SOUTHWEST CLIMATE CHANGE INITIATIVE

Jemez Mountains Climate Change Adaptation Workshop: Process, Outcomes and Next Steps

April 2009

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Executive Summary

The Nature Conservancy (TNC) convened a two-day workshop on climate change adaptation in the Jemez Mountains on April 21-22, 2009 in Los Alamos, New Mexico. More than 50 representatives of state and federal agencies, tribal governments and non-governmental organizations (NGOs) participated.

The Jemez Mountains Climate Change Adaptation Workshop was the first in a series of four to be 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 and University of Washington. The goal of the SWCCI is to provide information and tools for climate change adaptation planning and implementation to conservation practitioners in the Four Corners states: Arizona, Colorado, New Mexico and Utah.

The workshop goal was to help resource managers develop strategies for helping species and ecosystems adapt to climate change, and to enhance cross-boundary collaboration using new tools and the best available climate change science. The objectives of the workshop were:

1. Provide background information on climate change and its effects in the one million-acre Jemez Mountains landscape;
2. Assess the effects of climate change on key species, ecosystems and ecological processes;
3. Using a new adaptation planning framework, identify management actions to reduce climate change impacts;
4. Identify opportunities for learning, collaboration and application of the adaptation planning process for natural resource management in the Jemez Mountains.

Over the course of two days, managers, scientists and conservation practitioners worked together to identify adaptation strategies under two climate change scenarios – one moderate, and one more extreme. Key outcomes included:

- Identification of practical adaptation strategies that can be implemented by managers now to build resiliency and conserve important resources. Participants found that many of the conservation strategies already being planned or implemented in the Jemez Mountains can be used to prepare for climate change. But, even under the more conservative of the two climate change scenarios we explored, the scale, sequencing, priority and cost of these strategies will likely need to be adjusted if management objectives are to be met.

  Priority strategies identified by the group included:

  - System-wide management planning for fire and climate change.
  - Improvement of riparian ecosystem health by fencing out elk and cattle or by reducing the landscape's elk herd.
  - Landscape-scale ecological fire management.
  - Widening the prescribed fire window (that is, expanding the suite of weather conditions under which prescribed burning can be implemented).

- Application of forest thinning prescriptions that allow for maximum infiltration of precipitation.

  Participants listed numerous actions that could be taken to carry out these strategies, and they identified both barriers to and opportunities for implementation.

- Recognition that more work is needed to develop strategies to reduce the impacts predicted for more extreme climate change scenarios. The ecological changes that could occur under these scenarios will require more intensive and extensive management intervention or perhaps even wholesale changes in management goals.

- Acknowledgement that effective communication local stakeholders and with policy makers is critical to building trust and to engaging people in the development of realistic management objectives as we face the possibility of undesired future conditions; and

- A commitment by participants to multi-jurisdictional collaboration and the development of an over-arching climate change adaptation strategy for the Jemez Mountains landscape.

Following the workshop, representatives of the Santa Fe National Forest, Valles Caldera National Preserve, Jemez Pueblo, NM Forest and Watershed Restoration Institute and TNC resolved to work together to develop an ecological restoration strategy for a 210,000-acre mixed-ownership landscape in the southwestern Jemez Mountains. Next steps for this initiative include:

- Development of a strategic landscape restoration plan.
- Preparation of a proposal to the Collaborative Forest Landscape Restoration Fund for up to $4 million annually for ecological restoration treatments on the Santa Fe National Forest and Valles Caldera National Preserve.

Recovery and resilience-building for the Jemez Mountains salamander is another center of follow-up activity from the workshop. TNC, the US Fish and Wildlife Service (USFWS) and the NM Department of Game and Fish (NMDGF) are organizing a series of workshops for early 2010 that will produce adaptive management strategies for the Jemez Mountains salamander, an endemic species that has been petitioned for federal listing and that is considered to be highly vulnerable to climate change.

Finally, the work of the Southwest Climate Change Initiative continues. In December 2009, a second climate change adaptation workshop was held for Colorado's Gunnison Basin (see http://www.nmconservation.org/projects/new_mexico_climate_change for products) , and a third is scheduled for April 2010 for the forests of northern Arizona. A fourth workshop will be held in Utah in mid-2010.

Introduction

The Nature Conservancy in New Mexico (TNC-NM), working with the USDA Forest Service, University of Arizona and Wildlife Conservation Society, convened a two-day workshop on climate change adaptation in the Jemez Mountains on April 21-22, 2009 in Los Alamos, New Mexico. (See Appendix 1 for the agenda.) More than 50 representatives of state and federal agencies, tribal governments and non-governmental organizations (NGOs) participated (Appendix 2).

The workshop goal was to help natural resource managers to identify and implement climate change adaptation strategies and to enhance multi-agency collaboration and planning using new tools and the best available climate change science. The objectives of the workshop:

5. Provide background information on climate change in the Jemez Mountains landscape;
6. Determine the effects of climate change on two target species, systems or processes;
7. Using a new adaptation planning framework, identify management actions to reduce climate change impacts;
8. Discuss opportunities for learning, collaboration and application of the adaptation planning process for natural resource management in the Jemez Mountains.

Why the Jemez Mountains?

We selected the Jemez Mountains landscape for a pilot case study workshop for a number of reasons. First, TNC-NM recently completed a statewide climate change impacts and vulnerability assessment that identified the Jemez Mountains as an area that has both a high climate change exposure (e.g., significant drying over the last 37 years due to temperature increases and precipitation decreases) and a high density of species vulnerable to climate change when compared to other regions in the state (Enquist & Gori 2008, Enquist et al. 2008).

Second, effects of climate change may already be evident in the Jemez Mountains. Recent decades have seen significant declines in snowpack, large, severe wildfires, bark beetle outbreaks, dieback in piñon and ponderosa forests, invasion by cheatgrass and population declines of sensitive high-elevation species such as the endemic Jemez Mountains salamander (*Plethodon neomexicanus*) and Goat Peak pika (*Ochotona princeps nigrescens*) (Breshears et al. 2005, New Mexico Department of Game and Fish 2006, Allen 2007).

Third, many managers in the Jemez Mountains are interested in, and have a successful history of, collaboration across land ownership boundaries. Several land managers in the Jemez Mountains participated in the TNC–sponsored Fire Learning Network in the early 2000s and, more recently, federal agencies and the Jemez Pueblo have initiated a large landscape restoration strategy in the southwestern part of this million-acre mountain range.

The Jemez Mountains Climate Change Adaptation Workshop was the first of a series of four to be organized by the Southwest Climate Change Initiative (SWCCI), a project of The Nature Conservancy and collaborators from the Wildlife Conservation Society, USDA Forest Service, University of Arizona and University of Washington. The goal of the SWCCI is to provide information and tools for climate change adaptation planning and implementation to conservation practitioners in the Four Corners states: Arizona, Colorado, New Mexico and Utah.

Workshop Outcomes

Over the course of two days, participants worked through an interactive process to identify adaptation strategies under two climate change scenarios. Key outcomes included:

- Development of conceptual ecological models for two important ecosystem processes, fire and instream flows, and the identification of management intervention points using these models. Documenting these steps in the planning framework helps managers and the public track the assumptions and logic behind specific management actions for reducing negative impacts of climate change.

- Identification of practical adaptation strategies that can be implemented by managers now to build resilience and conserve important resources. Participants found that many of the conservation strategies already being planned or implemented in the Jemez Mountains can be used to prepare for climate change. But, even under the more conservative of the two climate change scenarios we explored, the scale, sequencing, priority and cost of these strategies will very likely need to be adjusted if management objectives are to be met.

- Recognition that more work is needed to develop strategies to reduce the impacts predicted for more extreme climate change scenarios. The ecological changes that could occur under these scenarios will require more intensive and extensive management intervention or perhaps even wholesale changes in management goals.

- Acknowledgement that effective communication local stakeholders and with policy makers is critical to building trust and to engaging people in the development of realistic management objectives as we face the possibility of undesired future conditions; and

- Commitment by participants to multi-jurisdictional collaboration and the development of an over-arching climate change adaptation strategy for the Jemez Mountains landscape.

Background Information for Development of Adaptation Strategies (Workshop Plenary 1)

Introduction: concerns and uncertainties regarding climate change

The purpose of the opening plenary session was twofold: to give participants a chance to share their current thinking and concerns about climate change, and to provide foundational information that participants could apply during the adaptation planning exercise . The workshop was led by **Gregg Garfin** of the University of Arizona (UA). Dr. Garfin is an expert in Southwest climatology and is the UA's Deputy Director for Science Translation and Outreach at the Institute of the Environment. The opening session began with Garfin asking participants to identify their concerns and uncertainties regarding climate change (Box 1). Participant responses were diverse but consistent with the concerns natural resource managers are expressing throughout the United States (US Government Accountability Office 2007).

Presentations: climate change in the Jemez Mountains

Following this session, a series of introductory presentations were given by locally-based experts on the evidence for climate change in and around the Jemez Mountains landscape.

Craig Allen, Research Ecologist with the US Geological Survey Jemez Mountains Field Station, provided the rationale for the workshop in his first presentation, *Warming Together and Working Together Warmly in the Jemez Mountains*. Key points:

- Irrespective of the specific climate scenario or model, the Jemez Mountains are going to get warmer and landscapes will be under increasing stress.
- Despite these changes, there are things that managers can do, including protecting key ecosystem features and processes, reducing anthropogenic stressors, and increasing collaboration and coordination across the Jemez landscape.
- Managers must recognize that changes are occurring and anticipate future changes, e.g., "skate to where the puck is going, not to where it's been (Wayne Gretzky)." Several resources can help managers address climate change (*cf.* Appendix 8).

Box. 1. Opening session break-out groups responses to the question: *"What is your greatest uncertainty, or management challenge, relative to climate change?"*

How to prepare for:

- Changes in precipitation and run-off patterns
- Longer periods of fire danger
- Movement/change in habitat & endangered species

How to anticipate and understand:

- Ecosystem response at landscape scale
- Non-linearities, episodic events and their effects on species/systems
- Phenology changes in species and their cascading ecological effects
- Impacts of renewable energy on species and systems

Concerns related to the ability to manage:

- What if we make the wrong decision?
- How do we meet multiple management goals—sequestration plus other forest health goals?
- Will management change be adequate to keep pace with rate & magnitude of climate change?
- Can agencies work together?

Todd Ringler, Research Scientist and climate modeler at Los Alamos National Lab (LANL), gave an overview of regional climate change impacts—*The Known, the Unknown, and the Uncertain*. Key points:

- Scientists cannot explain current warming without including increasing CO_2 concentrations, which are rising at unprecedented levels.
- The best use of climate change simulation data is to generate climate scenarios; these data should be used for insights, not answers, because of model uncertainties.
- Planning for climate change is a century-long exercise and managers should think in terms of 10-year planning increments in order to adapt to changing information. Also, managers should plan (and manage) for the high-end estimate of change (e.g., 5^{o}C increase, 25% less precipitation & episodic drought) because it is now apparent that the current "worst case" projections are under-predicting the climatological effects of increases in greenhouse gas concentrations.

- There are still climate “wildcards” that increase the uncertainty of models and simulation data: (1) potential changes in El Niño-Southern Oscillation (ENSO) effects; and (2) changes in the North American summer monsoon system which is currently too difficult to model due to regional feedbacks from large land masses. The largest source of model uncertainty is what choices society will make regarding our energy future.
- Given uncertainty, managers should look for win-win strategies, e.g., climate adaptation practices that meet additional resource objectives. Our understanding of climate change will evolve, so managers should build flexible adaptation plans and “monitor, monitor, monitor.”

Bob Parmenter, Chief Scientist at the Valles Caldera National Preserve (VCNP), gave an overview of the ecological trends and consequences of climate change in the Jemez Mountains landscape, focusing on water processes and management in the Jemez River watershed. Key points:

- Over the last 100 years, mean annual temperature has increased, with summer temperatures rising twice as rapidly as those in winter (about 4ºF warmer); precipitation has only decreased slightly over this period.
- Stream gage data since 1972 show a 40% decrease in Jemez River stream flow; this may be due to climate change and/or other factors, e.g., Pacific Decadal Oscillation, growth of dense tree stands following logging and fire suppression.
- Thinning treatments can assist with snowpack management and affect water availability. Research has shown that thinning forests to 20-50% canopy cover can maximize snowpack on the ground, reducing sublimation, and provide sufficient shade to delay spring melt, increasing snowpack water storage. These actions can also reduce fire risk and increase forage for wildlife and livestock.
- Diminishing snowpack reduces aquatic habitat for fish and other aquatic species and will affect elk distribution and herbivory impacts. Elk will migrate to new areas if the snow depth exceeds 21 cm, whereas, if the area receives less they will stay and browse extensively on a suite of species. To study this and other climate change effects, the VCNP is monitoring at numerous sites across the Preserve.

Craig Allen’s second presentation**,** *Implications of Climate Change for Jemez Mountains Ecosystems*, focused on disturbance processes and feedback in the Jemez landscape. Key points:

- Significant climate-induced changes have occurred in the region, including recent die-off events of piñon, especially severe in the Jemez, of Douglas-fir at higher elevations; and of piñon and ponderosa pine on more than 2 million acres in the Four Corners states.
- Increased beetle infestations, resulting from drought stress, have been reported for several tree species and in locales throughout the West. Predicting these mortality events is not yet possible because threshold conditions for precipitation and temperature that lead to tree death are unknown.
- Increased fire intensity and extent and longer fire seasons are predicted as forest dieback expands in the future. However, there are some confounding factors in this scenario. For example, as dieback progresses and needles fall, reducing tree flammability, crown fires may decrease and surface fire may increase with the added fuels. As areas become more arid, reduced cover and less frequent fire co-occur with increased erosion. Interactions between

climate, dieback, insects, fire and soil erosion can amplify individual disturbance processes; predicted climate changes could accelerate these processes.
- Climate is an important driver of elk distribution. During the 1996 drought, elk stayed at higher elevations where they browsed on aspen saplings, greatly reducing their recruitment after the high-severity Dome fire of April 1996. Climate-induced changes like these cross jurisdictional lines and require cross-boundary collaboration and management.

Panel Discussion: climate change and adaptation initiatives at the state and federal levels
Toward the end of the morning plenary session, agency representatives were asked to give three minute overviews of what their organizations are doing to address climate change. Panelists included **Bob Davis** (US Forest Service Southwest Region), **Mary Stuever** (NM State Forestry), **Bob Parmenter** (Valles Caldera National Preserve), **Mima Falk** (US Fish and Wildlife Service), **Matt Wunder** (NM Department of Game and Fish), and **Craig Allen** (US Geological Survey and National Park Service, Bandelier National Monument).

Carolyn Enquist of The Nature Conservancy in New Mexico (TNC-NM) gave a lunchtime presentation on the Southwest Climate Change Initiative (SWCCI). Key points:

- An October 2007 climate change workshop for New Mexico natural resource managers (jointly sponsored TNC-NM and the University of Arizona) provided the motivation for a state-wide climate change assessment, completed in 2008.
- TNC-NM's Climate Change Ecology and Adaptation Project addressed climate change using a four-part framework: (1) development of a regional climate impacts assessment, (2) generation of hypotheses of vulnerability for priority conservation areas, (3) climate change adaptation planning in high priority landscapes (such as the Jemez Mountains), and (4) development and application of additional tools as they become available to ensure the project remains dynamic and relevant to stakeholders.
- We have now expanded this strategy to the remaining states in the Four Corners region (Colorado, Arizona, Utah) through the SWCCI.
- SWCCI's specific objectives:

    1. Assess and map the exposure of natural areas in the Four Corners states – Arizona, Colorado, New Mexico and Utah – to past and projected future climate change.
    2. Identify vulnerable landscapes, watersheds, habitats, and species.
    3. At one case study landscape in each of the four states, build understanding of how climate change may affect ecosystems, and identify strategies that natural resource managers can use to prepare for and adapt to climate change.
    4. Use the lessons learned at each workshop to refine and improve an adaptation planning framework that can be applied to many other landscapes in the southwestern U.S.

Introduction to Adaptation Planning (Workshop Plenary 2)

Molly Cross, Climate Change Scientist at the Wildlife Conservation Society (WCS), provided an overview of climate change adaptation concepts and approaches including a new adaptation planning framework in her presentation, *Planning for Conservation and Management as Climate Changes*. Key points:

● General principles of adaptation and approaches to reframing management goals such as the "5Rs+1" (Box 2) are useful at a conceptual level, but more specific solutions are needed by managers working at landscape and site levels; the lack of specific direction is causing *uncertainty paralysis*, preventing managers from taking action in the near term.

● The Wildlife Conservation Society and the National Center for Ecological Analysis & Synthesis (WCS-NCEAS), working closely with a group of scientists and managers from multiple institutions and agencies, have developed an adaptation planning 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, participatory process (Cross et al. *in review*). The identified actions are then evaluated for social, political, regulatory and economic feasibility. The adaptation planning process is iterative; assists in identifying research and monitoring needs; identifies management actions that can be implemented immediately; and documents assumptions and logic, helping the public understand why particular management actions are proposed in a landscape. A more detailed description of the framework follows.

Box 2. General concepts for thinking about climate change adaptation and natural resource management.

The "5-R's + 1" Framework (adapted from Millar et al. 2007):

- Resistance – hold back the tide
- Resilience – decrease stressors
- Response – conserve for all extremes
- Realign – conserve for new reality
- Reduce – mitigate greenhouse gases
- Triage – prioritize action (medical triage = address the most sick first; military triage = address those that are most likely to get back onto the battlefield).

Question: Will promoting resistance and resilience be feasible in light of the magnitude of projected changes?

General Principles of Adaptation (adapted from Glick et al. 2009):

- Reduce non-climate stressors
- Manage for ecological function and protection of biodiversity
- Establish buffer zones and connectivity
- Implement proactive strategies
- Increase monitoring

Challenges: How to deal with complexity and uncertainty? How do principles, concepts apply to particular systems?

Implementation of the WCS-NCEAS Adaptation Planning Framework

Application of the *planning phase* of the framework involves five steps (Fig. 1). The **first** is to identify a conservation target. A target can be a species, an ecological process, or a plant or aquatic community. Management objectives for each target should also be identified. The **second** step is for the planning team to build a conceptual model that illustrates how different climatic, ecological, social, and economic drivers affect the target and each other. The team then examines how the target and its drivers may be affected by plausible climate change scenarios; driver influence may increase or decrease under a particular scenario. If more than one scenario is examined, the direction of change or the relative importance of drivers may change. Step **three** is to look at the model and find the management intervention points (the points in the system that management actions can influence) and the potential actions at these intervention points that will be required to achieve management objectives for the target under the different climate change scenarios. Once strategies are identified, step **four** is to evaluate their feasibility and potential tradeoffs, and then prioritize them for implementation.

Once a suite of adaptation strategies has been developed in the *planning phase*, managers are advised as part of the framework to conduct an *implementation and efficacy evaluation phase*. In this phase, practitioners: (1) develop an action plan that incorporates the strategies developed in the planning phase; (2) implement the prioritized actions; and (3) monitor and evaluate the efficacy of the actions implemented.

For the purposes of this workshop, breakout groups focused on completing the first four steps of the *planning phase*. Workshop facilitators divided the participants into two groups, each with a different target: **(1) fire process** and **(2) water process,** specifically instream flows and watershed function. Targets were selected prior to the workshop through a participant survey.

Climate Scenarios for the Jemez Mountains

To guide our discussions of the impacts of climate change and potential adaptation strategies, Los Alamos National Laboratory's Todd Ringler presented two climate change scenarios:

1. Increases in mean annual temperature between 2-4°C with increased drying, on average, and periodic extreme events in the first half of the century; precipitation reduced but skewed toward fewer larger events. *Planning horizon: 10-30 years with focus on resilience-building management strategies, (i.e., "managing for resilience").*

2. Increases in mean annual temperature between 2-6°C with increased drying, on average, and increased frequency of extreme events (e.g., episodic "mega" drought) by mid-century; note that drought has been a natural part of the SW for thousands of years. (For Scenario #2, think Scenario #1's general temperature range but with only 67% of its precipitation). *Planning horizon is 30+ years with focus on response and/or realignment management strategies (i.e., "managing for change").*

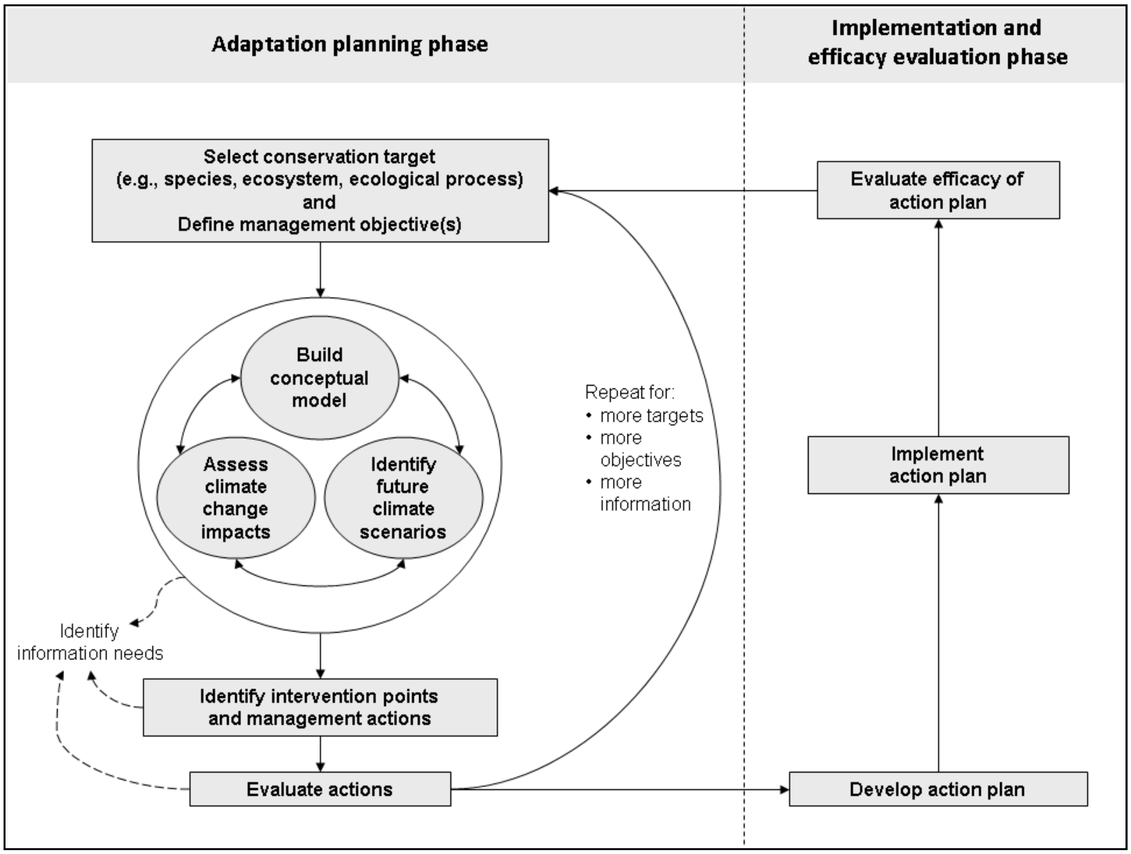


Figure 1. Cross et al.'s (*in review*) iterative climate change adaptation framework for natural resource management and conservation. The left side represents the adaptation planning phase; the right side represents the action plan implementation.

Climate Change Adaptation Strategies for Fire as an Ecological Process (Break-out Session 1)

Defining a Management Objective

Facilitated by Gregg Garfin and Carolyn Enquist, the Fire break-out group consisted of 33 workshop participants, most of whom have considerable expertise in the use of fire as a management tool in the Jemez Mountains landscape. The first activity was a brainstorming exercise to identify a management objective specific to the target (fire) to further focus the adaptation planning process. The group selected the following objective:

> "*Increase the resilience to climate change by maintaining or restoring heterogeneous forest structure and processes, especially fire, across the Jemez landscape*."

Other brainstormed objectives included:

- Manage forest structure to improve retention of water and snowpack
- Conserve resilient populations of all native species
- Soil retention

- Maintain health and safety of human communities
- Restoring heterogeneity of fire processes

Questions that were raised during the discussion of objectives went to the heart of the matter regarding restoration vs. creating forests resilient to climate change impacts.

Key question: *Do we want to restore to historical conditions in light of future climate change conditions? Related questions:*

- *How do we measure effects and the appropriateness of our actions?*
- *There are a set of species that evolved in "historic" conditions –to retain them do we restore to those conditions?*
- *Are our existing reference conditions for planning an appropriate guide given the expected climate conditions?*

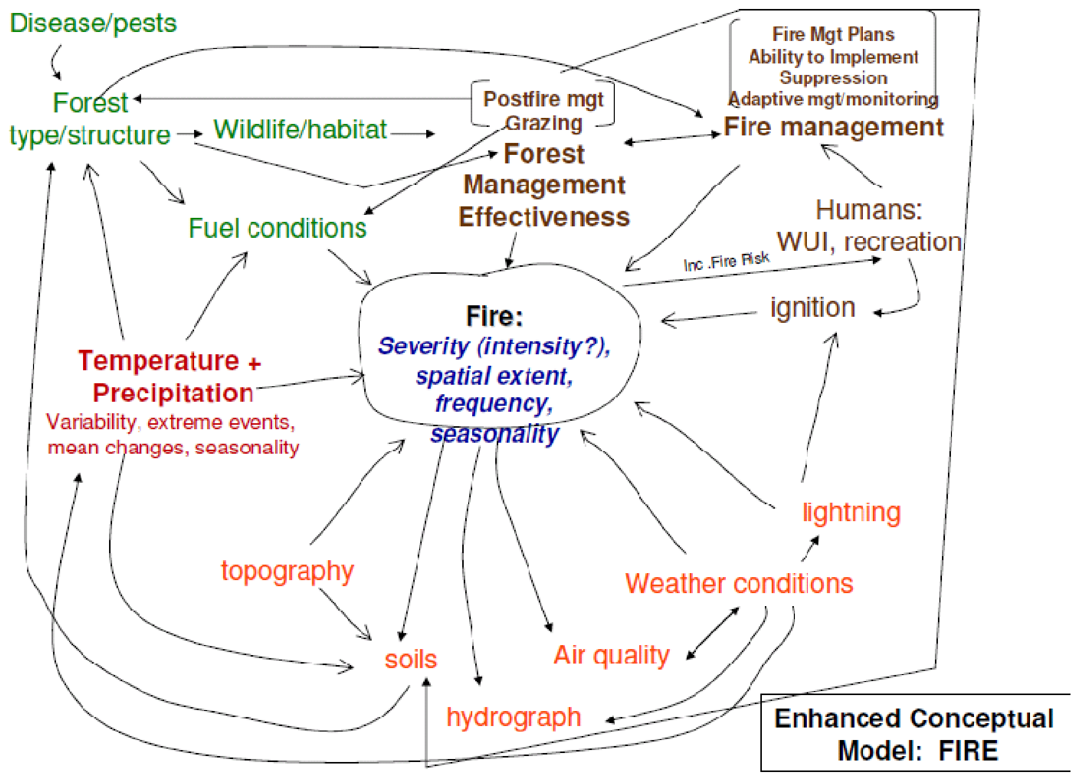
Conceptual Model Development & Impacts Assessment

Participants developed a simple conceptual model of the fire process by identifying the most important direct and indirect ecological, climatic, social and economic drivers in the Jemez Mountains (Fig. 2). The group then looked at the drivers and assessed potential changes likely under the different climate change scenarios. As an example, expected impacts driven by the changes in temperature and precipitation included increased intensity and frequency, greater spatial extent, of fires due to longer fire season, with an expectation that fires would start earlier in the year. Other observed and predicted impacts of climate change and are summarized in Box 3. The fire group next attempted to identify intervention points in the system model where management actions could be taken to lessen potentially negative effects and increase the likelihood of achieving the overall management objective. Although they initially found this step to be difficult, each participant subsequently had the opportunity to describe a management approach currently employed –or an approach that could be better applied—to manage fire relative to the impacts of climate change.

Management Intervention Points & Adaptation Strategies

As a result of this exercise, facilitators were able to group these approaches into a thematic list of overall management intervention points, ranging from wildlife, forest and fire management to agency policy and public outreach and communications. These intervention points then were incorporated as rows in a matrix designed to guide the next step of brainstorming specific management actions, or adaptation strategies, relative to the two climate change scenarios (Appendix 3).

Figure 2. Conceptual model of the ecological process of fire in the Jemez Mountains. Participants were asked to identify direct and indirect drivers to system: physical (red), ecological (green), social & management factors (brown). Direct effects to the target are in blue.



Scenario #1—"Managing for resilience"

Overall, adaptation strategies identified under Scenario #1 resembled many of the strategies already used by managers. What was different about these, however, was discussion regarding *when and how* strategies might be applied. For example, given the anticipated warming and drying earlier in springtime, prescribed burns might take place earlier in the season. Thinning treatments could be designed to leave a greater diversity of trees, and/or provide more shade. Bark beetle mitigation to prevent build up should also be considered in the timing of thinning treatments. The lack of markets for small diameter wood and biomass was a concern shared by many participants, since thinning large acreages without market incentives is prohibitively expensive. Another participant observed that within large fire areas, there are often islands of vegetation that survive. These can serve as refugia protected from subsequent fires by the burned areas around them. These areas could be a priority for preservation as refugia for species. Grazing and browsing, particularly by elk were discussed as an important interactive process that, by limiting vegetative re-growth, could exacerbate climate-induced impacts on vegetation. As a practical response to elk migration into burned areas, the group concluded that a relevant strategy was to create migration barriers with fences and fallen trees, especially in critical riparian areas. Perhaps most importantly, participants conveyed a renewed sense of urgency for implementing many of these conventional, yet potentially effective, adaptation strategies.

Scenario #2—"Managing for change"

Participants were more challenged by attempting to brainstorm strategies for the extreme Scenario #2, but discussion did provoke some participants to consider ideas not yet part of their normal management. These included assisted migration and using new species mixes during post-fire planting to facilitate revegetation or to prepare to accept, landscape "realignment," or vegetative type conversion. Monitoring work has been going on in the Jemez since the catastrophic Cerro Grande fire of 2000. Lessons learned from this work suggests that the dominant life form of the future may well be the clonal resprouting shrub; if this is true, how do we better manage post-fire treatments? Some suggest that pouring lots of grass seed is pre-empting succession and that this typically involves introducing weed species. A participant also observed that the more successful these grass treatments are, the poorer the tree species regeneration tends to be. This led to the conclusion that there may be a real need to change current BAER prescriptions. There was also agreement that the Jemez will be in for an all-out landscape realignment if the north slopes are forested but everything else is shrub-dominated.

Box 3. Observed and predicted climate change impacts (direct & indirect) in the Jemez Mountains.

1. Increased drought episodes
2. Snowpack reduction
3. More rain than snow during the winter
4. Earlier timing peak stream flows
5. Floods more frequent & intense (flashier streams)
6. Extreme erosion post-fire due to decreased surface cover & infiltration
7. Increased stream temperatures and post-fire ash deposition affecting habitat of native and stocked aquatic species
8. Increased bark beetle outbreaks
9. Broad scale forest mortality
10. Ecosystem shifts (e.g., type conversions)
11. Species unable to respond to rapid habitat shifts
12. Increased fire frequency, size, severity
13. Fire season earlier & longer
14. Disturbance and ecosystem changes leading to genetic isolation of endangered species populations
15. Intensified browsing and disturbance by elk as vegetation food sources (e.g., aspen) become more stressed especially those at limits of distribution
16. Abrupt, non-linear ecosystem and ecological process changes more likely
17. Traditional uses of plant species compromised
18. Recreational uses of forest reduced; loss

Discussion

The discussion of ecological realignment provided a segue into a discussion of eventual political and agency realignment, with participants noting that, with the shifting of habitat boundaries, a shift in jurisdictional boundaries may come as well. The need for more socio-ecological adaptation became a predominant discussion item at this point, with observed complications arising from growing wildland-urban interface (WUI) issues. For example, because human-caused ignitions are a large problem in the Jemez, managers may need to revise agency Travel Management policy and close more back roads. However, it was pointed out that some balance may be required so as to not cut off all backcountry access to humans. Cutting off vehicle access could exacerbate the increasing disconnect people feel with the natural world.

To capture the barriers to successful implementation of adaptation strategies, facilitators documented these in Appendix 3 (*cf.* column 3). Participants also discussed the possible prohibition of fire insurance, required use of fire-wise prescriptions around homes, and banning of certain activities (e.g. OHV use). However, it was largely agreed that enforcement of new restrictions is problematic and that more public outreach and education is needed, including identifying better zoning and building codes. Lack of communication has led to a situation where the public typically perceives that humans can control fire. Many of the points raised led to participants pointing out that there is a need for better visualization tools for the public and managers alike. Examples included the expected change to a drier ecosystem – e.g., the Chihuahuan Desert pushing northward – as well as more information to share with the public to help them realize the cost-benefit of proposed mitigation strategies

Overall, key *barriers* identified included *uncertainty, as discussed during the opening session of the workshop, lack of coordination between agencies and programs, and lack of dedicated funding resources*. This included the current constraints for agency resource management created by over-allocating funding to single activities, such as fire fighting to protect structures in the WUI. A positive development was noted by many participants on this front: New Mexico State Forestry has helped the Forest Service move away from some WUI-related activities by creating major funding incentives for landowners to treat WUI acres under their new Fire Management Plan.

A final question raised during this session was whether it is even worth taking management actions to combat the effects of climate change if the root cause is unconstrained CO_2 emissions. While Todd Ringler noted that if all emissions were stopped today (we have only committed about 1ºC of warming to the system), warming just may stop –depending on lag times. What we don't know is how close we are to tipping points and feedbacks with their resultant non-linear effects in the climate system. For example, we don't know when we might experience a dramatic release of methane currently tied up in the arctic tundra, or when the oceans will no longer be able to absorb vast quantities of CO_2. These are the kinds of complexities that challenge climate model development –and probably always will. Participants seemed to overwhelmingly agree that it we should maximize the potential to reach management goals by taking immediate action concurrently with policy-makers' work to reduce emissions.

Climate Change Adaptation Strategies for Water (Hydrologic Regime) as an Ecological Process (Breakout Session 2)

Defining a Management Objective

Facilitated by Molly Cross and Dave Gori, the water breakout group consisted of 17 workshop participants, many of whom were either aquatic specialists or who had expertise in the hydrology of the Jemez Mountains landscape. Following the steps laid out in the WCS/NCEAS planning framework, the first group activity was to brainstorm management objectives for the target and select one to inform the adaptation planning process. The group ultimately selected the objective: *"Maintain sufficient water in the system to support aquatic species and riparian vegetation."*

Other proposed objectives, not selected, were:

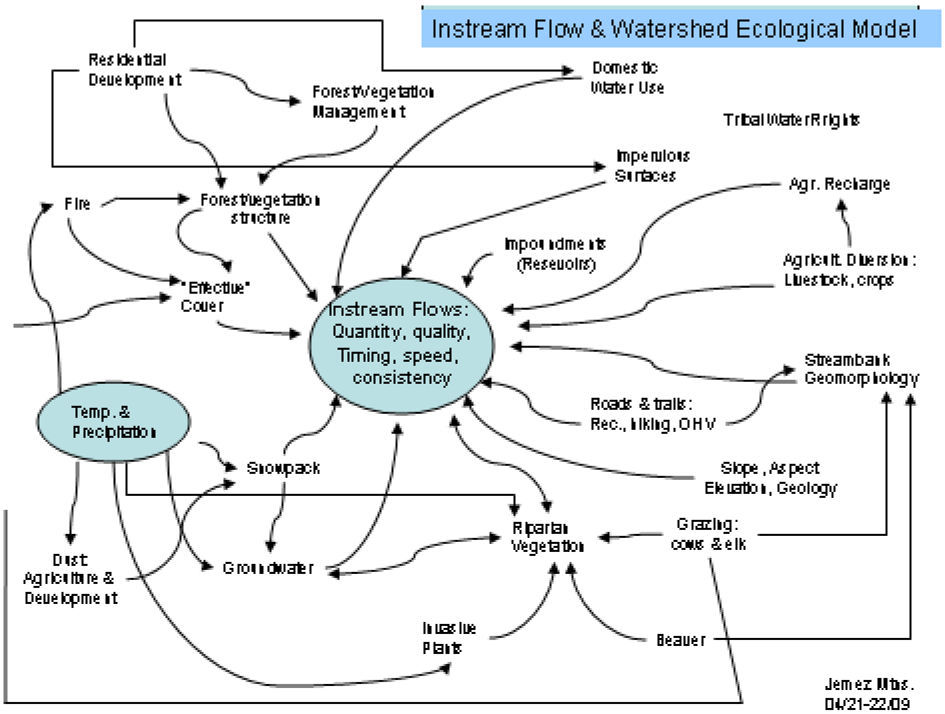
- *Maintain water quality*
- *Maintain water quantity*
- *Maintain flows for fish and wildlife needs*
- *Maintain integrity of springs and artesian systems* (e.g., wildlife use will concentrate at reliable water sources while human demands to develop/divert springs may increase)
- *Maintain wet meadows and wetlands*
- *Minimize introduction and expansion of non-native species* (e.g., rainbow, brown trout)
- *Maintain groundwater recharge* (80% of all NM groundwater originates from a small number of montane systems like the Jemez Mountains)
- *Maintain riparian communities*
- *Maintain watershed condition and function*
- *Minimize movement of soil and sediment*

Conceptual Model Development and Impacts Assessment

Participants developed a conceptual model for the target by identifying the most important direct and indirect ecological, climatic, social and economic drivers to instream flow processes in the Jemez River (Fig. 3). Flow components important for riparian and aquatic species and that are likely to be affected by temperature and precipitation changes include: water quantity, quality and the timing, speed and consistency of stream flows. Speed, here, refers to the timing and magnitude of runoff following precipitation events (rain, snow); together these flow components describe the stream's hydrograph.

Once the conceptual system model was built, participants discussed its applicability to other perennial, intermittent and ephemeral streams in the Jemez Mountains landscape; considering flow properties of these latter streams and the watershed processes that give rise to them, they concluded that the model was broadly applicable across stream types. The majority of perennial streams are located on the west slopes of the Jemez Mountains, most streams in the Valles Caldera are perennial, and 95% of streams on the east side are intermittent. These differences are related to local, subsurface geology.

Figure 3. Conceptual model of the process of in stream flows and watershed function in the Jemez Mountains. Direct climate effects to the target are in blue.



Box 4. Observed and predicted climate change impacts (direct & indirect) in the Jemez Mountains for related to in stream flows and watershed function.

1. Decreases in snowpack – increased rain on snow, increased rain to snow ratio
2. Changes in timing of snow – later first snowfall and earlier last snowfall, longer fire season
3. Earlier snowmelt and earlier peak runoff
4. Fewer storms, but more extreme events; increased variability in precipitation and flows
5. Increased sublimation of snowpack due to higher temperatures and less frequent storm events
6. Decrease in peak flow amount
7. Warmer water temperatures
8. Lower base flows (more variable flows)
9. Perennial streams: more will become intermittent – affect riparian communities
10. Intermittent streams: period of drying will increase, some will cease to flow, becoming ephemeral
11. Mixed effects on groundwater: if more winter precipitation falls as rain & magnitude of events increases, greater groundwater recharge may result; 50% of snowpack now lost to sublimation
12. Direct impact of temperature on forest structure (dieback)
13. Insects change forest structure, impact of insects may decrease following dieback
14. More fire, altered vegetation cover & structure, altered "effective cover", greater erosion & sedimentation (near term); "effective cover" may increase w/ reduced competition (long term)
15. Changes in riparian tree/plant composition & density; reduced flooding, dropping water tables, non-native riparian species move in
16. Increased water demand from agriculture & for domestic uses – increased groundwater/surface withdrawals; reduced flows
17. Impervious surfaces generally increasing; decrease water quality, increased water quantity
18. Increased recreation demand and impacts
19. Warmer temperatures increase desertification (bare ground) & dust – decreased snowpack

Using the two climate change scenarios presented in the plenary session as a guide, participants identified observed and predicted impacts of climate change (Box 4). They discussed how the drivers of the modeled system could be affected by these impacts and how these, in turn, may affect instream flows. For example, under Scenario #1, perennial streams/springs will likely experience lower flows due to reduced snowpack, earlier and lower peak flows, and higher evaporation rates. Some perennial streams will become intermittent, while intermittent streams will experience longer dry periods with some becoming ephemeral (e.g., flows occur only during runoff events). These changes were observed during the 1950s and recent (2002-2003) droughts. The form of intermittency, that is, the magnitude of flow when a spring/stream is wet and the duration of flow, is important in determining the ecological consequences of climate-induced changes in hydrology. Species that need flowing water may have the ability to sustain themselves in intermittent reaches as long as some critical threshold is not crossed. That is, spring-fed streams may lose some aquatic invertebrate species if they cannot complete their life-cycle or disperse before the stream goes dry while other species will persist because they have faster life cycles or are better at dispersing.

As another example of climate change impacts on instream flows *vis-à-vis* modeled drivers, the group identified more frequent fires and insect outbreaks as likely outcomes under Scenario #1. These disturbances would reduce the density and cover of trees and herbaceous vegetation in the watershed in the short term, resulting in more frequent, high intensity floods, greater erosion within the floodplain and greater sediment loads in streams due to increased soil erosion in the watershed. In the long-term, however, the reduced competition with overstory trees may result in increased herbaceous or "effective" cover in the watershed which may increase infiltration and enhance stream base flows.

The group noted that the type of drought will influence its ecological effects. For example, if drought occurs due to reduced winter precipitation, this will have a greater impact on trees, whereas if drought occurs because of a failure in monsoon (summer) precipitation, then grasses will decline.

Other shifts in species composition are also likely. For example, participants expected changes from C_3 to C_4 plant types (i.e., water use efficiency of plants will increase) and a shift from spring to summer grasses and forbs. In addition, low flows are likely to increase solute concentrations and salts in pools with variable, species-specific effects on fish and aquatic invertebrates. Furthermore, warmer water with increased turbidity and lower dissolved O_2 concentrations will favor fish species that are more tolerant of these conditions. Fish species tolerant of higher water temperatures already occur in Jemez stream systems and will likely increase in abundance, e.g., brown and rainbow trout (exotics), Rio Grande chub, razorback sucker (natives), resulting in a change in fish species composition.

Management Intervention Points and Adaptation Strategies
Using the conceptual model as a guide, participants selected management intervention points. These included forest/vegetation management, invasive riparian species management, grazing management, recreation-transportation management (roads, trails), fire management, snowpack management, and agriculture diversions and domestic uses (Appendix 4).

Since instream flows are ultimately a function of water going into and out of the system, participants suggested that there are two overarching strategies for intervention: 1) reduce diversion and withdrawals and 2) increase infiltration. Given that the diversion issue and water rights are 100-year old concepts and unsustainable under climate change, it's possible that the current view and laws surrounding water rights will be revised through the political or judicial process (as has occurred in Australia in the face of ongoing climate change). However, land managers have little direct control over this process, so participants focused on identifying strategies designed to increase infiltration.

Scenario #1--"Managing for resilience"
Overall, adaptation strategies identified under Scenario #1 resembled many of the strategies already used by managers (Appendix 4). Participants acknowledged, however, that in order to address climate change impacts at scale, these actions would need to be implemented over a much greater area and, in some cases, in different locations than they are currently to have the greatest impact on instream flows. These strategies include thinning treatments in both the watershed and in riparian areas and the removal of invasive riparian species as mechanisms to increase water infiltration. For example, recent studies conducted by University of Arizona researchers showed that thinning trees to a canopy cover of 25-50% in Ponderosa pine and mixed conifer forests increased the amount of snow on the ground and provided sufficient shade to maximize snowpack retention and minimize evaporative/sublimation losses. This thinning treatment can also increase the amount of herbaceous vegetation or "effective cover" and reduce the risk of high-intensity, stand-replacing fire which together will increase infiltration and reduce soil erosion and sediment input into streams. Thinning around springs may help to increase flows and retain it in surface channels, instead of trees transpiring it. The group also discussed the use of artificial snow fences, agreeing that they could potentially work along roads. However, there was consensus that more experimentation would be required, including the potential use and effectiveness of live vegetation fences.

Other existing management strategies were also discussed as possible responses to Scenario #1. For example, as a component of riparian vegetation management, planting shade species (e.g., willows) may help to cool stream temperatures and increase recharge during floods—although this may be at the expense of increased evapotranspiration by trees. Similarly, reducing the stocking rate and duration of use by livestock in riparian areas will permit native vegetation to re-establish naturally. For example, at the Vales Caldera National Preserve (VCNP), livestock were removed during the 2002-2003 drought and riparian vegetation increased, resulting in a narrowing and deepening of the stream channel as the colonizing vegetation interacted with flood events. Water temperatures have decreased in these areas by as much as 1ºC in 5 years. Reducing elk use of riparian areas through fencing or emulating the large predator-fear response using trained dogs would have similar effects on stream channel morphology, groundwater recharge, water depth and temperature. Finally, improved management of beavers could increase the number of dams, slowing down stream flows, impounding and spreading water across the floodplain, and thereby increasing infiltration. See Appendix 4 for other management actions identified under Scenario #1.

Scenario #2—"Managing for change"
Before attempting to identify adaptation strategies for Scenario #2, the water group discussed the consequences of intensified "mega-drought" cycles. Extreme impacts would include the drying of intermittent streams and some perennial springs and streams; the collapse of marginal agricultural land; riparian vegetation die-off as the water table decreases below root level;

reduced flooding and nutrient inputs, changing riparian processes and function; stream channel down-cutting due to reduced riparian vegetation and infrequent, high-energy flood events; type conversion to grassland and scrubland in the watershed due to fires, insect outbreaks; and frequent fires with more fires on the west side of Jemez Mountains as it becomes drier (although fires frequency may ultimately decline as drought restricts fuels).

The group acknowledged that many of the management actions identified in Scenario #1 could also be applied in Scenario #2 (Appendix 4). However, mega-drought cycles could result in the loss of vegetation structure on the landscape as a result of drought, fire and insects which will require managers to construct or use mechanical features to compensate for this loss. For example, if there is insufficient riparian vegetation to reduce flow velocity during large floods, mechanical structures such as check dams and water catchments can be constructed to slow flows down and encourage infiltration/recharge. In the watershed, mechanical lop and scatter and slash treatments in woodlands can provide interim “effective” cover. Woodlands have a lot of exposed soil that is vulnerable to erosion during summer storm events. When these treatments were applied to dieback areas in Bandelier National Monument, grass cover increased and soil erosion was reduced within a season or two following treatment. Other strategies discussed by the group included post-fire planting with native species from lower elevations and from further south, places that already experience warmer summers, less precipitation and longer growing seasons.

Participants also noted the need for a contingency plan when faced with a severe drought. For example, an inventory of springs and perennial stream segments for each management unit that identifies likely spring/stream refugia could help with prioritizing areas for enhanced management. Aquatic habitats could be engineered in these refugia so that the full array of microhabitats is present to sustain riparian and aquatic species; water could be pumped from the lower end of these springs and stream reaches up to augment flow at the top. Design and planning for these sorts of actions should be done in advance (NEPA-cleared) so that plans and strategies are in place when they are most needed. In addition, the contingency plan should identify critical thresholds or trigger points to indicate when the plan should be implemented.

Additional contingency plans could be focused on other management intervention points, for example, grazing management with trigger points articulated for when to remove livestock from the landscape or when to allocate additional resources for elk fencing or reducing elk herds. On a broader level, participants recognized the importance of policy-related actions to limit and renegotiate water diversions and domestic water use as well as the need to enact conservation measures that could relieve some of the demand on upland systems to provide water (e.g., cisterns, water catchments, etc.).

Adaptation Planning: Wrap-up

Discussion and Synthesis of Fire and Water Breakout Group Sessions

The two breakout groups re-convened in plenary to discuss management strategies. The groups had identified several shared or overlapping strategies, including changes in grazing management for livestock, and elk and fuel treatments (thinning, prescribed burning) to reduce disease/pest outbreaks and the risk of high-intensity, stand replacing fires (Appendices 3, 4). Many of the strategies discussed in both breakout groups are in line with existing best practices for natural resource management, but participants acknowledged that the scale of actions would need to be expanded, placement of treatments would need to be re-prioritized, and that management actions should be approached with a greater sense of urgency. Overall, a renewed commitment to best practices was strongly recommended. This was particularly true for strategies identified under Scenario #1. Alternatively, participants acknowledged that more time and thought could be put into strategies under Scenario #2. The adaptation planning process for Scenario #2 process should engage the public and other stakeholders to inform them about the undesired conditions associated with this more extreme scenario and the potential need for more intensive management intervention. Participants agreed that better visualization tools would greatly facilitate such communications efforts and that a continued commitment to monitoring would provide important baseline information for understanding ongoing climate change effects.

Pitfalls associated with identified adaptation strategies were noted. For example, some participants mentioned potential negative feedbacks resulting from management actions, where an action may benefit one focal target but inadvertently have negative consequences on another management priority. Further, an action could have positive effects in the short-term but negative effects in the long run. As a result, it will be important to consider potential feedbacks and synergies between objectives and to identify trade-offs. A few additional suggestions were made regarding the breakout groups' approaches to identifying strategies. For example, the fire group could have focused more on strategies involving water availability. Although fisheries, snowpack, and riparian issues were briefly touched on in the fire group, the group did defer to the water group noting that watershed hydrological processes are inextricably linked to fire. Finally, many participants stressed that managers need to be sure in the near term, through monitoring, that current management actions are actually effective at building ecological resilience. Otherwise, we may be faced with even greater negative consequences in the future.

Barriers & Opportunities to Implementing Adaptation Strategies

Facilitator Gregg Garfin reviewed the combined list of adaptation strategies created by the fire and water breakout groups. He directed small groups of participants to select one of the strategies and document current barriers to their effective implementation. Once barriers were listed, the small groups developed proposals for overcoming them and identified logical next steps (Appendix 5). Several common themes emerged from this exercise. For example, public and stakeholder perception that climate change is not occurring and that projected impacts will be small was identified as a major barrier to implementing many of the highest-priority adaptation strategies. Participants also felt that the lack of funding, cross-jurisdictional coordination (e.g., different agencies have different goals) and consensus on priority actions, largely stemming from uncertainty, greatly hindered their ability to implement strategies. Another example of a strategy and a barrier is to broaden fire prescriptions and expand the prescribed burning "window" in order to significantly increase the use of prescribed burning to reduce the risk of large, severe fires (which are expected to increase in frequency as the climate warms). However, social constraints, such as liability and safety, will likely keep the prescribed burning window from broadening in the near-term.

In spite of these sizeable and very real hurdles, participants saw that opportunities to overcome identified barriers. Consistent themes included enhancing perception and trust through increased public education and outreach (e.g., creation of prescribed fire councils to help build public support for burning) and the development of a multi-jurisdictional climate change strategy for the Jemez Mountains landscape.

Research Needs

Facilitated by TNC-NM's Dave Gori, participants identified priority research needs related to understanding climate changes, ecological responses, and adaptation strategies (Appendix 6). Research needs fell into three broad categories: (1) basic research and modeling; (2) identification, application and testing of management options; and (3) priorities for monitoring. Academic and agency research programs can use this list to help catalyze ongoing and emergent research priorities.

Workshop Conclusion and Next Steps

Fostering Landscape-Scale Collaboration

A major point of consensus that emerged from the workshop was the need for greater agency and partner coordination and collaboration in the Jemez Mountains landscape. Accordingly, participants were asked to brainstorm ways to foster collaboration in the region relative to climate change (Appendix 7). The recent TNC-sponsored Jemez Mountains Fire Learning Network was proposed as a useful model for initiating a similar learning network for climate change. Participants from a range of agencies agreed to participate in a follow-up gathering, facilitated by TNC-NM, to begin to prepare a multi-agency climate change adaptation strategy. However, it also was noted that we do not want to artificially construct or rush collaboration. The expectation is that there will be federal funding for work of this kind. The Nature Conservancy hopes to catalyze the process so that the emerging Jemez collaborative group is in a position to not only receive funds but to put them to good use.

Maintaining the Momentum

There was broad agreement that a climate change adaptation initiative arising from the Jemez workshop would be a useful pilot project; management actions identified as part of a multi-agency climate change adaptation strategy could be implemented using funds from sources like the Collaborative Forest Restoration Program (CFRP). Workshop participants also thought that a Jemez-wide compilation of data sets–similar to what Craig Allen has done on the east side of the region—would be a tangible goal to work toward in the near-term. Several participants agreed to make presentations about the workshop to local groups such as the East Jemez Resource Council (which is now developing a new charter). The group also noted that, while higher-level managers need to be engaged throughout the region, we must not let bureaucracy impede action.

Closing remarks

Terry Sullivan and Anne Bradley of TNC-NM offered the following closing thoughts:
At the state and federal level, action on climate change is beginning to happen. It is important to capitalize on the urgency and hope coming out of this workshop to push forward local action. TNC would like to continue working with local scientists and managers to conserve biodiversity and other natural resources in the face of climate change. The Jemez Mountains landscape, with its expansive science base and existing collaboration (e.g., resource and fire councils, learning

networks, and CFRP projects), could be an ideal site for addressing climate change in a coordinated manner across a large landscape.

Acknowledgements
The organizers of this workshop include Craig Allen (U.S. Geological Survey), Karen Bagne (USFS Rocky Mountain Research Station), Anne Bradley (The Nature Conservancy), Molly Cross (Wildlife Conservation Society), Carolyn Enquist (The Nature Conservancy), Gregg Garfin (University of Arizona), Dave Gori (The Nature Conservancy), Lisa Graumlich (University of Arizona), Marilyn Myers (U.S. Fish and Wildlife Service), Bob Parmenter (Valles Caldera National Preserve) and Todd Ringler (Los Alamos National Laboratory).

Post-Workshop Update

The new federal Forest Landscape Restoration Act has provided a strong incentive for action on an unprecedented scale on many of the resilience-building fire and forest management strategies that emerged from the Jemez Mountains Climate Change Adaptation Workshop. The Santa Fe National Forest, Valles Caldera National Preserve, Jemez Pueblo, NM Forest and Watershed Restoration Institute and TNC are working together to develop an ecological restoration strategy for a 210,000-acre cross-jurisdictional landscape in the southwestern Jemez Mountains as the basis for a proposal to the US Forest Service's Forest Landscape Restoration Fund. Next steps for this initiative include:

- Development of a strategic landscape restoration plan (using TNC's CAP methodology) in January-February 2010.
- Preparation of a proposal to the Collaborative Forest Landscape Restoration Fund for up to $4 million annually for ecological restoration treatments on the Santa Fe National Forest and Valles Caldera National Preserve.

Recovery and resilience-building for the Jemez Mountain Salamander is another center of follow-up activity from the April Climate Adaptation Workshop. TNC is working with the US Fish and Wildlife Service (USFWS) and the NM Department of Game and Fish (NMDGF) to organize a series of workshops in early 2010 that will produce adaptive management strategies for the Jemez Mountain Salamander, an endemic species that has been petitioned for federal listing and that is considered to be highly vulnerable to climate change. These strategies will be used to guide research and management by the National Park Service, NMDGF, USFWS, Jemez Pueblo, Santa Clara Pueblo, Valles Caldera National Preserve, Forest Guardians, TNC and the interagency Endemic Salamander Team.

Finally, the work of the Southwest Climate Change Initiative continues. In December 2009, a second climate change adaptation workshop was held for Colorado's Gunnison Basin (see http://www.nmconservation.org/projects/new_mexico_climate_change for products), and a third is scheduled for April 2010 for the forests of northern Arizona. A fourth workshop will be held in Utah in May or June 2010.

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Appendices

Appendix 1. Workshop agenda

SOUTHWEST CLIMATE CHANGE INITIATIVE (SWCCI):

CLIMATE CHANGE ADAPTATION WORKSHOP FOR NATURAL RESOURCE MANAGERS IN THE JEMEZ MOUNTAINS

FINAL WORKSHOP AGENDA

WORKSHOP GOAL: To empower resource managers to identify and implement climate change adaptation strategies that cross jurisdictional boundaries and include multi-agency collaboration and planning using new tools and the best-available climate change science.

WORKSHOP OBJECTIVES:

1. Provide background information on climate change as it applies to the Jemez Mountains landscape;
2. Determine the consequences of climate change on two target species, systems or processes;
3. Identify management actions to reduce climate change impacts using an adaptation planning framework
4. Discuss future opportunities for learning, collaboration and moving the adaptation planning process forward for natural resource management in the Jemez Mountains.

TUESDAY, APRIL 21, 2009: DAY ONE, AM: 8:30 AM -12:15 PM

- Welcome, housekeeping & "getting started"
    - Terry Sullivan, *State Director, The Nature Conservancy in NM*
    - Gregg Garfin, *Climate Scientist & Science Translation Specialist, University of Arizona (Workshop Facilitator)*
    - Carolyn Enquist, *Conservation Scientist, TNC-NM*

- Statement of the problem & rationale for workshop
    - Craig Allen, *Research Ecologist, Jemez Field Station, USGS*

- Overview of regional climate change impacts: the known, the unknown, & the uncertain
    - Todd Ringler, *Climate Modeler & Scientist, LANL*

- Overview of ecological status, trends, & consequences of climate change in the Southwest & the Jemez Mountains
    - Bob Parmenter, *Chief Scientist, Valles Caldera National Preserve*
    - Craig Allen, *USGS*

- Panel/group discussion: how federal & state agencies are addressing climate change?

BREAK: 10:45 - 11:00 AM

- Translating climate change science for management planning & implementation: an overview of recent TNC-NM climate change reports and the SWCCI
  - Carolyn Enquist, *TNC-NM*

- Overview of Adaptation and "Adaptation Planning" for conservation & management
  - Molly Cross, *Climate Scientist & Adaptation Specialist, Wildlife Conservation Society*

- Implementing a framework for adaptation planning: goals & logistics for remainder of the workshop
  - Gregg Garfin & Molly Cross

LUNCH: 12:20 - 1:15 PM

DAY ONE, PM: 1:15 - 4:00 PM, W/ BREAK AT 2:30 – 2:45 PM

- Break-out groups assemble in separate rooms
  - **Fire** (large room) Facilitator: Gregg Garfin
  - **Water/ Watershed processes & Jemez River In-stream flows** (small room) Facilitator: Molly Cross

  - *Goals for the two groups include: identification of management objectives, development of a conceptual model, application of climate change scenarios, and identification of management intervention points*

DAY ONE ADJOURN: 4:00 PM

<u>APRIL 22, 2009, DAY TWO, AM: 8:00 AM -11:45 PM</u>

- Re-assemble into two break-out groups and designated room
  - *Goals include: identification of adaptation strategies by building on the work of the previous day*
  - *Note "Identification of Adaptation Strategies" matrix included in participant folder*

BREAK: 10:15 - 10:45 AM

- Break-out groups reassemble in large room and report back
  - Both groups give an overview of their discussions,
  - Facilitated summary & synthesis
  - Group discussion of the adaptation planning process

LUNCH: 12:00 - 12:45 PM

<u>DAY TWO, PM: 12:45 - 4:00 PM</u>

- General discussion of feasibility of identified adaptation strategies: guidelines for evaluating strategies; barriers & opportunities for implementation; social, economic & political ramifications
  - Facilitators: Molly Cross, Gregg Garfin
  - *Note "Feasibility Analysis" matrix included in participant folder*

- General discussion of monitoring & future research priorities
  - Facilitator: Dave Gori, *Director of Science, TNC-NM*

BREAK: 2:15 - 2:30 PM

- Group Discussion
  - What are the strengths & weaknesses of the framework
  - Can the adaptation framework be readily incorporated into existing planning processes?
  - Are there other tools that could/should be developed?
  - What are the policy implications?
  - What are future opportunities for learning, collaboration & moving this process forward in this landscape?

- Closing Remarks: Anne Bradley, *Forests and Fire Program Manager, TNC-NM*

WORKSHOP ADJOURNS: 3:45 to 4:00 PM

<u>Appendix 2</u>. Jemez Mountains Climate Change Adaptation Workshop Participants

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NCEAS - National Center for Ecological Analysis & Synthesis; UCSB – University of California, Santa Barbara; RMRS – Rocky Mountain Research Station

Appendix 3. Management intervention points and adaptation strategies identified by participants to reduce the effect of climate change on the ecological process of **FIRE**. Two climate change scenarios were considered and barriers to strategy implementation were identified. The management objective was to "increase resilience to climate change by maintaining or restoring heterogeneous forest structure and processes, especially fire, across the Jemez landscape."

Management Intervention Points	Scenario# 1: "Manage for Resilience" (+2-4°C from current "norm") "BUSINESS AS USUAL"	Scenario# 2: "Manage for change" (+2-6°C & extreme drought event) "UNDESIRED CONDITIONS"	Barriers to implementation (e.g., economic, social, political, regulatory)
Wildlife & Habitat	Monitoring species responses; maintain biodiversity; facilitate north-south corridors/connectivity, ecosystem services; explore options for post-fire planting dealing with invasives	Captive breeding; assisted migration (AM); new species mixes; triage? Accept novel assemblages	• Don't know enough (assist. migration to where?); • Human-created features are barriers to movement • Lack of historic landscape characteristics
Disease/pests	Thinning prescriptions; leaving more tree spp. diversity; timing of treatments; more research on using biological agents; risk of transporting fire wood	Identify and/or devise alternative treatments	• Currently no market thinned trees
Elk Browsing/Grazing management	Elk herd reduction (grazing reduces fine fuels); adjust grazing programs; think about movement of populations (e.g., fencing, more tree planting, etc.)	Improve options for carcass disposal after catastrophic and more frequent fires	• Resistance to more radical management of elk
Forest-Fire Management	Develop plans; getting climate change science into management plans, more restoration at landscape scale; prepare for stand-replacing fires & post-fire treatments (BAER); prioritize existing "refugial" areas; obtain more resources for Rx fire & fuel breaks	Landscape realignment (species mixes, etc.); manage for type conversions to clonal, resprouting shrubland; identify consequences for regeneration after Rx treatments; develop new Fire Plan (x-jurisdiction); push biomass use, create markets	• Increasing uncertainty around knowing what to expect; • Different jurisdictional policies inhibit application (e.g. LANL); • Resistance to implementing new actions under uncertainty; • LACK OF RESOURCES
Fuel Quantity & Arrangement	Hazardous fuels reduction; market small diameter trees; think about "unwanted" ramifications of this (e.g., moving *Ips* pops downwind?)	Prevent "unwanted" ramifications of this (moving *Ips* pops downwind?)	• Air quality issues

Agency Policies	Rx Fire Council, inter-agency cooperation & collaboration/cross-boundary planning & implementation; deal with complexity; re-direct agency resources	Agency re-alignment	• Lack coordination, funding, staff capacity

<u>Appendix 4</u>. Management intervention points and adaptation strategies identified by participants for reducing the impacts of climate change on the ecological process of **INSTREAM FLOWS & WATERSHED FUNCTION**. Two climate change scenarios were considered. The management objective was to "maintain sufficient water in the system to support aquatic species and riparian vegetation.

Climate Change Impacts	Intervention Points (Fill in with strategies)	Scenario# 1: "Manage for Resilience" (+2-4 deg C from current "norm")	Scenario# 2: "Manage for change" (+2-6 deg C & extreme drought event)
Reduced frequency of flooding, potential for reduced groundwater recharge and dropping water tables resulting in increased establishment & abundance of riparian invasives.	**Invasive Plants-Riparian Vegetation Management**	Remove riparian invasives that have strong impacts on stream function in locations where it is feasible and effective; methods (e.g., herbicide application) are controversial.	
Decreases in snowpack & greater variability in precipitation inputs to streamflow, reduced baseflows.	**Forest Management**	Apply forest prescriptions that maximize infiltration; thin trees to a density/cover that maximizes infiltration appropriate for slope and aspect; confirm/refine SAHRA results through research and monitoring.	
Decreases in snowpack & greater variability in precipitation inputs to streamflow including larger runoff events; reduced baseflows under Scenario #1. Effects more pronounced under Scenario #2.	**Riparian Vegetation Management**	Encourage groundwater recharge by: 1) planting riparian vegetation; 2) increasing course woody debris, beaver dams in stream channel & floodplain; and 3) artificially creating beaver dams, check dams, lop and scatter branches. Thin vegetation around springs to increase flows.	If not enough riparian vegetation to reduce flow velocity during large floods, then may need to construct mechanical structures, check dams, water catchments.
Reduced baseflows & loss of riparian vegetation cover; more variable flows including larger runoff events; and increased water temperatures under Scenario #1. Effects more pronounced under Scenario #2 including potential for greater stream channel changes due	**Grazing Management** to improve streambank "verticalness" and increase riparian vegetation cover (e.g., sedges, grasses, willows)	Reduce stocking rates (livestock numbers and season of use). Livestock reductions during recent drought allowed re-colonization of exposed streambanks by sedges, grasses & willows. Post-drought this vegetation persisted, resulting in changes in stream channel morphology—the stream got deeper—and decreasing water temperatures (despite increasing surface/ambient temperatures). Fence riparian areas to exclude cattle and elk.	More extreme changes in grazing management; complete destocking; increased resources for fencing out elk, reducing elk herds.

to periodic dewatering, followed by high-energy flow events.		Reduce and redistribute elk population in riparian areas by reintroducing wolves (e.g., riparian recovery at Yellowstone following reintroduction of wolves) or by emulating the large predator fear response in elk—dogs, fishermen.	
Greater variability in precipitation inputs including larger runoff events; increased sediment inputs & erosion w/ increased potential for stream downcutting; reduced baseflows.	**Recreation/Transportation Management**	Focus road/trail maintenance on those with the greatest potential impact on sediment yields, stream geomorphology, and flows; incorporate French-drain like structures in wet meadows to provide infiltration beneath roads; replace existing culverts w/ fish/stream-friendly ones (e.g., bottom-less culverts) that will have a lower impact on fish migration and stream morphology. Reduce total miles and density of roads and trails; decommission and rehabilitate roads (e.g., seeding, remove culverts) in places where these actions will have the greatest impact on stream condition and function.	
Increased fire frequency, intensity & size under Scenario #1. Fire occurrence may decline under Scenario #2 due to reduced fine fuels.	**Fire Management** (landscape)	Reduce probability of catastrophic fire through strategic implementation of vegetation treatments. Need for more cooperation between timber, fire and wildlife staff so that shared treatment priorities can be identified and implemented. Application of post-fire treatments that reduce erosion impacts in a cost-effective manner; additional post-fire response/treatments: to plant or not to plant?	
Reduced "effective" vegetation cover; increased runoff and sediment erosion following precipitation events; reduced infiltration, groundwater recharge and stream baseflows under Scenario #1; effects exacerbated under Scenario #2.	**Forest (and Grazing) Management/Effective Cover**	Commercial thinning to increase effective ground cover and enhance/increase infiltration.	Woodlands have lots of exposed soil, if don't have sufficient vegetation cover to reduce runoff & erosion during extreme precipitation events then mechanical structures need to be constructed. Install snow fences to catch/accumulate snowpack in areas to augment infiltration & recharge. Vegetation planting following fire or insect outbreaks—"natives" from lower in elevation or from further south; rethink species being planted.
Reduced snowpack	**Snowpack Management**	Thin trees to maximize snowpack retention, while providing optimal shade to minimize sublimation and evaporation losses.	
Increased water demand for agriculture and domestic use under Scenario #1; these demands	**Agricultural Diversion**		Major changes in water policy and land use; conservation measures that reduce agricultural/domestic use to relieve some of the

increase under Scenario #2.			demand on the upland systems that provide the water (e.g., cisterns, water catchments, other).
Reduced baseflows; loss of perennial flow in perennial segments; intermittent streams may flow less or not at all under Scenario #1. Intermittent streams are dry, some springs dry up; loss of perennial flow more extensive under Scenario #2.	**Riparian/Stream Management, also Grazing Management**	Inventory of springs and stream reaches to identify those most likely to retain water/flows during drought and act as critical refugia; confirm through ongoing monitoring.	Need a contingency plan—what happens when you're 2-3 years into a long drought—that identifies springs and stream segments that are likely to be refugia; re-engineer aquatic habitat in these refugia so that all microhabitats are present to sustain species. Run pump at the lower end to move water up and augment flow at the top. Design and planning done in advance so that plans/strategies are in place when they are most needed. GENERAL DISCUSSION: Need to identify critical thresholds or trigger points where we take drastically different actions. If trigger point is reached—certain amount of the stream goes dry—then the plan is implemented. There are all sorts of potential decision or trigger points for these more extreme measures, e.g., when to get livestock off the land during an extended drought; could be an agreed upon part of the grazing permit.

<u>Appendix 5</u>. Adaptation strategies, barriers to implementation, and potential opportunities for overcoming them.

Management Strategies	**Barriers to implementation**	**Opportunities**
System-wide management planning (fire, climate)	• Need buy-in at high levels within agencies • Different agencies have different goals with respect to climate change and other objectives • Perceived lack of urgency	• Interagency fire management planning may be a good model for climate change • Climate change provides an (urgent) opportunity to create an overarching strategy across boundaries
Improving riparian community health by fencing out elk and cattle	• Expensive • Fencing creates restrictions on wildlife movement • Conflict with ranching community	• Use alternative ways to keep cows out of riparian (e.g., shock collars) • Volunteers to build fences • Use range riders/dogs • Build spatially discontinuous fences
Or by reducing elk herd	• Hunter resistance and public perception • Lack of elk predators • Potential loss of revenue to agencies and communities from decreased hunting opportunities	• Education to change perceptions • Reintroduce elk predators • Providing stable alternative revenue streams and rewarding vcnp and other preserves for producing woody vegetation
Fire management	• Lack of markets for small diameter trees to facilitate management • NEPA process • Lack of public and agency involvement and education • Funding • Uncertainty leads to inaction • Denial of climate impacts	• Climate change can be a motivator – provides added incentive to continue doing the things we're already doing • Can look for areas of overlap between adaptation and mitigation • Opportunities for collaboration exist – collaboration already beginning to happen and have examples to follow • Collaboration on climate change may provide access to more funding

Widening the prescribed fire window (conditions under which Rx can be implemented)	• Air quality concerns • International balloon fiesta • Public perception of fire risk (high after large wildfires, perception of radionucleides being released) • Workforce limitation • Manager liability	• NM Environment Dept. exemptions for prescribed fire permits • Public education – NM Forest & Watershed Restoration Institute, NM State Forestry • Prescribed Fire Councils • Capitalize on wildfires to educate and convey that more may be coming • Modify "Smokey's" message (use twitter) • Development of large-scale mobile fire crews, building off of existing models • Omnibus Lands Bill – language to reduce manager liability for taking risks (reduces career risks)
Mechanical treatment of forest structure	• Impact to listed species • How to dispose of material • Cost • Social issues related to large scale treatments • Equipment is a vector for spread of invasives • Need for additional roads and their associated impacts • Legal and social issues in Wilderness • Debate of what is "best" prescription • Viewshed – public perception of what's ok or not • How much and how fast can we do what we need to do? • Lack of public trust	• Prioritize where we treat and engage multiple partners and new funding opportunities • Develop new markets for small-diameter trees • Provide fuelwood and wood products to local communities • New employment and economic opportunities • Shift in agency philosophies on working across boundaries • Opportunities to achieve multiple objectives • Monitor and adapt activities to improve outcomes and identify "best" prescriptions • Education and public involvement • Use extensive road network that already exists – use equipment to rehabilitate and decommission roads • Inventory invasives while out in field; find and treat early • Through collaboration we can build trust between agencies and with public

Altering forest composition – including canopy cover to increase infiltration	• Is it going to work? • High cost depending on method • Agencies and managers averse to pushing prescribed fire prescriptions • Grazing impacts may prevent achieving desired conditions – established allotments • Desperation-based water solutions	• Flexible livestock stocking rates as we got through variable wet-dry years • Achieving desired outcomes helps to reduce concerns about risks • Provide alternative solutions when water demands get desperate • Public outreach around demonstration projects that have multiple benefits
Using fire instead of mechanical operation to modify vegetation	• Public perception and opposition to large fires • Timing – fire suppression is the focus during best times for Rx fires • Air quality regulations • Technical limitations • Cultural resources • T+E species regulations • Risk of escape and damage to homes • Internal accountability	• Pick a realistic and feasible area to do burns • Do strategic treatments around burn unit to reduce risk of escape • Do burning in fall rather than spring • Burn when smoke, particulate dispersion is better (although tradeoff with escape risk) • Create Fire Councils to help build support for the idea of Rx burning, wildland fire use • Disseminate research on effects of fire on cultural resources • Set up an appropriate MOU with State Historic Preservation Office • Revise regulations around T&E species – more open conversations btw USFS and USFWS re: when and where to burn and associated tradeoffs

<u>Appendix 6</u>. Research and monitoring needs identified by workshop participants that would assist in managing instream flows and fire under climate change in the Jemez Mountains landscape.

- Basic Research and Modeling:
  1. Modeling to determine how stream temperatures and flow are predicted to change over time with climate change and how this relates to aquatic species' requirements.
  2. Research to better understand the regeneration requirements of key plant species and how their spatial distribution will change with climate change; studies to identify temperature and moisture stress tolerances for species of interest (plants, wildlife).
  3. Vegetation maps of plant associations at a useable scale that cross jurisdictional boundaries; monitoring plots and treatment areas mapped across the landscape; high resolution maps exist for different management units – challenge is how to stitch these maps together.
  4. Study to determine the importance of Jemez Mountains as a stop-over location for migratory bird/bat species; how will climate-induced habitat changes and loss of connectivity affect migratory species?
  5. Economic research – value of ecosystem services provided by Jemez Mountains systems; more specific quantification of water-related and carbon-related services, other services.
  6. Sociological research—how to increase the effectiveness of public education about climate change, impacts on natural resources, and adaptation strategies.

- Monitoring Priorities:
  7. Monitoring elk populations (numbers, sex ratio, age structure, fecundity) and their predators to determine elk population size trajectories over time; determine trade-offs between population size(s) that allow for woody riparian vegetation and aspen regeneration as well as economic/recreational opportunities through hunting.
  8. Identification and monitoring of indicator species for different systems (e.g., species of greatest conservation need, species vulnerable to climate change); monitor soil temperatures and moisture to improve understanding of Jemez salamander population dynamics.
  9. Monitor cumulative effects of climate change and other activities on species and systems.

- Management Options (identification, application, and testing):
  10. Study to determine forest management prescriptions that will maximize infiltration and where implementation of treatments will be feasible and most effective.
  11. Research to determine the water balance consequences of increased establishment of riparian vegetation (water use, recharge) vs. evaporation in the absence of riparian cover. If more riparian vegetation is beneficial, where is it feasible and most effective to encourage its establishment from a water balance standpoint?

12. Study to determine water balance consequences of removing exotic riparian plant species from riparian areas and where removal would contribute most to stream flow.
13. Research to determine the effects of fire on riparian vegetation and develop specific treatment prescriptions that reduce the probability of high-intensity fire in riparian areas.
14. Experiments to determine effectiveness of snow fences and plantings (e.g., live snow fences) in increasing snowpack and water infiltration.
15. Assessment to identify and prioritize where road maintenance will reduce impacts (sediment, runoff, geomorphic effects) on riparian and aquatic habitats.
16. Know more about regeneration envelope of plant species in relationship to climate change – i.e., how to manage a PIPO forest knowing that the species may not be able to regenerate there
17. Studies in catchment basins to investigate the relationships between snowpack infiltration, runoff and transpiration by herbaceous vegetation following tree thinning treatments.
18. Investigate species from farther south (Mexico) that may adapt well to changed conditions in New Mexico; candidates for assisted migration or re-vegetation.

<u>Appendix 7</u>. Suggestions by workshop participants for enhancing cross-jurisdictional collaboration to address climate change in the Jemez Mountains.

1. Look to collaboration between multiple agencies on elk management as a model (e.g., collaborative, cross-boundary monitoring, agreement on protocols, "Seeking Common Ground" effort);
2. Share data (e.g., monitoring, research, vegetation data, LANDSAT, etc.) at the landscape level;
3. Develop an overarching, multi-jurisdictional strategy on climate change;
4. Bring the climate change collaboration to other groups (e.g., range groups);
5. Engage higher level managers within agencies;
6. Ensure demonstrated efforts to address climate change are written into performance standards at high levels within agencies; e.g., every year there is a meeting to inform staff about new and ongoing management and monitoring efforts to address climate change;
7. Establish MOU's between Jemez agencies to address climate change;
8. Value community-based collaborations – get community decision-makers to the table; multi-jurisdictional strategy to address climate change more likely to be supported and implemented if it has community input and buy-in;
9. Identify a leader and convener to invite all parties to the table and to keep this climate change collaboration going – doesn't need to be a "new" leader, could be one of the agencies/organizations already working here (e.g., NM Forest and Watershed Health Office, NM Forest & Watershed Restoration Institute; East Jemez Resource Council, expand Council to include the entire Jemez landscape based on issue of climate change);
10. Position ourselves to be recipients of climate change adaptation funding;
11. Convince Congress that this kind of collaboration is necessary – output from this meeting can be used to convey that message (concise half-page information piece). For example, what is a "climate change adaptation strategy" and why do we need new money to implement it?
12. Use the Collaborative Forest Resources Program to promote adaptation demonstration projects and to leverage other funding sources;
13. Look to collaborative models in other systems (e.g., Greater Yellowstone Coordinating Committee) for ideas and strategies;
14. TNC Fire Learning Network is a potential model – series of workshops organized around different species, systems or climate change issues to discuss what are the logical next steps;
15. Take small next steps – give presentations on what we've done at this workshop to various groups mentioned above.

Appendix 8. Other resources related to climate change adaptation planning and regional climate change science.

- Online resources (from Craig Allen's talk):
  - Natural Resources Canada; Enhancing Resilience in a Changing Climate: http://ess.nrcan.gc.ca/ercc-rrcc/index_e.php
  - Information and Tools for Land Managers at the US Forest Service's Climate Change Resource Center website: http://gis.fs.fed.us/ccrc/
- Federal scientists using a collaborative approach to develop adaptation strategies:
  - Connie Millar (US Forest Service, Pacific Southwest Research Station)
  - Linda Joyce (US Forest Service, Rocky Mt. Research Station)
  - Dave Peterson (US Forest Service, Pacific Northwest Research Station)
- NOAA weather station can be accessed online (from Bob Parmenter's talk):
  - http://www.ncdc.noaa.gov/crn/newmonthsummary?station_id=1138&yyyymm=200904&format=web
- Information about the Southwest Climate Change Initiative (SWCCI) and its products, including the Southwest regional climate change exposure assessment products, can be accessed online:
  - http://nmconservation.org/projects/new_mexico_climate_change
- The Nature Conservancy's Climate Adaptation workspace, which provides tools and case studies for landscape-scale climate adaptation:
  - http://conserveonline.org/workspaces/climateadaptation
- ClimateWizard, a web-based program that allows the user to choose a state or country and both assess how climate has changed over time and to project what future changes are predicted to occur in a given area:
  - http://www.climatewizard.org/