach, it can be used more efficiently for other conservation features.

Participant: The process is neat and fascinating: a way to handle complex issues quickly. Wonders where TNC is going from here with this project. Can we have fact sheet, some kind of summary that will help us remember what we accomplished in the workshop? How does TNC plan to follow up?

Participant: Need to follow up on the list of research needs: make sure this group addresses research and information needs before actions are taken.

Participant: It would have been helpful to have a video tour of the Bear River watershed: wetlands, floodplains, etc.

What participants want from the forthcoming workshop report

Participant: Describe the relevance of this workshop in TNC's conservation program for the Bear River watershed. Put workshop into context of past, current and future conservation activities.

Participant: Perhaps include photos of the ecological models before and after the session?

How participants would like to see the workshop organizers follow up

Participant: Share the information developed in the workshop with other conservation professionals and organizations working in the Bear River watershed.

Participant: Produce a model and a pamphlet for agencies.

Participant: What is the expectation that, from this effort, the report will feed into a commitment to making things happen on the ground? Is there some other group that needs to come together to get organized and contribute to a larger conservation effort on the ground?

Participant: A multidisciplinary group led by Joan Degiorgio has already produced a Conservation Action Plan (CAP) for the Bear River. Over the past two days we've completed a climate change adaptation workshop. Now what?

Participant: It would be ideal to merge a "climate change adaptation group" with the group implementing the CAP.

Participant: This process can be used to address so many things (including other species and wetland categories). We can work through other issues we have at the State using this process.

Participant: We also need to look at opportunities to look outside the area to look at influencers such as the Ecological Site Description(ESD) system employed by the Bureau of Land Management and the Natural Resources Conservation Service as a land management tool. We should offer help to the BLM in developing ESDs for riparian areas.

Participant: How much more climate analysis would you do, Linda and Joe, if you knew that the scenarios would be the definitive foundation for adaptation action?

Participant: We need to strike balance in describing scenarios between capturing complexity and uncertainty and making messages clear and concise.

Participant: In the climate change scenarios, we must avoid overwhelming with detail, but still need to convey the depth of technical knowledge that underlies the conclusions.

Closing Remarks

Southwest Climate Change Initiative director Patrick McCarthy thanked participants for their diligence and good humor during the workshop, and for their willingness to spend two days thinking and learning about the new and challenging subject of climate adaptation.

Workshop organizer and TNC Northern Mountains Regional Director Joan Degiorgio thanked participants for their persistence, dedication, and creative thinking. She expressed enthusiasm for integrating the results of this workshop into the Bear River Conservation Action Plan, and for collaborating with TNC's conservation partners to implement the many worthy adaptation strategies that emerged from two days of learning and deliberation about the impacts of climate change on the Bear River Basin.

Acknowledgements

Many thanks to Linda Mearns and Joe Barsugli for developing and presenting the climate change scenarios, and to Fred Wagner for preparing an informative presentation on the impacts of climate change in the Intermountain West. We also thank Gregg Garfin for his excellent work as overall workshop facilitator and keeping us on track, along with the other SWCCI facilitators (Molly Cross and David Gori). Special thanks to our panelists (Bryan Dixon, Betsy Hermann and Floyd Roadifer) for agreeing on short notice to share their ideas and impressions in the plenary session. Thanks to Chris Cline, Eve Davies and Allison Jones for help in building the conceptual models.

We thank all of the participants for taking the time to attend the workshop and helping to address climate change in the Bear River Basin. Finally, thanks to the Utah Field Office staff that helped with the workshop: Dave Livermore, Joel Tuhy, Barry Baker, Chris Montague, Gen Green and especially Pauline Blanchard for handling all of the workshop logistics, including meals, meeting space, and lodging.

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The basis for the hydrologic scenarios is shown in the figures of projected flows, snowpack, and soil moisture from these simulations. Shaded bands on these figures indicate the 25th and 75th percentiles of the projections from different models. Preliminary results from the Colorado River Water Availability Study was also used to inform the descriptive scenarios, as these used a different methodology that showed greater reductions in flow for the median scenario than did the work by Levi Brekke.

Appendices
Bear River Climate Change Adaptation Workshop
May 26-27, 2010

1. **Final Agenda**
2. **Participant List**
3. **Annual and Seasonal Temperature and Precipitation Projections**
4. **Bear River Basin Hydrologic Scenarios**
5. **Bonneville Cutthroat Trout Climate Change Impacts**
6. **Bonneville Cutthroat Trout Adaptation Strategies**
7. **Oxbows Wetlands Climate Change Impacts**
8. **Oxbow Wetlands Adaptation Strategies**
9. **Bonneville Cutthroat Trout "Work-In-Progress" Draft Model**
10. **Oxbow Wetlands "Work-In-Progress" Draft Model**

Appendix 1. Final Agenda

SOUTHWEST CLIMATE CHANGE INITIATIVE (SWCCI)

BEAR RIVER
CLIMATE CHANGE ADAPTATION WORKSHOP

May 26 and 27, 2010
Salt Lake City, Utah

WORKSHOP GOAL:
Identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for their implementation.

WORKSHOP OBJECTIVES:
1. Provide background information on climate change and its effects in the Bear River Basin.
2. Introduce a framework for landscape-scale climate change adaptation planning.
3. Assess the impacts of climate change on a set of high-priority species and ecosystems.
4. Identify strategic management actions that will reduce climate change impacts.
5. Identify opportunities for ongoing learning, collaboration, and implementation of on-the-ground climate change adaptation projects in the Bear River Basin.

DESIRED OUTCOMES:
1. Shared understanding of the known current and potential future effects of climate change, through development of conceptual models, for Bonneville cutthroat trout and Bear River wetlands.
2. Identification of strategic actions to promote conservation resilience and realignment for Bonneville cutthroat trout and Bear River wetlands in the face of climate change.
3. Identification of opportunities to facilitate successful implementation of strategic actions.
4. Statement of research and monitoring needs for climate adaptation in the Bear River Basin.
5. Recommended next steps to be taken by natural resource managers of the Bear River Basin.

<u>MAY 26: 8:30 AM -11:45 PM</u>

8:30-8:40 Welcome
- Dave Livermore, *State Director, The Nature Conservancy, UT*

8:40-8:50 Southwest Climate Change Initiative (SWCCI) Overview
- Patrick McCarthy, *Director, SWCCI, The Nature Conservancy*

8:50-9:10 Statement of the Problem and Rationale for Workshop

- Gregg Garfin, *Director of Science Translation and Outreach, University of Arizona (Workshop Facilitator)*

9:10-9:40 Overview of Regional Climate Change Impacts: the Known, the Unknown, and the Uncertain

- Linda Mearns, *Senior Scientist, National Center for Atmospheric Research*

9:40-10:15 Overview of Past and Potential Future Trends in River/Stream Flows in the Bear River Basin

- Joe Barsugli, *Western Water Assessment, University of Colorado*

BREAK: 10:15 - 10:30 AM

10:30-11:00 Overview of Ecological Consequences of Climate Change

- Dr. Frederic H. Wagner, *Professor Emeritus, Utah State University*

11:00-11:30 Overview of Conservation Adaptation Planning

- Molly Cross, *Climate Scientist and Adaptation Specialist, Wildlife Conservation Society*

11:30-11:45 Implementing a Framework for Adaptation Planning: Future Climate Scenarios, Goals & Logistics for Remainder of the Workshop

- Gregg Garfin & Molly Cross

LUNCH: 11:45 – 12:45 PM (PROVIDED)

12:45 - 4:30 PM, W/ BREAK FROM 3:00 – 3:15 PM

12:45-4:30 Conservation Target Break-out Groups (separate rooms): Session One

- Bonneville Cutthroat Trout Facilitator: Patrick McCarthy
- Wetlands Facilitator: Molly Cross

Objectives for the two groups include:

- *Identify management objectives*
- *Refine the conceptual ecological model*
- *Assess impacts of two future climate change scenarios*
- *Complete Table 1: Climate Change Impacts (in participant packet)*

DAY ONE ADJOURN: 4:30 PM

HAPPY HOUR: 4:30 PM (AT THE SAME LOCATION AS THE WORKSHOP)

<u>MAY 27, 2010, 8:30 AM -12:00 AM W/ BREAK FROM 10:15 – 10:30 AM</u>

8:30-12:00 Conservation Target Breakout Groups: Session Two

<u>*Objectives for two groups include:*</u>
- *Identify management intervention points*
- *Identify strategic actions for climate change adaptation*
- *Complete Table 2: Identification of Strategic Actions (in participant packet)*
- *Review management objectives*
- *Evaluate level of urgency/priority and identify opportunities for implementation*
- *List research and monitoring needs*

LUNCH: 12:00 – 1:00 PM (PROVIDED)

<u>1:00 – 4:30 PM</u>

1:00-2:00 Break-out Groups Re-assemble in Large Room and Report Back (Gregg)
- Each group presents/reviews their priority strategic actions
- Facilitated summary and synthesis

2:00-3:00 Opportunities for Strategic Action Implementation: Integrate and evaluate top priority actions considering barriers and key uncertainties, e.g., cost, social, political, regulatory, lack of knowledge, and opportunities for implementation.

Mini-breakout groups meet for 10 minutes to discuss barriers and opportunities, followed by report-out and whole-group discussion. Facilitator: Gregg Garfin

<u>*Outcomes:*</u>
- *Barriers to implementing strategic actions*
- *Opportunities for overcoming barriers to implement the actions*
- *Suggest lead agency and timeline*

BREAK: 3:00-3:15 PM

3:15-4:00 PM Facilitated Discussion on Emerging Themes, Implementation and Next Steps (Moderators: Joan Degiorgio and Joel Tuhy)

<u>*Outcomes:*</u>
- *What strategies might apply to all targets?*
- *What work planned or underway will be affected by climate change?*

4:00-4:20 Participant Feedback on Workshop Process and Outcomes

4:20-4:30 Closing Remarks: Joan Degiorgio and Patrick McCarthy

PLEASE COMPLETE EVALUATION FORM!! THANK YOU!!

WORKSHOP ADJOURNS: 4:30 PM

Appendix 2. Bear River Climate Change Adaptation Workshop Participant List

SWCII Bear River Workshop Participants

Name	Organization	Email
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Temis Taylor	Utah State University	temistaylor@gmail.com
Deb Freeling	Forest Service	

Appendix 3. Annual and Seasonal Temperature and Precipitation Projections

Time frame: 2041-2070 compared to 1971-2000
Region: Bear River Basin (40°-44°N, 110°-114°W)
IPCC SRES Emissions Scenario: A2 ("medium-high emissions")

Background and Method

The climate change scenarios were constructed using a variety of information, including: regional probabilistic information generated using the CMIP3 (CMIP: Coupled Model Intercomparison Project) suite of over 20 global climate model results used in the IPCC Fourth Assessment Report (based on methods explained in Tebaldi et al. 2004, and 2005), results from Chapter 11 of the IPCC Working Group 1 Report (Christensen et al., 2007), and some results from the NARCCAP (North American Regional Climate Change Assessment Program) regional climate model simulations (Mearns et al., 2009). The emissions scenario considered for the probabilistic information and for NARCCAP is the A2, a medium high scenario. However, for Chapter 11 of IPCC the A1B scenario, a lower (middle) emissions scenarios, was emphasized. The time period for the future is roughly 2041-2070, compared to 30 years in the current period (1971-2000) for NARCCAP but further out in the century for the CMIP3 climate model results in the IPCC Chapter. For the regional probabilistic information the time periods are similar to those used in NARCCAP. The quantiles of the probability distributions for temperature change and precipitation change are presented later in this document.

The quantiles of the probability distributions for temperature change and precipitation change (%) for annual and seasonal values for an area covering all of the Bear River Basin, for the A2 emissions scenario for around 2060, are used as the basis for choosing the Main Scenario. It is important to note that the distributions are based on multiple models, and other sources cited above are also taken into consideration. Thus, the same percentile is not chosen for all seasons for both temperature and precipitation. Below, key quantiles are presented from these distributions to give the reader a sense of the spread across the model simulations.

Main Scenario
For the main climate change scenario, annual precipitation increases very little (1.6%), and annual temperature increases by 3.5 °C *by about 2060*. These values are based on results from several climate models, but mainly the NCAR CCSM, which tends to fall around the 50th percentile for annual change in precipitation as well as for both summer and winter precipitation, and the temperature change in winter. The change in summer temperature, however, is greater than the 50th percentile –closer to the 95th percentile.

Season	Precip %	Temp °C	Temp °F
Annual	+1.6	+3.5	+6.3
Winter	+13.0	+2.5	+4.5
Spring	−6.0	+3.5	+6.3
Summer	−15.0	+4.5	+8.1
Fall	0.0	+3.5	+6.3

Alternative Scenario
For this scenario, the small area covering only the Bear River Basin was examined. It is actually more moderate than the Main Scenario, from the point of view of temperature change (2.7 °C annual temperature change, which is the 50th percentile), but is more extreme from the point of view of winter precipitation, which decreases compared to the main scenario. Annual mean change in precipitation is about –3%. The high resolution Canadian regional climate model CRCM, nested in the Canadian global climate model, serves as the basis for the alternative scenario.

Season	Precip %	Temp °C	Temp °F
Annual	−3.0	+2.7	+4.9
Winter	−5.0	+2.7	+4.9
Spring	+10.0	+2.0	+3.6
Summer	−20.0	+3.0	+5.4
Fall	+3.0	+3.0	+5.4

Scenario Framework: Quantiles of Probability Distributions

The quantiles of the probability distributions for temperature change and precipitation change (%) for annual and seasonal values for an area covering all of the Bear River Basin, for the A2 emissions scenario for around 2060, are used as the basis for choosing the Main Scenario. It is important to note that the distributions are based on multiple models, and other sources cited above are also taken into consideration. Thus, the same percentile is not chosen for all seasons for both temperature and precipitation. Below, key quantiles are presented from these distributions to give the reader a sense of the spread across the model simulations.

Temperature Difference in °C (°F)

Season	5th	25th	50th	75th	95th
Annual	1.8 (3.2)	2.3 (4.1)	2.7 (4.9)	3.0 (5.4)	3.5 (6.3)
Winter	1.2 (2.2)	1.9 (3.4)	2.4 (4.3)	2.8 (5.0)	3.6 (6.5)
Spring	1.4 (2.5)	2.0 (3.6)	2.5 (4.5)	3.0 (5.4)	3.6 (6.5)
Summer	2.0 (3.6)	2.7 (4.9)	3.2 (5.8)	3.7 (6.7)	4.5 (8.1)
Fall	2.0 (3.6)	2.4 (4.3)	2.7 (4.9)	3.0 (5.4)	3.4 (6.1)

Precipitation (% Change)

Season	5th	25th	50th	75th	95th
Annual	–14	–5	1	8	17
Winter	–12	3	12	20	36
Spring	–14	–4	2	7	17
Summer	–45	–25	–12	2	23
Fall	–18	–4	4	13	27

References

Christensen, J, B. Hewitson, and 15 co-authors [including L. O. Mearns], 2007. Regional Climate Projections. Chapter 11 in *The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 847-940.

Mearns, L. O., et al., 2009. A regional climate change assessment program for North America. *EOS* 90**:** 311-312.

Tebaldi, C., R. Smith, D. Nychka, and L. O. Mearns, 2005. Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multi-model ensembles. *Journal of Climate,* 18:1524-1540.

Tebaldi, C., L. O. Mearns, R. Smith, D. Nychka, 2004. Regional probabilities of precipitation change: A Bayesian approach. *Geophysical Research Letters* 31:L24213, doi:10.1029/2004GL021276.

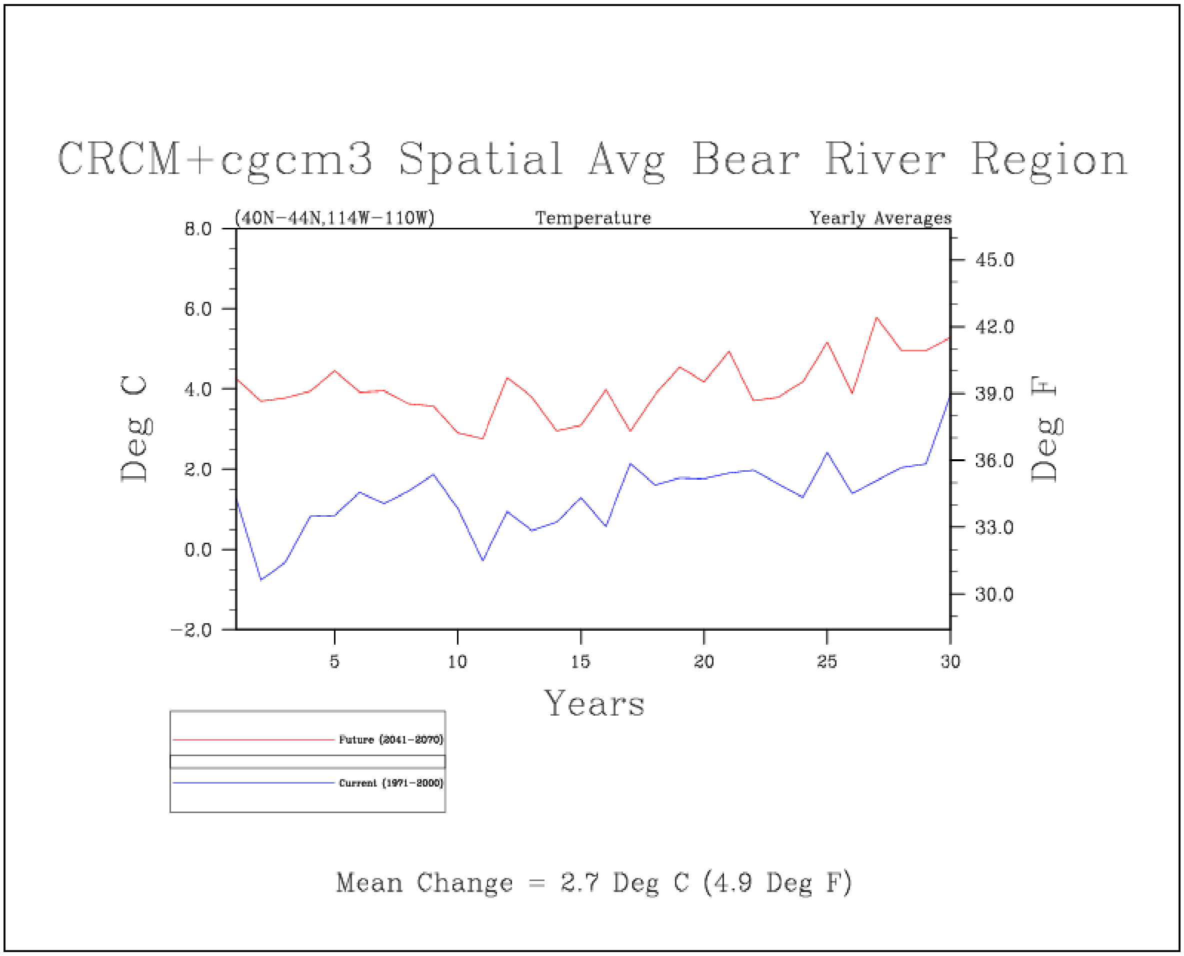


Figure 1. A3. Annual temperature for the Bear River Basin region: current (1971-2000; blue) and future (2041-2070; red). Results are based on the Canadian regional model (CRCM), driven by the Canadian global model (CGCM3), for an area covering 40°-44°N, 110°-114°W. A clear upward trend is exhibited in the current and future time periods, with a mean 2041-2070 temperature increase of 2.7 °C (4.9°F). Note the year-to-year variability in both time series. Particularly noteworthy are the years 5-11 for the 2041-2070 time series, where temperatures decrease steadily. This underscores that runs of years of decreases can be a natural feature of future climate even under conditions of long-term mean temperature increases.

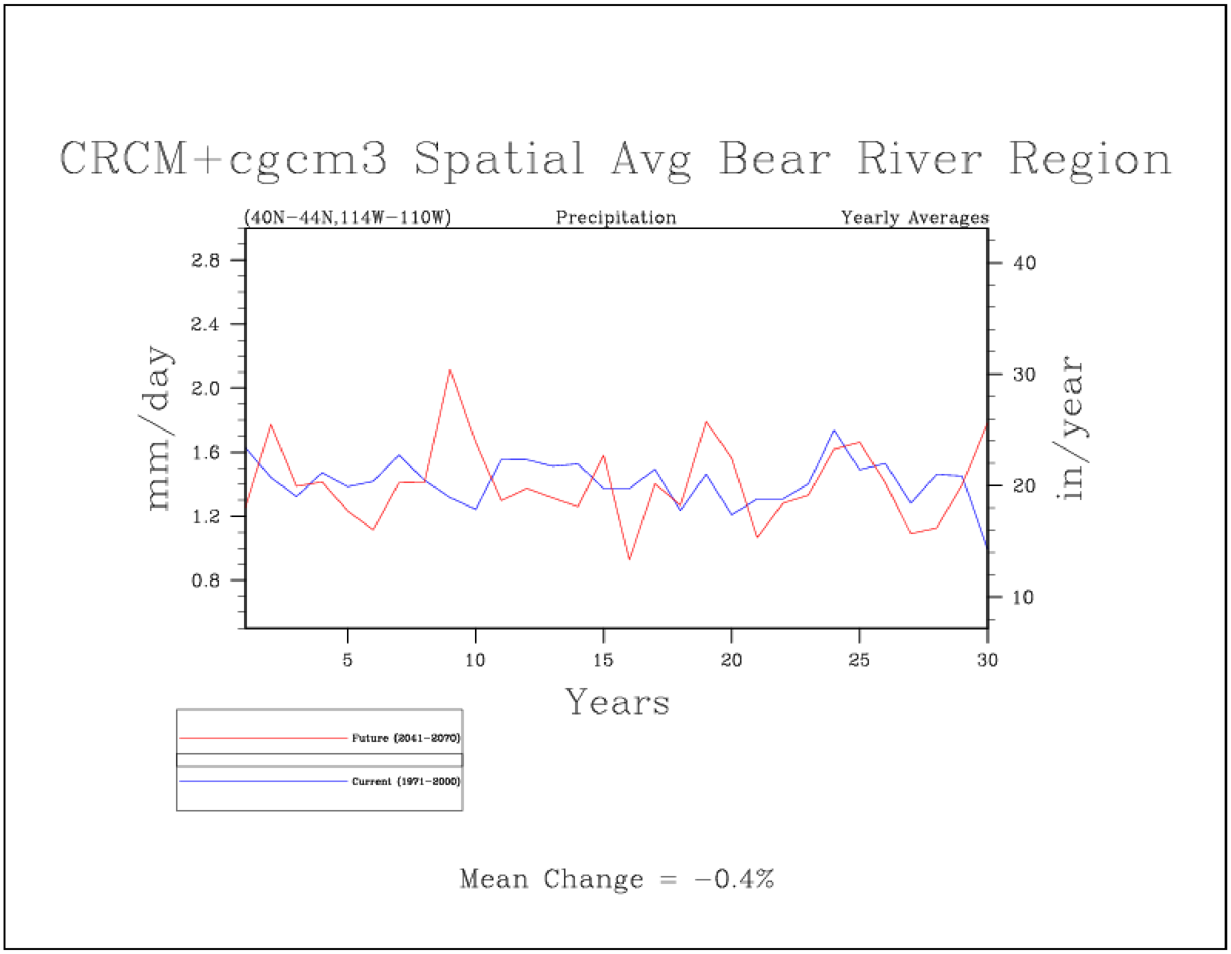


Figure 2. A3. Annual precipitation for the Bear River Basin region: current (1971-2000; blue) and future (2041-2070; red). Results are based on the Canadian regional model (CRCM), driven by the Canadian global model (CGCM3), for an area covering 40°-44°N, 110°-114°W. Neither time series exhibits a distinct trend. Mean annual precipitation decreases by only 0.4% between 2041-2070.

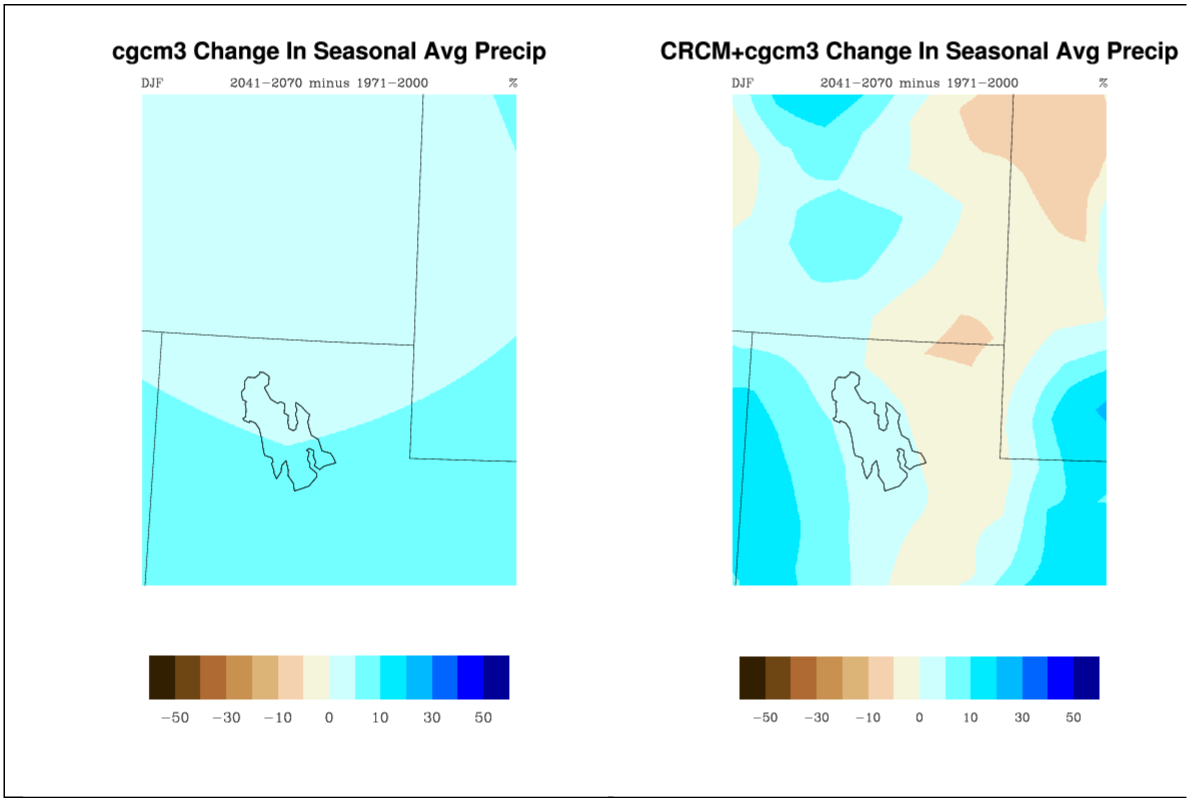


Figure 3. A3. Percent changes in Winter Precipitation simulated by the Canadian global model (CGCM3, on left) and from the Canadian regional model (CRCM, on the right), which was nested in the global model. A somewhat different pattern of change is seen in the two models. The regional model exhibits a decrease in precipitation in the center of the region, corresponding to the area of Bear River Basin, while the global model shows mild increases throughout the region. In NARCCAP, we are working to determine which results (here the global vs. the regional model) are more credible.

Appendix 4. Bear River Basin Hydrologic Scenarios

Background

The hydrologic scenarios are created from the temperature and precipitation changes chosen by Linda Mearns, by running these changes through a hydrology model to produce climate-altered flows and snowpacks for the Bear River. We consider only "natural" flows –unaltered by diversions and reservoir storage and are not able to address reaches of the river where groundwater interactions are important. Scenarios are referred to as "Main Scenario or Scenario 1" and "Alternative Scenario or Scenario 2."

Method ("delta method")

Historical temperature and precipitation data for 1915-2003 from the Hamlet and Lettenmaier (2005) gridded 1/8 degree (approx. 12 km or 7.5 mi.) dataset are input to the VIC (Variable Infiltration Capacity) hydrologic model to produce the baseline hydrology. The overall method simply adds the average projected change to data in the historic record. Historic temperatures are adjusted by adding the *difference* in temperature specified in the climate scenarios. Historic precipitation values are adjusted by the *percent change* specified in the climate scenarios. These adjusted meteorological sequences are then run through the hydrology model, producing climate-altered hydrologic sequences. The runoff and base (soil) flow were routed down the river network producing modeled streamflow. We will look at three tributary inflows and at the river basin as a whole.

Annual Natural Streamflow

The long term average "natural" flow in the basin decreases in both scenarios. The effect of warming alone would be to reduce flows by about 15-25%. However, the increases in the Winter (Main Scenario) and Spring (Alternative Scenario) precipitation somewhat compensates for the increases in evapotranspiration due to warmer temperatures.

Table 1. A4. Streamflow changes in thousands of acre-feet

Streamflow Location	Base (Historic)	Main Scenario	Alternative
Uinta Headwaters (BEARH)	187	153 (-18.2%)	162 (-13.4%)
Smith Fork (SMITH)	130	124 (-4.6%)	120 (-7.7%)
Logan River (LOGAN)	411	384 (-6.6%)	392 (-4.6%)
Bear River cumulative (BEARC)	1810	1659 (-8.3%)	1691 (-6.6%)

Timing of Spring Runoff

These scenarios show the timing of spring runoff occurring, on average, 1 to 3 weeks earlier than during the historic record. With the Main Scenario showing roughly twice the change of the Alternative Scenario. The receding limb of the spring hydrograph shows larger changes than the rising limb.

Table 2. A4. Changes in timing of Bear River spring runoff.

Hydrograph feature	Main Scenario	Alternative
Rising limb	2 weeks earlier	1 week earlier
Peak	2 weeks earlier	1 week earlier
Receding limb	3 weeks earlier	2 weeks earlier

Summer Low Flows

Summer flows decrease in both scenarios but the magnitude of change depends on whether we consider the low flows or high flows.

Table 3. A4. Changes in Bear River flow extremes.

Summertime Flows	Main Scenario	Alternative
Low flows (10^{th} percentile)	-10%	-15%
High flows (90^{th} percentile)	-25%	-50%
"7Q10 "	-8-15%	-15-20%

Analysis of NARCCAP regional model simulations indicates that the number of summertime rain days may decrease in arid areas such as Utah, although large individual rain events may actually increase in intensity. This would lead to longer dry periods during the Summer, with the potential for uncommon, but more intense flooding.

The low flows from these simulations should be regarded as qualitative information. The "delta method" does not alter the historic sequences of wet and dry days – it only changes the magnitude of precipitation for each event. In addition, the VIC model does not couple the shallow groundwater to the streams.

Cold-Season Flows

In the headwaters, the wintertime flows are not significantly changed, because temperatures remain below freezing during most winter precipitation events. In the Smith Fork and Logan River tributaries and for the river as a whole, average winter natural flows increase by about 30-50%, with peak events increasing by up to 150%. These flows increase because some events that would be snow in the present climate become rain events in warmer future projected for the region. There is little difference between the two scenarios in this regard.

Snowpack

Main Scenario: On average, snowpack starts accumulating about 1 month later than during the historic period. By March, the snowpack reaches values comparable to the historic period in the headwaters basin. However, peak snowpack values are between 10-15% lower than in the historic period. A rapid and early melt takes place, resulting in snow completely melting out from the headwaters basins about 2 to 4 weeks earlier than in the historic period.

Alternative Scenario: On average, snowpack starts accumulating about 1 month later, than during the historic period – the same as in the Main Scenario. Snowpack accumulation is slower than in the historic period, with 15-20% lower peak accumulation values. Increased spring precipitation prolongs the snowpack somewhat in high elevation basins. However, a rapid and early melt takes place, resulting in snow completely melting out from the headwaters basins about 2-4 weeks earlier than in the historic period.

At lower elevations, such as along the mainstem of the Bear River and in the surrounding valleys, in both scenarios, snow cover becomes more sporadic, and monthly average amounts can be reduced to less than one-third of historic values.

References

VIC hydrology model http://www.hydro.washington.edu/Lettenmaier/Models/VIC/index.shtml
Thanks to Alan Hamlet (U. of Washington) for providing the VIC model and parameters appropriate to the Bear River. Note that for the Bear River basin, the parameters of VIC have not been calibrated against historic natural flows; instead, typical values are used.

Gridded Meteorological Data

Hamlet A.F., Lettenmaier D.P., 2005: Production of temporally consistent gridded precipitation and temperature fields for the continental U.S., 2005: *Journal of Hydrometeorology* 6 (3), 330-336. http://www.hydro.washington.edu/Lettenmaier/Data/gridded/index_hamlet.html

This model was used in the following studies that include the Bear River basin:

Hamlet, A. et al., 2007. Twentieth-Century Trends in Runoff, Evapotranspiration, and Soil Moisture in the Western United States. *Journal of Climate* 20, 1468-1486.

Hamlet, A. and D. Lettenmaier, 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. *Water Resources Research*, 43, W06427, doi:10.1029/2006WR005099, 2007.

Hamlet, A. et al, 2005. Effects of Temperature and Precipitation Variability on Snowpack Trends in the Western United States. *Journal of Climate*, 18, 4545 -4561.

Figure 1. A4. Average Daily Hydrograph (Scenario 1 = Main Scenario; Scenario 2 = Alternative Scenario). Scenarios show earlier runoff (1-3 weeks earlier), and reduced future streamflows.

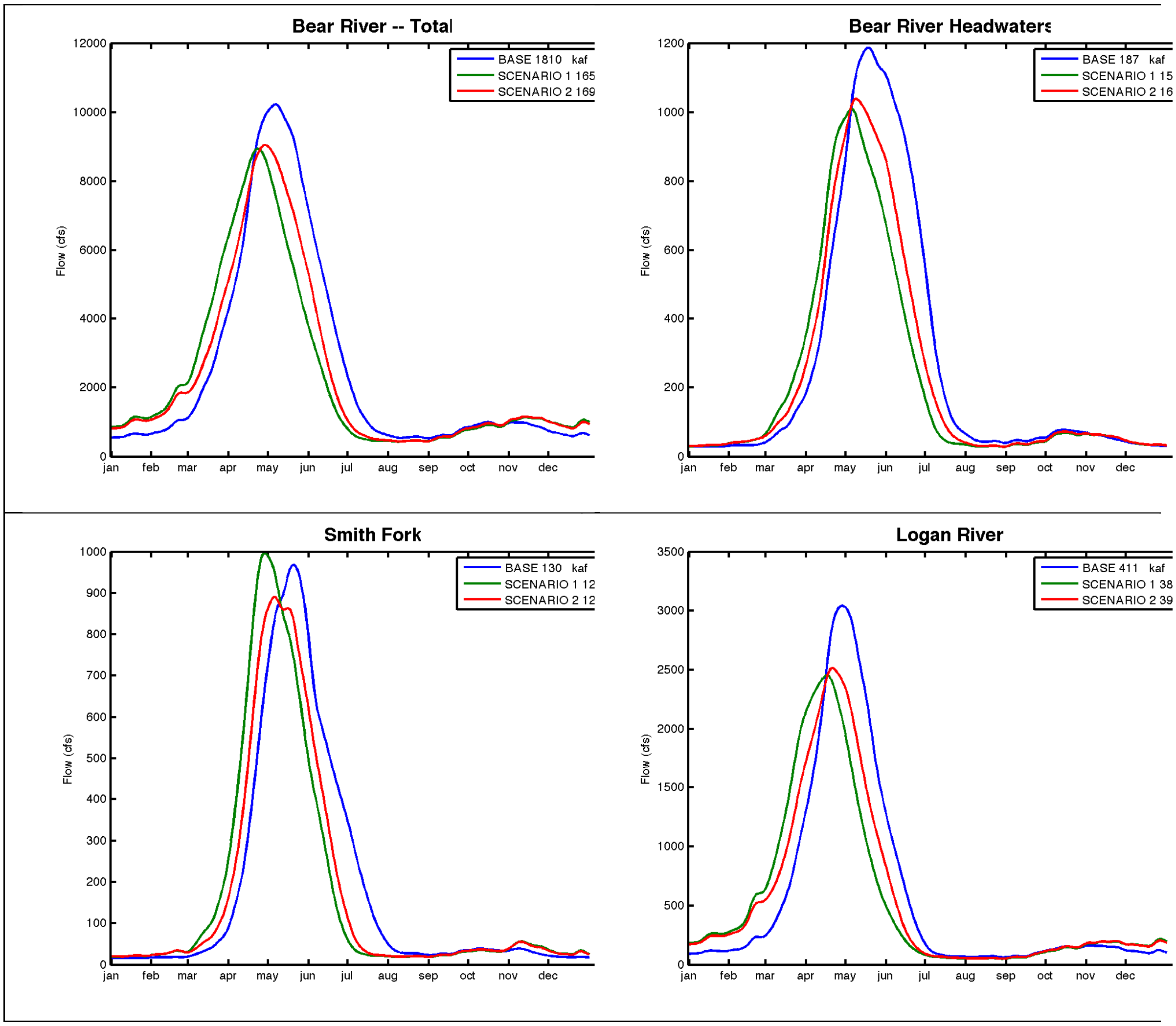


Figure 2. A4. Daily Flow Values ("box and whiskers" plots). Baseline (blue) and Main Scenario (red) are shown for each week of the calendar year. The dots in the center of the boxes denote the median (50th percentile) value; the top edge of each box denotes the 75th percentile, and the bottom edge of each box denotes the 25th percentile. The lines ("whiskers") reach the 95th percentile (top) and 5th percentile (bottom). Unfilled circles show outlier values. Note the earlier runoff peaks, and the decreased overall volume of runoff, especially during the summer months.

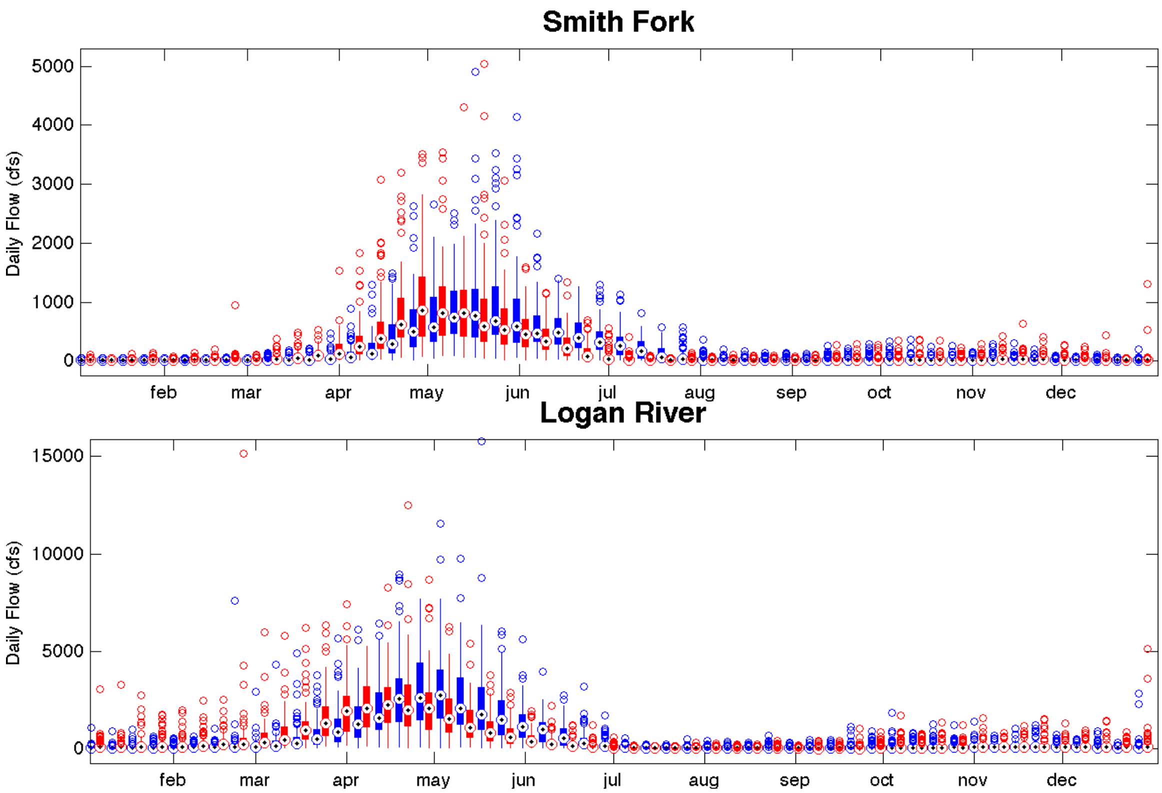
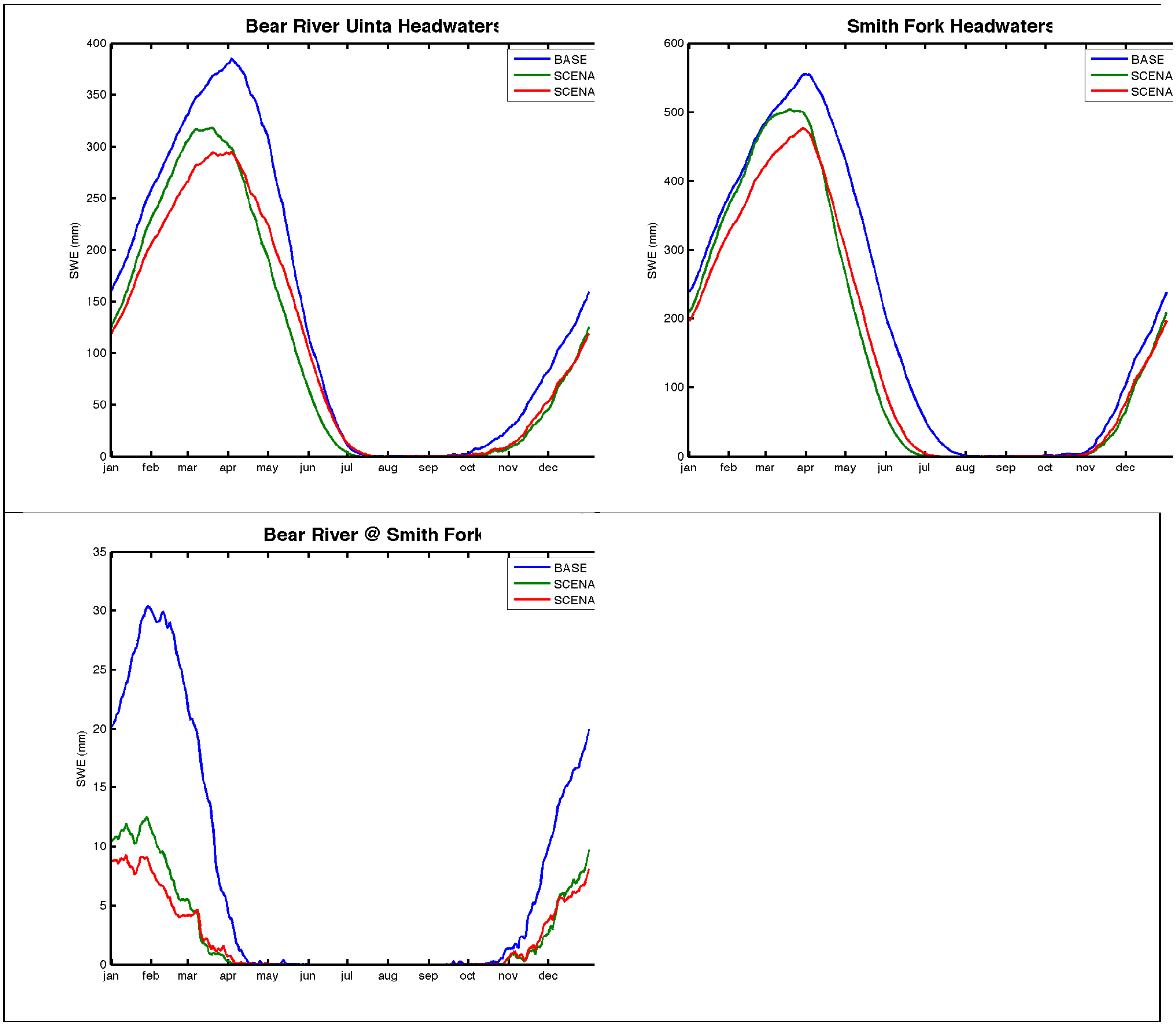


Figure 3. A4. Average Snow Water Equivalent (Scenario 1 = Main Scenario; Scenario 2 = Alternative Scenario). Scenarios show decreased snow amounts, and earlier snowmelt.



Appendix 5. Known and Projected Climate Change Impacts on the Bonneville Cutthroat Trout (Hypotheses of Change)

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change)	Comments, Notes, Sources
Increased air temperatures and decreased snowmelt runoff	Increased air temperature and decreased snowpack leads to increased water temperature, decreased dissolved oxygen (DO), and decreased BCT viability on the Bear River main stem.(S1)	Water quality – physiological stress
Increased air temperatures and decreased snowmelt runoff	Air temperature increases and decreased snowmelt runoff may lead to shifting plant species composition, density and structure (e.g., decreased groundcover). The changes in vegetation can lead to increased sediment load and transport, which affects BCT viability (e.g., silt on eggs), especially in tributary streams.(S1)	Vegetation cover loss and erosion – decreased BCT viability
Increased air temperatures, earlier snowmelt runoff, combined with decreased summer precipitation	Warmer air temperatures and earlier snowmelt, along with decreased summer precipitation results in greater forest and shrubland wildfire frequency, intensity and size. This will generate increased sediment transport and either direct fish mortality or additional physiological stress. This cascade of events also alters habitat, through changes in channel morphology. It is possible that this cascade of events will generate greater impacts in tributary streams.(S1)	Fire, erosion, – decreased BCT viability
Increased air temperatures and increased water demand	Increased air temperatures lead to earlier spring planting and earlier agricultural water demand. This can lead to increased diversions and tributary dewatering. The result for BCT is that they miss opportunity to move into headwaters to breed. Note	Water demand – less water for BCT - stranded

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]	Comments, Notes, Sources
	that though allocation of water rights is an intervening factor. (S1)	
Increased air and water temperatures	Increased air temperatures lead to increased water temperatures, which leads to an increase in the ranges of non-native fish, and increased predation and competition with BCT, by non-natives. Continued stocking of non-natives amplifies this impact.(S1)	Non-native invasion
Increased air and water temperatures	Increased water temperatures, increases the quantity and distribution of pathogens. Consequently, disease can more readily spread to BCT (e.g., increased occurrence of whirling disease), and decrease population viability. This chain of events is particularly potent when fish are already under physiological stress from above-average stream temperatures and other factors. (S1)	Pathogens - stress
Increased air and water temperatures	Increased air temperatures lead to increased water temperatures in main stem reservoirs, resulting in direct physiological stress on BCT. BCT in Bear Lake are especially vulnerable. (S1)	Water temperature – physiological stress
Increased air temperatures and decreased stream ice	Increased air temperatures decrease the amount of stream ice, particularly in small streams, which allows BCT to move upstream; thus expanding winter habitat. On the other hand, decreased snow bridging leads to less water temperature stability and fewer thermal refugia for BCT. High spring flood flows may remove ice in stream channels, and allow BCT improved chance for spawning – but this last point is speculative. (S1)	Less Stream ice – expanded habitat (good), fewer refugia (bad)
Increased air temperatures and decreased spring/summer precipitation, lead to lower baseflows in summer	Lower summer base flows dry out the riparian zone and affect the volume of water in streams, which affects overbank cover, altering the width of the riparian zone. Overbank cover is affected by lack of recruitment and/or mortality of riparian	Vegetation cover loss – loss of habitat, physical complexity,

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]	Comments, Notes, Sources
	species, as well as the current condition of the riparian zone. BCT are then affected by less stream shading, warmer water temperatures, and lower stream habitat complexity; the latter is favored by BCT. (S1)	
Desiccation of remote and proximal landscapes, results in disturbance of soil crusts and loss of vegetation cover. This leads to increased dust deposition on snowpack, and snowmelt earlier runoff	Earlier snowmelt and increased sublimation of snowpack, exacerbates all snowmelt runoff- related impacts. There are multiple causal factors leading to increased dust deposition. One factor is wildfire, denuding the landscape and liberating dust. (S1)	Amplification of snowmelt effects by dust
Increased air temperatures, earlier runoff timing and increased water temperatures	Earlier runoff timing upsets connections between spawning timing and water availability in streams. Fish may not be able to "catch up" in spawning, i.e., they may not be able to get up into tributary headwaters to spawn. Thus, the timing mismatch, a phenological change, leaves BCT stranded in the main stem. (S1)	Earlier runoff, phenological changes, BCT stranded
Increased air temperatures and decreased summer base flow	Decreased summer base flow leads to the expansion of reaches that are uninhabitable – due to declines in water quality, decreased aquatic habitat, increased water temperatures and decreased connectivity of stream reaches. This cascade of impacts is especially important in the Bear River main stem. Note: at present, fish in the Bear River main stem are exceptionally vulnerable to increases in water temperature. (S1)	Less water, increased temperature, water quality, decreased connections – physiological stress, stranded
Increased air temperatures and increased fraction of winter and spring precipitation as rain	Increased rain fraction during winter and spring, leads to decreased infiltration into soil layers; thus, less water makes it into Bear Lake and the Bear River main stem. Consequently, there is less water available for irrigation, and less water in main	Less water, increased tem– physiological stress

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]	Comments, Notes, Sources
	stem for BCT. Also, as Bear Lake storage decreases, water temperature increases, reducing habitat and increasing direct physiological stress on BCT. An example of this cascade of impacts occurred in May 2005. (S1)	
Increased air temperatures, drought and decreased forage quality and quantity	Drought and warmer air temperatures lead to vegetation mortality, more bare soil, and degraded watershed conditions. This leads to more runoff and sedimentation in grazed watersheds; as a consequence, livestock are moved on and off the range earlier than usual. The effects of the changes in rangeland management are more trampling, decreased soil percolation, and decreased riparian cover. BCT are directly affected by the impacts to riparian cover and sedimentation. (S1)	Vegetation change, grazing exacerbation, loss of habitat, physiological stress, viability
Increased air temperatures, drought and decreased forage quality and quantity	Warmer air temperatures and drought increase heat stress on cattle and drive them to seek shade in riparian zones, where food value is still high. The increased concentration of cattle in riparian zones leads to increased grazing impacts in riparian areas, and decreased habitat and direct sedimentation effects on BCT (e.g., physiological stress and reduced viability of eggs). (S1)	grazing exacerbation, loss of habitat, physiological stress, viability

[1] Indicate Scenario (see description in heading) the impact applies to: “S1” = Scenario #1 only, “S2” = Scenario #2 only, or “S1+S2” = both.

Appendix 6. Bonneville Cutthroat Trout Strategic Actions to Address Climate Change Impacts for Scenario #1

Management Objective: Maintain or expand the number of viable populations of the Bonneville cutthroat trout in the Bear River Basin. Achieve this by maintaining or restoring the following components of the trout's habitat, autecology and life history:

- *Connectivity between the mainstem and tributaries (reconnect diversions)*
- *Flows in actual and potential habitat (restore natural flow regimes)*
- *Habitat quality (channel morphology, riparian vegetation, etc.)*
- *Genetic diversity and integrity*
- *Aquatic community species composition and structure*
- *Water quality (temperature, dissolved oxygen, etc.)(restore water quality regimes)*

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
• Increased air temperature and decreased snowpack leads to increased water temperature, decreased dissolved oxygen (DO), and decreased BCT viability on the Bear River main stem. • Increased air temperatures lead to earlier spring planting and earlier agricultural water demand. This can lead to increased diversions and tributary dewatering. The result for BCT is that they miss opportunity to move into headwaters to breed. Note that though allocation of water rights is an intervening factor.	Aquatic habitat management and restoration; Fisheries management	• Inventory barriers; identify priority reaches; improve headwater stream habitat; develop conservation strategies to increase water flows; remove physical barriers; (happening now in Upper and Middle Bear River, but needs to be accelerated, esp. on Lower Bear). • Infrastructure changes to draw cooler water for BCT; create cool water pool in main stem; allow for migration to tributaries when main stem temperatures make reaches uninhabitable; pipeline to Bear Lake center,

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
• Increased water temperatures, increases the quantity and distribution of pathogens. Consequently, disease can more readily spread to BCT (e.g., increased occurrence of whirling disease), and decrease population viability. This chain of events is particularly potent when fish are already under physiological stress from above-average stream temperatures and other factors. • Increased air temperatures lead to increased water temperatures in main stem reservoirs, resulting in direct physiological stress on BCT. BCT in Bear Lake are especially vulnerable. • Increased air temperatures contribute to an increase in the fraction of winter and spring precipitation occurring as rain. Increased rain fraction during winter and spring, leads to decreased infiltration into soil layers; thus, less water makes it into Bear Lake and the Bear River main stem. Consequently, there is less water available for irrigation, and less water in main stem for BCT. Also, as Bear Lake storage decreases, water temperature increases, reducing habitat and increasing direct physiological stress on BCT. An example of this cascade of impacts occurred in May 2005. • Increased air temperatures decrease the amount of		to draw cooler water; education and outreach to land owners regarding cool water refugia – deepen and enlarge refugia. • Assisted migration of more southern BCT populations to improve chances of survival, genetic characteristics and genetic diversity.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
stream ice, particularly in small streams, which allows BCT to move upstream; thus expanding winter habitat. On the other hand, decreased snow bridging leads to less water temperature stability and fewer thermal refugia for BCT. High spring flood flows may remove ice in stream channels, and allow BCT improved chance for spawning – but this last point is speculative.		
Air temperature increases and decreased snowmelt runoff may lead to shifting plant species composition, density and structure (e.g., decreased groundcover). The changes in vegetation can lead to increased sediment load and transport, which affects BCT viability (e.g., silt on eggs), especially in tributary streams.	Vegetation management	Improve streambank vegetation, where spraying resulted in the loss of willows and other native phreatophytes. This will help improve streambank stability.
Warmer air temperatures and earlier snowmelt, along with decreased summer precipitation results in greater forest and shrubland wildfire frequency, intensity and size. This will generate increased sediment transport and either direct fish mortality or additional physiological stress. This cascade of events also alters habitat, through changes in channel morphology. It is possible that this cascade of events will generate greater	Vegetation and Fire management	Identify watersheds with the greatest risk for uncharacteristic fire and develop forest management plans to jointly address fire and BCT risks. Management methods include: prescribed fire, fuels management, fuel breaks around key tributaries, and judicious use of thinning. The key focus for the Bear River watershed is spruce-fir-aspen forests, which have longer fire return

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
impacts in tributary streams.		intervals. Note: the ecological benefits of various fuels management and fuel breaks need to be tested; thus this strategy should be used cautiously and in conjunction with monitoring.
Increased air temperatures lead to increased water temperatures, which leads to an increase in the ranges of non-native fish, and increased predation and competition with BCT, by non-natives. Continued stocking of non-natives amplifies this impact.	Fisheries management	• Reduce or remove stress-producing non-native fish species, especially in headwater tributaries. Inventory and prioritize key non-natives. Cease the stocking of rainbow trout in occupied BCT habitat. (Note: this strategy produces a co-benefit for management of northern leatherside chub). • Assisted migration of more southern BCT populations to improve chances of survival, genetic characteristics and genetic diversity.
• Increased air temperatures and decreased spring and summer precipitation lead to lower summer base flows. Lower summer base flows dry out the riparian zone and affect the volume of water in streams, which affects overbank cover, altering the width of the riparian zone. Overbank cover is affected by lack of recruitment and/or mortality of riparian species, as well as the current condition of	Riparian zone aquatic habitat management; Economic incentives; Water quality management; Policy action	• Repair and restore riparian areas in order to improve water quality and overbank shading. Concentrate on private land owners. Use economic incentives and tax benefits to increase participation in land and water conservation. Methods include conservation easements and deepening headwaters areas. Establish a private fund for matching dollars.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
the riparian zone. BCT are then affected by less stream shading, warmer water temperatures, and lower stream habitat complexity; the latter is favored by BCT. • Increased air temperatures lead to decreased summer base flow. Decreased summer base flow leads to the expansion of reaches that are uninhabitable – due to declines in water quality, decreased aquatic habitat, increased water temperatures and decreased connectivity of stream reaches. This cascade of impacts is especially important in the Bear River main stem. Note: at present, fish in the Bear River main stem are exceptionally vulnerable to increases in water temperature.		• Restoration of old mining-degraded reaches (e.g., Morris Creek, Idaho City) to improve habitat and water temperature characteristics. Use public-private partnerships to leverage resources, building on existing relationships, where possible. • Enforcement of TMDL regulations and improvement of TMDL regulatory process, to expedite regulation development and implementation. This must be accompanied by improved monitoring to ensure intended effects. (Note: the stakeholders that show up are ones most likely to regulated, which skews the process.) • Improve water flow, through conservation, in order to meet critical needs for BCT. Improve the potential for water banking and water law amendments, in order to increase flows.
Increased air temperatures lead to earlier runoff timing and increased water temperatures. Earlier runoff timing upsets connections between spawning timing and water availability in streams. Fish may not be able to "catch up" in spawning, i.e., they may not be able to get up into	Aquatic habitat management; Policy action	• Protect every spring through fencing to decrease water temperatures and improve water quality. Inventory and prioritize springs and treatments, based on criteria such as spawning potential (critical spawning

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
tributary headwaters to spawn. Thus, the timing mismatch, a phenological change, leaves BCT stranded in the main stem.		grounds). • Improve water flow, through conservation, in order to meet critical needs for BCT. Improve the potential for water banking and water law amendments, in order to increase flows.
Increased air temperatures and drought lead to vegetation mortality, more bare soil, and degraded watershed conditions. This leads to more runoff and sedimentation in grazed watersheds; as a consequence, livestock are moved on and off the range earlier than usual. The effects of the changes in rangeland management are more trampling, decreased soil percolation, and decreased riparian cover. BCT are directly affected by the impacts to riparian cover and sedimentation.	Land and water protection policy	Increase riparian buffers through the development of policy reforms, such as the creation of ordinances. Develop a model ordinance and provide technical assistance to help communities to tailor the ordinance to specific local needs.
Increased air temperatures and drought increase heat stress on cattle and drive them to seek shade in riparian zones, where food value is still high. The increased concentration of cattle in riparian zones leads to increased grazing impacts in riparian areas, and decreased habitat and direct sedimentation effects on BCT (e.g., physiological stress and reduced viability of	Grazing management	Purchase AUMs. Change allotment management plans. Establish forage reserves. Enforce existing standards and guidelines. Encourage rest rotation to promote regrowth on federal (BLM; USDA-FS) lands.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
eggs).		
Amplification of snowmelt effects by dust deposition. Desiccation of remote and proximal landscapes, results in disturbance of soil crusts and loss of vegetation cover. This leads to increased dust deposition on snowpack, and snowmelt earlier runoff. Earlier snowmelt and increased sublimation of snowpack, exacerbates all snowmelt runoff- related impacts. There are multiple causal factors leading to increased dust deposition. One factor is wildfire, denuding the landscape and liberating dust.	**THIS IS AN EFFECT RELATED TO EXACERBATION OF ALL SNOWMELT DRIVEN IMPACTS**	
FOR ALL IMPACTS	Education and outreach	• Increase public awareness of resources, and the observed and potential effects of climate change on riparian and BCT resources. Because this is controversial, it requires nuanced approaches, such as: involvement of citizens that have historic knowledge of "good" BCT fishing; a focus on stewardship values. With regard to climate change education, emphasize observed changes, historic trends, the "seeing is believing" approach.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point	Strategic Actions (Planning Horizon: 2040-2060)
		• Youth education about environment and water resources. This will be most effective, if it includes outdoor education experiences. Expand on existing programs to include BCT education.

[1] Indicate Scenario (see description in heading) the impact applies to: "S1" = Scenario #1 only, "S2" = Scenario #2 only, or "S1+S2" = both.

Appendix 7. Known and Projected Climate Change Impacts on Oxbow Wetlands (Hypotheses of Change)

Key Climate-Influenced Drivers/Effects (e.g., Physical, Ecological, Social, Economic)	Observed & Projected Climate Change Impact[1] (i.e., Hypotheses of Change)
Hydrology	Flashier floods and increased grazing impacts lead to increased downcutting, disconnecting the river from oxbow wetlands and decreasing water supply. (S1 & S2) Decreased baseflows lead to decreased water storage in oxbow wetlands (greater impact above Bear Lake, buffered impact below Bear Lake). (S1 & S2) The magnifying effect of climate change on top of over-allocation of flows will have a major impact on water availability for wetlands. (S1 & S2) Less water going to oxbow wetlands due to a decrease in return flows as irrigation efficiency increases. (S1 & S2) Spring flow pulses somewhat balance out the loss of summer flow pulses in Scenario #2. (S2) Dust on snow exacerbates earlier snowmelt reducing water availability later in the season. (S1 & S2, less of an impact in S2)
Wetland vegetation	Warmer temperatures and decreased water availability lead to summer stress on wetland vegetation, decreased productivity, and changes in plant species composition. Even worse in Scenario #2 (S1 & S2) Increased winter precipitation and winter flows from tributaries below Bear Lake may increase groundwater recharge and wetland storage with some benefits to wetland vegetation later in the season (which may mitigate some of the impacts of reduced snowpack & earlier snowmelt). (S1) Shift from wetter wetland types to more drier wetland types. Decrease in open water habitat and

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]
	a potential replacement of wetted area by emergent marsh and wet meadow (but overall wetland area will be reduced). (S1 & S2) Increased spring precipitation increases productivity in wetland plants in the spring, a benefit for spring migrant birds. But drier summer conditions are negative for fall migrants and nesting birds. (S2) Some migrating birds might be able to adapt to shifts in spring timing, but some will not. (S2)
Extent and condition of wetlands	Lower river levels and reduced groundwater inputs lead to decrease in wetland area and condition. (S1 &S2)
Water quality	Decreased water quality due to conversion from grazing to more intensive agriculture and increased fertilizer use, coupled with flashier runoff events (from feedlots and urban areas). (S1 & S2)
Invasive species	Drier spring and change from natural flow and disturbance regimes tend to favor some invasive species (e.g., cheatgrass, tamarisk). (S1 & S2) Drier spring, longer fire season will increase fire frequency, which will exacerbate spread of cheatgrass and tamarisk. (S1 & S2) Possibly more cheatgrass issues under Scenario #2 than Scenario #1 (S2).
Impoundments	Humans will be doing whatever they can to store flows (winter in S1 and spring in S2) by increasing the storage of water in existing impoundments and building new impoundments, leading to inundation and loss of existing wetlands. (S1 & S2)
Agricultural practices	Extended growing season leads to a shift in agricultural practices from grazing to alfalfa to grain or other crops that require more irrigation. (S1 & S2) Drier soils enable tilling in areas that are currently too wet to till, leading to a greater loss of wetlands. (S1 & S2)

Key Climate-Influenced Drivers/Effects	Observed & Projected Climate Change Impact[1]
Land development	Population growth is likely to be one of the biggest changes affecting wetlands. (S1 & S2) Increased risk of land development (conversion from agriculture to urban) in wetlands as they dry out (not just wetlands – all across the region). (S1 & S2) Increased urbanization will increase runoff and decrease groundwater recharge, drying out wetlands and negatively affecting water quality. (S1 & S2)
Erosion/sedimentation	Less water in oxbow wetlands lead to more cattle grazing on riverbanks resulting in increased erosion and downstream sedimentation. (S1 & S2) Decreased erosion from flash floods. (S2)
Fire	Warmer and drier conditions lead to increased fire frequency and severity in mountains and uplands in the “contributing area”, leading to increased erosion and sediment yields. Unclear impacts on hydrology and flows (e.g., mix of increased spring peak flows, flashier runoff after rainfall events, more snow reaching the ground, more snow sublimating, less snow being shaded; net effect will depend on how fires affect forest structure and herbaceous cover. (S1 & S2)

[1] Indicate Scenario the impact applies to: “S1” = Scenario #1 only, “S2” = Scenario #2 only, or “S1+S2” = both.

Appendix 8. Oxbow Wetlands Strategic Actions to Address Climate Change Impacts for Scenarios #1 and #2

Management Objective: 1) Maintain current wetland acreage and a diversity of wetland types; 2) Maintain and enhance wetlands to at least fair or good condition; 3) Maintain wetland functions including: bird and wildlife habitat, flood control, water storage, water infiltration, carbon and other nutrient sink, and connectivity for wildlife movement and ecological processes.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Strategic Actions (Planning Horizon: 2040-2060)
Hydrology: Decreased delivery of water to abandoned oxbow wetlands due to: • Decreased baseflows. (S1 & S2) • Increased downcutting, disconnecting the river from oxbow wetlands. (S1 & S2) • Decreased return flow as irrigation efficiency increases. (S1 & S2) • Dust on snow reducing water availability later in the season (S1 & S2, less in S2). • The magnifying effect of climate change on top of over-allocation of flows. (S1 & S2)	Water protection and management	• Establish water conservation laws that provide incentives for water conservation and changes in use (e.g., that provide financial incentives for users to leave some water in-stream). • Change regulations to identify instream flow as a more broad "beneficial use" than is currently recognized. • Secure instream flow water rights (this may involve policy changes since while it is possible for some entities to lease and purchase water rights under current laws, those laws could be expanded to allow more types of water rights holders). • Use clean water act and Total Maximum Daily Load regulations as tools to leverage better water management for wetlands. • Establish a conservation pool (e.g., create an "in-lake" flow right) in the Great Salt Lake to ensure sufficient flows and prevent over-allocation of water flows. Keeps water in the rivers through their whole length. • Consider using the highly managed nature of the Bear River to our advantage in providing water to oxbow wetlands – move agricultural diversions as far downstream as possible. But this might end up dewatering oxbows if you stop flood irrigation from recharging groundwater. • Find ways to move increased precipitation into the groundwater – e.g., by exploring ways to enhance infiltration, aquifer storage and recovery. • Cloud seeding to increase precipitation.

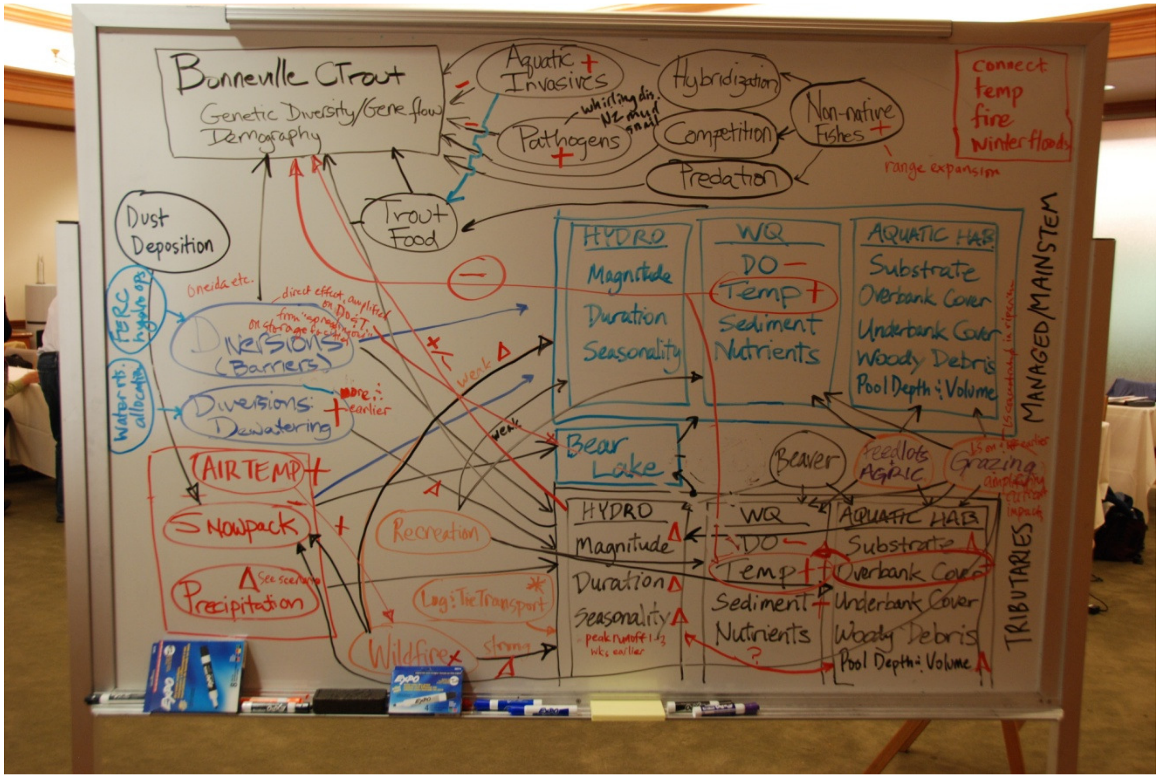
Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Strategic Actions (Planning Horizon: 2040-2060)
Land conversion: Increased risk of land development (conversion from agriculture to urban) in wetlands as they dry out (not just wetlands – all across the region). (S1 & S2)	Land protection	• Establish a Bear River land trust to hold easements, push for education on the benefits of easements to generate public support and funding, secure funding, manage some of the land and work with land owners. Ratchet up the importance of oxbow wetlands for existing land trust in Idaho. Establish a public funding mechanism/source to purchase conservation easements and water rights. Improved floodplain ordinances to assist/facilitate the work of land trust. • Invest in protecting existing wetlands through easements, land purchases, and transfer of development rights (TDR, where developers provide the funding) for the purpose of concentrating development in some areas and reducing development in sensitive areas. • Establish a wetlands mitigation bank – bring multiple owners together and provide an incentive for them to engage and make money. • Develop "best practices" for land development and wetland conservation, and work with county and city planners to influence county- and city-level land use decisions. Some useful models out there and movement in a good direction towards more planning, although varied progress on this across the region. • Improved land use planning, such as through the creation of special area management plans. • Prioritize wetlands for protection that maintain north-south and elevational connectivity, and a representative diversity of wetland types.
Hydrology (see above)	Upland vegetation and streamflow management	• Restore and maintain healthy upland watershed vegetation communities to improve watershed function & increase water retention and recharge. • Retain water higher in the watershed by ensuring healthy riparian vegetation and beaver populations (and other "natural" water retention strategies). • Stream restoration work to mitigate and prevent stream incisions and enhance

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Strategic Actions (Planning Horizon: 2040-2060)
		floodplain recharge (not through cement structures, but perhaps vegetation, woody material, and temporary dams). • Change grazing rotation and intensity to maintain healthy watershed vegetation to retain water in the system.
Changing wetland vegetation composition: Shift from wetter wetland types to more drier wetland types. (S1 & S2) Drier spring and changes in natural flow and disturbance regimes (e.g., fire) tends to favor some invasive species (e.g., cheatgrass, tamarisk). (S1 & S2)	Wetland vegetation & invasives	• Possible management of wetland vegetation as wetlands shift in species composition and from one wetland type to another – while taking measures to prevent invasive species from taking over.
Extent and condition of wetlands: Lower river levels, lower groundwater inputs, shorter flow period lead to decrease in wetland area and condition. (S1 &S2)	Wetland condition	• Improving condition of wetlands by facilitating agricultural use of Farm Bill and NRCS funding to improve wetlands. Requires match funding and getting famers on board. • Increase use of NAWCA funding to implement wetland condition improvement projects across a larger region, involving multiple stakeholders and landowners.
Impoundments: Increased water storage in existing impoundments and building new impoundments, leading to inundation and loss of existing wetlands. (S1 & S2)	Impoundments and diversions	• Identify alternatives to impoundments as "the solution" to human water needs. • Consider whether oxbow wetlands and associated aquifers can be protected as water storage systems.

Observed & Projected Climate Change Impact[1] (Hypotheses of Change)	Intervention Point[1]	Strategic Actions (Planning Horizon: 2040-2060)
All impacts	Education	• Education and marketing related to understanding and communicating the true value of wetlands (and the avoided cost of losing wetlands), and informing the agricultural community about wetland conservation incentive programs. Provides an incentive and motivation for caring about the loss of wetlands, and is necessary to encourage more dramatic changes in land use, policy, etc. • Education on climate change and local impacts so that the public cares and influence lawmakers; creative, more positive message points that educate rather than inflame.

[1]See list of Definitions in participants' packet.

Appendix 9: "Work-in-Progress" Draft Bonneville Cutthroat Trout Model



Appendix 10: Work-in-Progress Draft Wetlands Model