Seeps, Springs and Wetlands:

SAN JUAN BASIN, COLORADO

SOCIAL-ECOLOGICAL CLIMATE RESILIENCE PROJECT

Report Prepared for:

North Centeral Climate Adaptation Science Center

Recommended Citation:
Rondeau, R., M. Bidwell, B. Neely, I. Rangwala, L. Yung, and C. Wyborn. 2020. Seeps, Springs and Wetlands: San Juan Basin, Colorado. Social-Ecological Climate Resilience Project. North Central Climate Adaptation Science Center, Colorado.

Front Cover Photo: Fewkes Canyon Spring, Mesa Verde (George San Miguel)

Seeps, Springs and Wetlands: San Juan Basin, Colorado. Social-Ecological Climate Resilience Project

EXECUTIVE SUMMARY

Climate change is already having impacts on nature, ecosystem services and people in southwestern Colorado and is likely to further alter our natural landscapes in the coming decades. Understanding the potential changes and developing adaptation strategies can help ensure that natural landscapes and human communities remain healthy in the face of a changing climate.

An interdisciplinary team consisting of social, ecological and climate scientists developed an innovative climate planning framework and worked with the Social-Ecological Climate Resilience Project (SECR) and other stakeholders in the Colorado's San Juan River Basin to develop adaptation strategies for two large landscapes, pinyon juniper woodlands and seeps, springs and wetland resources under three climate scenarios between2035 and 2050. This report summarizes the planning framework and results for the seeps, springs and wetland resources (the pinyon-juniper woodlands results are provided in a separate report). This framework can be utilized to develop strategies for other landscapes at local, state, and national scales.

Diagrams, narrative scenarios, and maps that depict climate scenarios and the social-ecological responses help us portray the climate story in the face of an uncertain future.

Interviews and focus group workshops with agency staff and stakeholders who are users of public lands identified several important opportunities to improve the adaptation planning process for developing strategies that meet both social and ecological needs. Planning techniques that include or directly relate to specific resources, such as water and forage, or to activities, such as recreation or grazing, provide avenues for engaging diverse stakeholders into the process.

Utilizing the stories to understand the impacts to our social and ecological landscapes, three overarching landscape-scale adaptation strategies were developed. Each of these strategies has a suite of potential actions required to reach a desired future condition.

The three key strategies are: 1) identify and protect persistent ecosystems as refugia, 2) proactively manage for resilience, and 3) accept, assist, and allow for transformation in non-climate refugia sites.

If the framework and strategies developed from this project are adopted by the local community, including land managers, landowners, and users, the risk of adverse climate change impacts can be reduced, allowing for a more sustainable healthy human and natural landscape.

ACKNOWLEDGEMENTS

This project would not have been possible without the participation of the San Juan Climate Initiative, an informal public-private partnership that has been working since 2006 to prepare for change in the San Juan Mountain region, including the San Juan Basin in Colorado.

We thank the many stakeholders, agencies, consultants and representatives of the academic community who participated in a series of workshops, interviews, and focus groups over the past three years. Additionally, we offer a special thanks to George San Miguel, Mesa Verde National Park, and Gretchen Fitzgerald and Kelly Palmer, San Juan National Forest, who also provided agency insight and reviewed many products and reports to make the project more relevant to our partners. Their years of leadership within their agencies and communities to initiate climate conversations provided an opening for this project to take root and flourish.

We greatly appreciate funding, programmatic and technical support from the Department of Interior's (DOI) North Central Climate Science Center in Fort Collins, Colorado. We are equally grateful for the funding provided by Bureau of Land Management Tres Rios Field Office and San Juan National Forest to support the vulnerability assessments that provided an initial foundation. In addition, we thank the Rocky Mountain Research station for providing additional support for the social scientist interviews and focus groups.

We also appreciate the technical support of cooperators on this project from the University of Colorado, Wildlife Conservation Society, Western Water Assessment/NOAA, Colorado State University, and US Geological Survey, specifically Nina Burkardt and Rudy Schuster, who graciously guided the project. We want to thank Betsy Neely, The Nature Conservancy and the Gunnison Climate Working Group for sharing this initiative with the San Juan group, as we learned a lot from working in concert with the two watersheds. The exchange of ideas and experiences greatly enriched our project in the San Juan watershed.

Special thanks to Karin Decker, Colorado Natural Heritage Program, for formatting this report. The chain of consequences and results chains methods were initiated by Kristen Ludwig and Teresa Stoepler, US Geological Survey, and Terri Schulz of The Nature Conservancy. Special thanks to Chris Rasmussen, Ecosystem Mainstream Consultants, Stephen Monroe, National Park Service Inventory and Monitoring Program, Nicole Barger, University of Colorado, Kris Johnson, University of New Mexico, and Lynn Wickersham, Animas Biologic for technical contributions. Thanks to San Juan National Forest and Mesa Verde National Park for providing meeting space and reviewing this document. Finally, thanks to Jeff Morisette and his staff at North Central Climate Science Center, for helping to assemble the great team that it took to accomplish this project.

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ACRONYMS

ACT	Adaptation for Conservation Targets planning framework
BLM	Bureau of Land Management
CNHP	Colorado Natural Heritage Program
CSU	Colorado State University
CU	University of Colorado- Boulder
DOI	Department of Interior
FLC	Fort Lewis College
MEVE	Mesa Verde National Park
MSI	Mountain Studies Institute
NCCSC	North Central Climate Science Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PJ	Pinyon-Juniper
RCP	Reflective Concentration Pathways
SECR	Social-Ecological Climate Resilience Project
SJCI	San Juan Climate Initiative
SJNF	San Juan National Forest
SSW	Seeps, springs and wetlands, a landscape target system of this project
SUIT	Southern Ute Indian Tribe
SUIT BIA	Southern Ute Bureau of Indian Affairs
TNC	The Nature Conservancy
UM	University of Montana
UMUT	Ute Mountain Ute Tribe
USFS	United States Forest Service
USFS RMRS	United States Forest Service Rocky Mountain Research Station
USGS	United States Geologic Survey
US	United States
WCS	Wildlife Conservation Society
WWA	Western Water Assessment

INTRODUCTION

Environmental change is a constant feature of land management within the US Intermountain West. Fire, drought, insect infestations, and invasive species present pervasive challenges to the conservation and management of western lands. Southwestern Colorado is already experiencing higher temperatures, more frequent and prolonged drought, earlier snowmelt, larger and more intense fires, more extreme storms, and spread of invasive species (Saunders et al. 2008). These are all changes that are expected to intensify as a result of climate change putting livelihoods, ecosystems, public lands, and species at risk.

Climate change poses significant challenges for both ecological systems and human communities in southwestern Colorado. Resource managers need to consider climate change in management decisions and long term planning. Yet, while they are increasingly being tasked to incorporate climate change, many barriers and challenges exist that complicate integrating climate information and producing robust adaptation strategies. Climate change information is often at the global scale and projected over long time periods, which makes it difficult for managers to integrate it into local management plans with shorter timescales. Furthermore, the uncertainty of how climate will change, especially in hard-to-model mountainous landscapes, increases the difficulty of this task and the risk of taking any particular approach.

The Social-Ecological Climate Resilience Project (SECR) was formed to address these challenges. Over three years, a team of social, natural and climate scientists and planners worked with the San Juan Climate Initiative, a public-private partnership working to prepare for change in Colorado's portion of the San Juan River and Dolores River watersheds (referred to in this report as the San Juan Basin), natural resource management agencies and other stakeholders. This collaborative effort has developed practical adaptation strategies for selected systems in the San Juan Basin. The team was led by Colorado Natural Heritage Program (CNHP), Mountain Studies Institute (MSI), University of Montana (UM), and U.S. Geological Survey (USGS). Another team led by The Nature Conservancy (TNC) and CNHP led a similar effort in the Gunnison Basin for spruce-fir forest and sagebrush scrub landscapes.

The goal of the SECR project is to facilitate climate change adaptation that contributes to social-ecological resilience, ecosystem and species conservation, and sustainable human communities in southwestern Colorado. This project has developed and piloted an integrated adaptation planning framework, consisting of tools and principles that merge the strengths of the iterative scenario process, the Adaptation for Conservation Targets (ACT) planning framework, institutional analysis, and climate change modeling.

The framework was used to generate practical strategies and scientific knowledge to advance climate change adaptation in the Gunnison and San Juan Basins and, potentially, other landscapes. A key objective of this project is to work with decision-makers to develop social-ecological adaptation strategies and coordinate actions to reduce the impacts of a changing climate on nature and society. In order to accomplish this, SECR blends science from biophysical and social disciplines with participatory approaches to integrate expert knowledge, land management decision making, and local needs.

An adaptation target is a feature (livelihood, species, ecological system, or ecological process) of concern that sits at the intersection of climate, social, and ecological systems (adapted from Cross et al 2012). Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure. Resilience strategies may include managing for the persistence of current conditions, accommodating change, or managing towards desired new conditions (Department of Interior NPS 2016). These and other terms are defined in the glossary (Appendix A).

Intended implementers of the adaptation strategies are the stakeholders and participants who participated in the project process over the past two years: natural resource managers, local landowners, non-profit organizations, local government officials, etc.

Project Objectives

1. Build knowledge of social-ecological vulnerabilities to inform adaptation planning.
2. Create social-ecological scenarios and models to facilitate decision-making under uncertainty.
3. Develop a detailed set of actionable and prioritized adaptation strategies designed to conserve key species, ecosystems, and resources, and to address the needs of local communities and natural resource managers.
4. Identify the adaptive capacities and the institutional arrangements needed to advance these strategies into decision-making arenas.
5. Document best practices for effectively bringing climate science into decision-making.

Deliverables

1. Innovative, effective, integrated social-ecological adaptation planning tools and principles that can be applied in other landscapes.
2. Narrative scenarios of landscape change in southwestern Colorado and conceptual ecological models (ecological response models) that can be used in adaptation planning.
3. Summary reports on interview and focus group results.
4. An institutional analysis.
5. A set of actionable adaptation strategies for priority ecosystems that include specific conservation/adaptation targets and action steps/paths to implementation.
6. Manuscripts focused on adaptation decision-making and adaptive capacity, institutional analysis, and results and lessons learned from integrated adaptation framework.
7. Guidelines and a toolkit for practitioners to employ integrated adaptation planning in other landscapes.

Funding

This project was funded by the Department of Interior's (DOI) North Central Climate Science Center (NCCSC), Fort Collins, Colorado. Matching funds from Bureau of Land Management (BLM) Tres Rios Field Office and the San Juan National Forest (SJNF) supported the vulnerability assessments for ecosystems, vulnerable species, and rare plants that complimented this effort. Rocky Mountain

Research Station provided additional support for the social science.

Project Team

The project team consists of representatives of CNHP, MSI, TNC, UM, U.S. Geological Survey (USGS), Western Water Assessment (WWA)/ National Oceanic and Atmospheric Administration, Colorado State University (CSU), Rocky Mountain Research Station, US Forest Service Rocky Mountain Research Station (RMRS), University of Colorado (CU), and University of Cincinnati.

San Juan Basin Partners

Key partners and stakeholders participating in this project include the San Juan Climate Initiative, an informal public-private partnership working to prepare for change in the Colorado portion of the San Juan Basin consisting of the Mesa Verde National Park (MEVE), SJNF, BLM-Tres Rios Field Office, Ute Mountain Ute Tribe (UMUT), and Southern Ute Indian Tribe (SUIT) and Bureau of Indian Affairs (SUIT BIA). See Appendix B for full list of participants at the workshops.

Overview of Planning Framework and Process

Planning Framework Key Steps

1. Select socio-ecological landscapes to be the focus of the project and conduct literature search regarding natural processes, climate impacts
2. Develop three plausible climate scenarios
3. Develop ecological response models to help understand impacts under three climate scenarios to help inform development of robust adaptation strategies for the targeted landscapes
4. Develop three narrative scenarios
5. Conduct social science research through interviews and focus groups
6. Develop social ecological response models to identify impacts and interventions using Situation Analysis and Chain of Consequences
7. Hold a series of workshops to develop and refine adaptation strategies to address current and future climate vulnerabilities

Landscape Selection

In December of 2013, the SECR partners selected the pinyon-juniper landscape and seeps, springs and wetlands as the focus of this project because of their social, economic, and ecological importance to the San Juan Basin. Criteria considered included: vulnerability rank from San Juan/Tres Rios Climate Change Ecosystem Vulnerability Assessment (Decker and Rondeau 2014), nested species and rank from Sensitive Species Assessment of Vulnerability to Climate Change on San Juan Public Lands (Rhea et al. 2013), opportunity for success in building resilience, social concerns and livelihoods that benefit from the ecosystem services, relevance to decision makers regarding upcoming management decisions, available data, biodiversity values, and wildlife values.

Three Climate Scenarios

Uncertainties in the future climate present managers with challenges and opportunities. To help in decision-making for a range of future conditions, Imtiaz Rangwala, Western Water Assessment, University of Colorado, developed attributes associated with three climate scenarios for southwestern Colorado and the Gunnison Basin for the year 2035. He used a base of 72 models and 2 Representative Concentration Pathways (RCPs 8.5 and 4.5) and then identified three potential clusters that represented different future pathways for the project. The scenario clusters represented three different plausible futures – a hotter drier future, a warmer future where annual precipitation increases, and a future with high inter-annual variability between hot dry years followed by cold wet years. The climate scenarios are named respectively: 1) Hot and Dry; 2) Warm and Wet; and 3) Feast and Famine (Appendix C). The Feast and Famine climate scenario predicts more frequent and intermittent severe-drought conditions, large year-to-year fluctuations that range from "hot and dry" to "warm and wet" conditions, and a doubling in the frequency of alternating extreme dry and wet conditions relative to the present (Appendix D).

Renée Rondeau, CNHP, researched the potential ecological impacts of the three climate scenarios to the targeted landscapes. This information was used to develop a set of ecological response models and narrative scenarios to assist managers in developing social-ecological adaptation strategies under the three climate scenarios.

Ecological Response Models

The team, working closely with natural resource managers, developed reference condition and ecological response models for the pinyon-juniper landscape in the San Juan Basin. The purpose of ecological response models was to help evaluate potential impacts of the three climate scenarios on the two landscapes in the San Juan Basin. The team held a series of small group work sessions between January and March, 2015 to develop draft preliminary reference models and ecological response models for the landscapes. Participants included representatives from SJNF, MEVE, BLM Tres Rios Field Office, Southern Ute Indian Tribe (SUIT) and Bureau of Indian Affairs (SUIT BIA), Ute Mountain Ute Tribe (UMUT), and private ecological consultants. Ecological response models are in Appendix E.

Narrative Scenarios

Renée Rondeau (CNHP) and Imtiaz Rangwala (WWA) drafted three narrative scenarios for the San Juan Basin that described plausible landscape changes that could take place over the next 20 years. The scenarios were descriptive stories that depicted potential changes in the landscape based upon the climate scenarios that are referred to as "Hot & Dry," "Warm & Wet," and "Feast & Famine." The narrative scenarios were developed for use during the focus group workshops for the social science research. They were reviewed by the SECR team and subject experts familiar with the ecology and local systems. The experts' comments were incorporated into the final narrative tool that was used in workshops led by our social scientists (see Appendix F).

Social Science Research

Carina Wyborn, College of Forestry and Conservation, UM, and Marcie Bidwell, MSI, reached out to agencies, partners and members of the ranching community to conduct in-depth semi-structured interviews to understand their perspectives on landscape changes in the San Juan Basin (Wyborn et al. 2015). The interviews queried stakeholder's perceptions of current conditions and impacts, future conditions as envisaged under a changing climate, management approaches, capacity to realize goals, and decision making in the face of uncertainty.

Fieldwork was conducted from April through July 2014. Dr. Wyborn conducted 34 in-depth, semi-structured interviews with ranchers and public land managers at three agencies[1]. Results were audio-recorded and transcribed verbatim to assist in analysis. Transcripts were then coded using Nvivo software. Coding was used to identify themes and facilitate analysis. The results were summarized in a separate report (Appendix F).

Narrative Scenario Workshops

Two workshops were conducted between June 24th and July 10th, 2014. The goal of the workshops was to explore possible future changes that might take place in the San Juan Basin over the next 20 years and to understand the impact of those changes on land management in the region. SJNF hosted the first workshop, which focused on the Glade Landscape, an area being evaluated through a grazing landscape analysis. This workshop was attended by 17 USFS employees and 11 permittees from the Glade Landscape. The second workshop was hosted by MEVE to discuss the intersection of pinyon-juniper woodlands within a national park management setting. This workshop was attended by 12 NPS employees. A secondary goal of the workshops was to introduce participants to a process that can be used to support decisions in the context of uncertainty. Each workshop was centered on the three narrative scenarios described above (Hot and Dry, Warm and Wet, and Feast and Famine; Appendix C). Scenarios were presented individually and then followed by a series of questions regarding anticipated impacts, management needs, conflicts, compromises and potential strategies.

Socio-Ecological Response Models

The team worked with stakeholders to integrate social and ecological responses of climate change on wetlands, seeps and springs using two different approaches: Situation Analysis and Chain of Consequences.

The Situation Analysis approach defines the context within which a project is operating and, in particular, the major forces influencing the biodiversity of concern at a site, including the direct and indirect threats, opportunities, and scope (Foundations of Success, 2009). The process of developing a Situation Diagram helps teams create a common understanding of the biological, environmental, social, economic, and political systems that affect targeted landscapes. This method has been used around the world by the Conservation Measures Partnership, TNC, and others.

The DOI Strategic Sciences Group developed the Chains of Consequences method for teams of scientists to identify the potential short- and long-term environmental, social, and economic cascading consequences of an environmental crisis and to determine intervention points to aid decision-making. The method has been used to identify the consequences and potential interventions of the Deep Water Horizon oil spill in the Gulf of Mexico and Hurricane Sandy (DOI Strategic Sciences Working Group 2010, 2012; Department of the Interior, 2013).

See Appendix H for the Situation Analysis and Appendix I for Chain of Consequences results.

Stakeholder Workshops

The Team hosted a series of workshops with the San Juan Climate Initiative and other stakeholders from March 2015 through May 2016 to identify climate impacts to the landscapes under climate scenarios, identify interventions (preliminary adaptation strategies), develop social-ecological models, and develop adaptation strategies. These workshops are summarized below.

May 2015 Climate Adaptation Strategy Workshops

To prepare participants for the workshops, the team held a series of pre-workshop webinars on the following topics: 1) three climate scenarios; 2) ecological response models for pinyon-juniper woodlands and seeps, springs and wetland resources; 3) methods for identifying preliminary interventions; and 4) preliminary results of social science interviews and focus groups. The team also developed a participant packet of materials including an agenda, materials produced to date, description of methods, and the approach for facilitating discussion focused on climate change.

The team hosted a workshop on May 4th, 2015 in Durango to develop social-ecological climate response models for pinyon-juniper woodlands and seeps, springs and wetland resources; identify a suite of preliminary intervention points and potential high-level adaptation strategies for one climate scenario; and prepare for fall workshop to develop in-depth adaptation strategies (from Phase I). This workshop focused only on one climate scenario, Feast and Famine, due to time constraints, with the intention of addressing the two other scenarios at future workshops. The workshop provided an opportunity to compare two methods (Situation Analysis and Chain of Consequences) for developing interventions and identifying preliminary adaptation strategies.

The May 2015 workshop was the first of several workshops to develop social-ecological adaptation strategies for the pinyon-juniper landscape for three climate scenarios in the San Juan Basin. The outcomes included: 1) integrated findings from climate models, ecological response models and social science to produce social-ecological response models for the Feast and Famine climate scenario (one of three climate scenarios); 2) comprehensive list of preliminary interventions that provide a foundation for developing more in-depth adaptation strategies for the targeted landscapes under three climate scenarios; and 3) improved stakeholder buy-in for developing and implementing local and regional interventions and adaptation strategies. Methods for each process are detailed in Appendix G and I. Products of the meeting can be found in Appendix H and I.

March 2016 Climate Adaptation Workshop

At the March 1st 2016 workshop, stakeholders reviewed the management goals and interventions that were developed for the different scenarios at the 2015 workshops. The interventions were reviewed for a set of three climate adaptation strategies for seeps, springs, and wetlands. The participants helped to prioritize the intervention points to inform the development of strategies at the next meeting.

April 2016 Climate Adaptation Workshops

The April workshop developed draft adaptation strategies. We utilized the results of the intervention points to create *Results Chains* or diagrams for three overarching strategies that depict causal linkages between strategies and desired outcomes needed to reduce climate change impacts and other threats. The process creates a logic diagram by describing a sequential series of expected intermediate outcomes and actions necessary to achieve the desired outcomes *(*Margoluis 2013). This process helped to build a common understanding of the outcomes and actions needed to reduce the impacts of climate change for each strategy.

The objectives of the final workshops held in April 2016 were to: 1) review and refine goals/objectives for seeps, springs and wetlands; 2) refine social-ecological climate-smart strategies to prepare the landscapes and the people who depend on them for increased drought, wildfire, and other associated climate impacts; and 3) identify challenges and opportunities to ensure successful implementation of strategies. Following the workshop, the team revised the Results Chains based on the feedback at the meeting and turned the diagrams into bulleted text to summarize each of the strategies, including desired outcome, intermediate outcomes, and actions.

Workshop Participants

Workshops included participants from federal, state and local government agencies, academia, non-profit organizations, and the private sector. Participants included land and water managers, wildlife biologists, ecologists, foresters, researchers, planners, professors, social scientists, county officials, and other stakeholders. Participants included representatives from BLM, CNHP, Colorado Parks and Wildlife, Colorado State Forest Service, MEVE, National Park Service, TNC, MSI, Natural Resources Conservation Service, New Mexico Heritage Program, SUIT, SUIT BIA, CU, New Mexico Forest Service, SJNF, and private consultants.

THREE CLIMATE SCENARIOS FOR THE FUTURE

Climate Scenario Summaries

Projected changes in temperature and precipitation by 2035 for the three climate scenarios are shown in Figure 1, and the consequences of these changes summarized by scenario below. See Appendix C for table comparing the three climate scenarios.

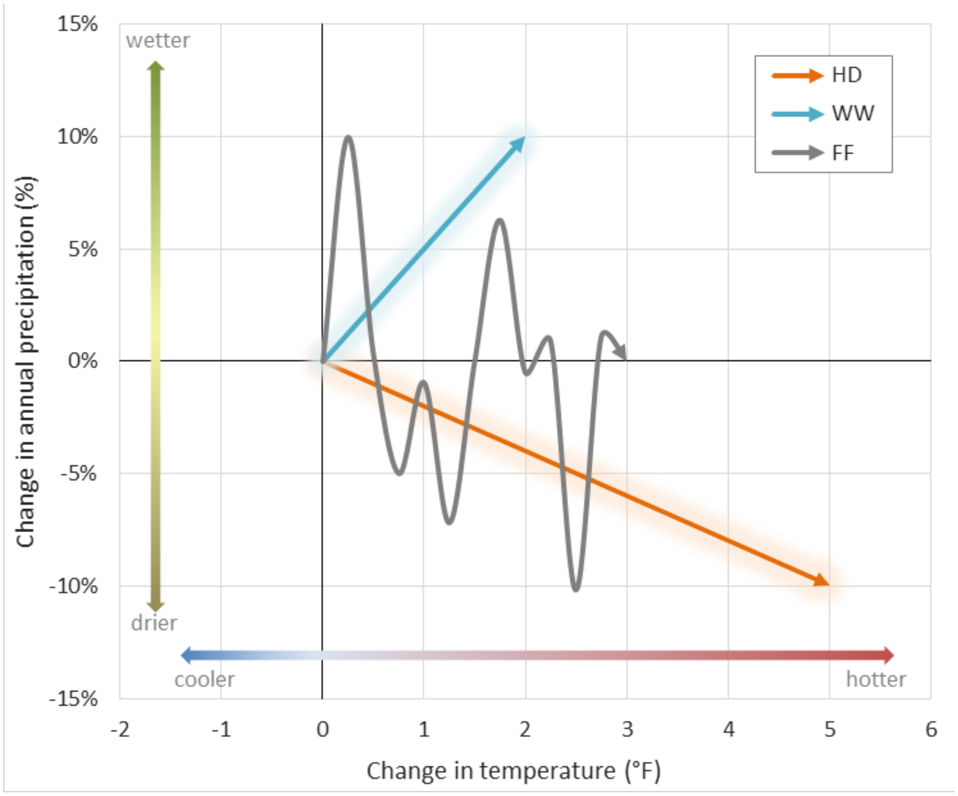

Figure 1. Generalized depiction of change in annual precipitation and temperature for three climate scenarios (Hot and Dry, Feast and Famine, and Warm and Wet).

Hot and Dry (hadgem2-es.1.rcp85)

Average annual temperatures are projected to be 5°F higher than now, combined with a decrease in annual precipitation of 10%, produces drier conditions year-round. Summers at lower elevations are expected to have 30 additional days with temperatures above 77°F (25°C), and many nights with lows of 68°F or above. Heat wave conditions are severe and long lasting. Rain events are likely to be less frequent, but more intense, and summer monsoon rains decrease (20% less than recent historic). Droughts comparable to 2002 or 2012 occur on average every five years.

Hot and dry conditions lead to:

- Longer growing season (+3 weeks), reduced soil moisture, increased heat stress
- Higher elevation of permanent snowline (+1200 ft)
- Frequent extreme spring dust-on-snow events
- Earlier snowmelt and peak runoff (+3 weeks, earlier with dust events). Decreased runoff (-20%)
- Longer fire season (+1 month) greater fire frequency (12x) and extent (16x) in high elevation forest

Feast and Famine (Moderately Hot/No Net Change in Precipitation, cesm1-bgc.1.rcp85)

Average annual temperatures are 3°F higher than now and increased magnitude of inter-annual fluctuations in precipitation levels produce generally drier conditions, especially during the growing season, but some years with strong El Niño patterns may be quite wet. Summers at lower elevations are expected to have 14 additional days with temperatures above 77°F (25°C) and many nights with lows of 68°F or above. Heat wave conditions are common every few years. Strong El Niño events can be expected every seven years on average, while droughts comparable to 2002 or 2012 occur on average every decade. During wetter years, increased temperatures lead to increased vegetation growth and subsequent greater fuel loads for wildfire.

A "feast or famine" pattern fluctuating between hot/dry and warm/wet conditions leads to:

- Longer growing season (+2 weeks)
- Higher elevation of permanent snowline (+900 ft)
- Increased extreme spring dust events in dry years
- Earlier snowmelt and peak runoff (+2 weeks, earlier with dust events). Decreased runoff (-10%)
- Very high fire risk during dry years after wet years, greater fire frequency (8x) and extent (11x)

Warm and Wet (cnrm-cm5.1.rcp45)

Average annual temperatures 2°F higher than now combined with an increase in net annual precipitation of 10% produce generally warmer but not effectively wetter conditions in comparison with recent historic levels. Summers at lower elevations are expected to have 7 additional days with temperatures above 77°F (25°C). Heat wave conditions may occur once a decade. Droughts may be more intense, but with fewer instances of extended drought.

Warmer and slightly wetter conditions lead to:

 Extended growing season (+1 week)

 Higher elevation of permanent snowline (+600 ft)

 Occasional extreme spring dust events in dry years, comparable to current conditions

 Earlier snowmelt and peak runoff (+1 week). No net change in runoff volume

 Increased fire frequency (4x) and extent (6x)

SOCIAL-ECOLOGICAL VULNERABILITIES

As part of the SECR Project, twenty-six agency staff from three agencies and eight grazing permittees were interviewed about landscape changes in the San Juan Basin. Interviews focused on changes to pinyon-juniper woodlands and seeps, springs, and wetlands as the resource targets. Questions also explored climate change, adaptation, and uncertainty in land management. See Appendix F for the full report summarizing the interviews.

Key Findings

Both agency staff and permittees envisioned changes to these systems in terms of impacts to specific resources (e.g. water and forage) and activities (e.g. recreation). For agency staff from the BLM and USFS in particular, pinyon-juniper was the location for key management activities (e.g. gazing, oil and gas, and recreation) and not managed for specific ecosystem features. Similarly, permittees focused on rangeland conditions and the management of grazing permits in pinyon-juniper. For most of the NPS interviewees, the management of pinyon-juniper revolves in part around questions about appropriate fire management and different views on how to best conserve the human infrastructure of the park (both contemporary and historic dwellings) and less often to conserve the ecosystem itself. Like some from MEVE, BLM and USFS participants suggested that they were unsure of the “natural” state of pinyon-juniper, questioned what the management goals for the system should be and wondered whether pinyon-juniper is a “climax” community or one that is encroaching on other communities that are valued more highly (i.e. sagebrush). For all participants, changes to seeps, springs, and wetlands were seen as important and raised concerns about water availability for a range of human uses, including grazing and recreation. Permitees also expressed concerns about long-term drought, the timing of their on-off dates, staff turnover within the agencies, communication with the agencies, and the length of time taken to receive permission to undertake actions related to their permits.

Participants had different views of what climate adaptation might mean in the San Juan Basin. Both agency staff and permittees conveyed that they had a limited capacity to extend beyond current activities. For the agency staff, this meant that they were unsure of the extent to which they could take on extra climate adaptation activities. Limited capacity for adaptation was linked to budget and staffing constraints. In particular, inadequate resources for monitoring translated into a lack of understanding of how the system and resources are changing over time, depriving the process of knowledge necessary to assess the efficacy of adaptation efforts. In the context of uncertainty and incomplete knowledge, agency staff discussed drawing on a broad, interdisciplinary group of specialists to form a more complete picture to inform decision-making. Uncertainty was believed to promote a risk-averse, conservative approach to decision-making within the agencies.

Given these findings, effective climate adaptation on federal lands in the San Juan Basin may benefit from incorporating climate impacts into future management decisions, thereby benefiting people and nature.

Conclusions

Based on interviews with 34 agency staff and permittees, we found the following:

- There was widespread awareness about climate change and recognition that climate change would impact target systems and that these impacts needed to be addressed. However, most participants felt challenged to effectively deal with climate impacts due to uncertainty and limited knowledge and resources.
- The focus on ecological targets enabled in-depth discussion of particular systems and insights into how management agencies and permittees think about and manage these systems. However, this focus did not produce detailed understanding of broader social vulnerabilities as they relate to climate change.
- The focus on ecological targets did enable us to uncover a critical disconnect between the adaptation literature and the way agencies actually manage public lands. In short, most agency managers address specific short-term activities that occur on an individual site (e.g. grazing, recreation, forestry, fire management) rather than specific long-term ecological targets within those systems.
- Thus, for adaptation within seeps, springs and wetlands and pinyon-juniper woodlands in the San Juan Basin to be effective, decision makers need to understand how on-the-ground activities impact the ecological values. One way to do so is to integrate climate impacts and adaptation strategies into management decisions. Such an approach would:
    - Leverage existing resources. All participants expressed concerns about their lack of capacity to pursue additional management activities related to climate adaptation. Integrating adaptation into existing management activities (e.g. range management, silviculture, etc.) might provide a mechanism to leverage existing resources and increase overall capacity for adaptation action.
    - Integrating vulnerable species and ecosystems into on-the-ground management and monitoring would likely improve the knowledge of the ecological value and ecosystem services. There was widespread agreement that agencies do not manage for the ecological values of pinyon-juniper or seeps, springs, and wetlands per se, but rather focus on specific management activities within these systems, with an understanding that these activities influence ecological processes and individual species. Further, improved monitoring was seen as critical for effective adaptive management.
    - Resonate with the public and key stakeholders. Federal agencies will likely find more support for adaptation actions if these actions are meaningful to local community members. A focus on the uses and values of the landscape that people care about may help build support for adaptation.
- Efforts to prepare federal land management agencies for climate adaptation may also need to consider the following:
    - Effective responses to climate change may require that the concept of climate adaptation be well-defined and mainstreamed in the agencies. We found that agency staff had very different definitions of climate adaptation and many participants were uncertain about the relationship between adaptation and land management.
    - Adaptation efforts need to be cognizant of the ways that uncertainty influences agency decision-making. Agency staff are accustomed to dealing with uncertainty,

but tend more toward conservative, risk-averse strategies and longer decision-making processes as uncertainty increases.

- Climate change may drive system transformations in some places, but many agency staff are just beginning to consider the possibility of transformative change and the social and technical challenges that this presents to management.
- The notion of managing for a range of climate impacts is not yet well-established in agency decision-making. It is important to provide useful information about how scenarios and other tools can be used to consider different possible futures and integrate uncertainty into management decisions. At the same time, efforts to integrate new processes, such as scenarios into decision-making need to consider the increased analysis burden.
- More work is needed to determine how to adapt decision-making processes to enable more nimble management. In particular, lengthy decision timeframes and NEPA processes may present barriers to effective climate adaptation.
- Agencies and different stakeholder groups, such as permittees, may benefit from dialogue regarding the knowledge that would assist in decision making.
- Dialogue processes that enable managers and stakeholders to share knowledge might also help address disagreements regarding the value and vulnerability of pinyon-juniper. Building a common understanding of the ways that climate change potentially impacts pinyon-juniper may be important to enable adaptation efforts in response to changes in this system.

Seeps, Springs and Wetlands and their Ecosystem Services

Photo: Mesa Verde National Park, wildlife camera captures three chipmunks drinking at the seep at Spring House Ruin.

Seeps, springs, and other groundwater-dependent wetlands within the San Juan Basin (Figure 2) occur throughout every elevation band and major vegetation type. In general, the seeps, springs, and wetlands above 8,500 feet are considered less vulnerable to climate change, primarily due to the amount of winter precipitation that is likely to fall as snow. The lower elevations (4,500-8,500 ft) seeps, springs, and wetlands are considered highly vulnerable to future climate, and are the focus of this document. The most important (primary) driver is groundwater recharge. Winter and spring moisture are the most critical months for recharge as most of the precipitation events will percolate down into deeper depths, including the aquifer. Snow is generally better at recharging an aquifer than rain, thus monsoonal rains generally are not as critical for recharging the aquifer.

We consider the following wetland types within the 4,500-8,500 ft. elevation band as our focus for developing adaptation strategies: slope wetlands, depressional wetlands, mineral and soil wetlands, riverine wetlands, springs, and seeps. At the lower elevation bands these wetlands will most often be associated with desert shrublands/grasslands, and pinyon-juniper, sagebrush, or mountain shrubland ecosystems. Ponderosa pine and oak shrublands are the most common ecosystem type within the upper elevation band. These wetland types occur across multiple ownership types, including tribal, federal, state, and private lands.

Numerous species and human communities in the San Juan Basin rely on functioning seeps, springs, and wetlands. In spite of their small footprint on the landscape, they are critically important for human livelihoods, wildlife, and rare species. Generally speaking, many of the lower elevation wetlands have been altered and may be even more vulnerable to climate stressors. Uncertainties in future climate scenarios present managers with both challenges and opportunities. In order to plan and adapt to future climates, we present three plausible climate scenarios for the year 2035 (Table

1) and their potential ecological impacts to the focal wetlands (Table 2). This information forms the basis of an ecological response model which can assist managers in developing social-ecological adaptation strategies under future climate scenarios.

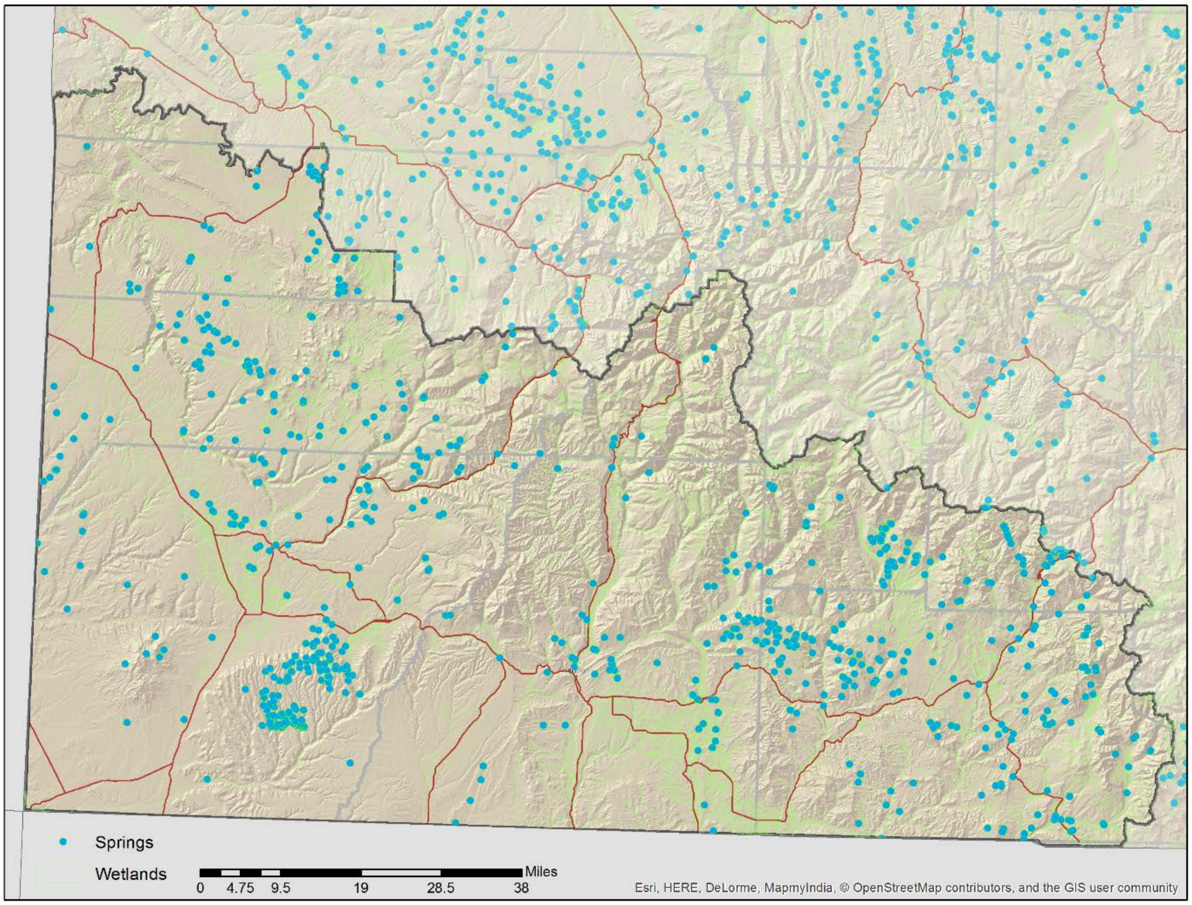

Figure 2. Mapped wetlands, seeps and springs in the San Juan-Tres Rios area. Note that many of these features remain unmapped.

CLIMATE CHANGE IMPACTS AND RESPONSE MODELS

Response Models

Response models are conceptual tools to describe how the landscape operates and provides a context for evaluating potential impacts of different climate scenarios. The models help identify outside environmental influences or drivers. They help visualize the relationships among the main contributing factors that drive one or more of the direct threats that, in turn, impact the landscape. The purpose of assessing the resources under three different climate scenarios is to provide a foundation of scientific understanding and to inform the development of robust social-ecological adaptation strategies for seeps, springs and wetlands in the face of an uncertain future. The ecological response model is presented in Appendix E, which serves as an ecological framework for the Situation Analysis Diagram (Appendix H).

Primary and secondary ecological drivers for these wetlands, based on literature review, local knowledge and expert opinion are summarized in Table 2. The process of groundwater recharge and movement is considered to be the primary driver for these systems. Projected changes in seasonal precipitation are shown in Table 1. The later table provides a context for evaluating potential impacts of the two climate scenarios most likely to impact the ecosystems. The purpose of assessing the landscape under different climate scenarios is to provide a foundation of scientific understanding and inform the development of robust social-ecological adaptation strategies for seeps, springs, and wetlands in the face of an uncertain future.

Table 1. Projected change in precipitation under three climate scenarios and ecological impacts associated with reduced groundwater recharge relative to 1971-2000 baseline.

Scenario	Winter	Spring	Summer	Fall	Annual	Impacts to Seeps & Springs	Comments
Hot and Dry	+19%	-10%	-19%	-16%	-10%	19% increase in winter/spring recharge; 19% decrease in monsoon recharge.	The increased winter/spring recharge is likely to be beneficial however warmer temperature are likely to negate part of the increase; the decrease monsoon is likely to have less impact than the winter moisture, however indirect impacts will exist.
Feast and Famine	+6%	0	+3%	-9%	0	The increased winter precipitation is likely offset by increased temperature, thus leading to neutral or a small increase; summer recharge will be negative due to increased temperature	This scenario has the least amount of groundwater recharge of the three scenarios. It is likely to be the worst case scenario.
Warm and Wet	+13%	+6%	+8%	+10%	+9%	10% increase in winter/spring recharge; 9% increase in monsoon recharge.	Best case scenario with recharge seasons having increased precipitation.

Reference Condition Model

The Reference Condition Model is based on our expert reviewers and stakeholder workshops.

Seeps, springs, and other wetlands are primarily associated with groundwater in the San Juan / Tres Rios area. The primary climate variables driving groundwater recharge in this system are annual average temperature and winter moisture. Winter moisture, in the form of snow, has the highest recharge value as moisture penetrates into the deeper soils and the aquifer. Winter moisture, even in the form of rain is better at recharging groundwater than growing season moisture, due to minimal transpiration. While late summer/early fall moisture is often plentiful, groundwater recharge during this period is low due to several factors: high intensity rainfall often leads to more surface runoff than infiltration (exceptions exist) and evapotranspiration rates are extremely high, resulting in much of the precipitation used or lost before reaching groundwater.

In addition to the important climate variables, the geomorphological and vegetation attributes of the basin can also drive seeps, springs, and wetlands. Geology, slope and aspect, soil water retention capacity, and vegetation structure and cover can all influence the hydrology of seeps, springs, and other groundwater-dependent wetlands.

Hot and Dry Climate Scenario

In the Hot and Dry scenario, winter precipitation increases by nearly 20% while spring precipitation is reduced by 10%. Consequently, there is an overall increase in the capacity for groundwater recharge, associated with these two seasons. Conversely, this scenario projects an increase in the growing season by 3 weeks, which will increase the evapotranspiration, leading to less recharge. An 18% decrease in monsoonal precipitation will further exasperate recharge. In general, the increased winter/spring recharge is likely to be more beneficial than the other negative impacts, however a growing season that begins earlier due to warmer temperatures may have ramifications.

Feast and Famine (Moderately Hot) Climate Scenario

The feast and famine scenario may have the most negative impact to the seeps, springs, and wetlands, primarily due to the winter recharge season. In this scenario the increase in winter precipitation is 6% but because of the 3 F increase in temperature the overall recharge value will be low to none, especially if much of the precipitation is in the form of rain. While monsoon rains are less critical to groundwater recharge than winter/spring recharge, this is still an important parameter. The feast and famine scenario is likely to have more monsoonal precipitation but probably not enough to offset the important winter recharge season.

Warm and Wet Climate Scenario

In this scenario there is an approximate 10% increase in soil moisture recharge during winter/spring seasons. Monsoon recharge would increase by 9%. This is the best-case scenario for seeps, springs and wetlands because both recharge seasons are projected to see an increase in precipitation.

Table 2. Climate and non-climate drivers for seeps, springs, and wetlands comparing scenarios. Color of cells indicates the severity of change (key below table).

Primary Drivers	Hot and Dry Change	Feast and Famine Change	Comment
Winter snowpack	**+19%** increase in precipitation and **+4°F** temperature increase; much of the snow becomes rain	**+6%** increase in precipitation and **+3°F**; much of the snow becomes rain	Winter temperatures would go up in all three scenarios, ranging from 3.25-4F increase; thus, the difference in impact between scenarios is due to winter moisture, which is highest in the Hot and Dry and Warm and Wet, while the Feast and Famine has only a slight increase in winter precipitation and the lowest increase in winter temperature. However, note that the winter temperature is still high enough to cause much of the snow to fall as rain. There is probably a gradient, with the upper end of this elevation band being less impacted and the lower end being more impacted.
Spring precipitation	**-9%** precipitation **+ 4°F** temperature increase	**0%** change in precipitation and **+ 2°F**	The loss of spring precipitation in the Hot and Dry scenario would pose some loss of moisture and recharge for wetlands.
Summary of winter/spring recharge	Moderate to High	High to Moderate	The changes in the winter snowpack was evaluated as a higher concern than spring precipitation because snow recharges the groundwater better than rain.and plants are not growing (transpiring) in the winter. Currently our spring moisture comes as a mix of snow and rain. Further, the spring temperatures do not rise as much as winter temperatures, except in the Hot and Dry scenario. Plant growth often peaks in the spring and early summer season, thus more water use.
Summer/Fall rain	**-17%** precipitation and **+ +5-6 °F** temperature increase	**-3%** precipitation (small increase in summer and 9% decrease in fall); **+3°F** temperature increase	While monsoon rains are less critical to groundwater recharge than winter/spring recharge, this is still an important parameter. For the Hot and Dry scenario, the loss of the monsoon coupled with increased temperatures is likely to result in a large change to the landscape-scale vegetation that leads to many unknowns in terms of groundwater recharge.
Vegetation amount and type in basin	Drought years like 2002 occur every 5th year and negatively impact basin vegetation	Drought years like 2002 occur every 10th year. Vegetation receives beneficial wet years in between	If cover and composition of vegetation changes significantly basin-wide, the process of groundwater recharge can be negatively impacted. Reduced canopy cover can reduce evapotranspiration, but also increase the chance of surface runoff without infiltration. The Hot and Dry and Feast and Famine scenarios are more likely to cause large changes in vegetation.
Runoff generation and infiltration	Less frequent but more intense individual rain events. Flooding could scour the basin and reduce recharge	No change in frequency of rain events, but increase in more intense events	Increased runoff due to reduced vegetation cover may damage and erode soils, with a negative impact on groundwater recharge. In the Hot and Dry and Feast and Famine scenarios the landscape-level changes in vegetation are likely to negatively impact the infiltration capability.

Table 2, continued. Climate and non-climate secondary drivers for seeps, springs, and wetlands. Color of cells indicates severity of change (key below table).

Secondary Drivers	Hot and Dry Change	Feast and Famine Change	Comment
Evapotranspiration	Increased evapotransipiration intensifies the lack of precipitation	Not quite as high as Hot and Dry	In general, for every 2°F increase in temperature, evapotransportation increases about 5%, although other factors may offset the effect of temperature.
Hydrophobic soils	Depends upon the cycle of wildfires and changes in vegetation	Erosion is a high concern with the cycle of droughts alternating with intensive storms in wet years	Soils that are not naturally hydrophobic may become so after an intense fire. The effect can last for several years, but is not usually a long-term change.
Landscape level wildfire	Fire season widens by 1 month, coupled with increased drought length and severity	Fire season increases by 2 weeks; the Feast and Famine scenario could increase fire risk due to higher biomass during Feast years	In all scenarios, wildfire is anticipated to play an increasing role in disturbance in the landscape, altering basin-wide vegetation cover, changing the water balance, and altering soil water retention capabilities.
Faunal concentration	Faunal concentration goes up due to overall decrease in moisture	More year to year variation than Hot and Dry scenario	Due to the lack of options for finding water on the landscape, reliable sources of water will see increased, concentrated use by wildlife.
Invasives	Areas of bare soils develop with lack of moisture	Good summer moisture enables weeds to out compete other plants	Due to the cycle of dry years and wet years, invasive plants will out compete other vegetation by surviving in dry years and thriving in wet years.

Severity of Change
high
moderate
low to moderate
low

Impacts and Interventions

In order to focus our attention on the most robust and large-scale adaptation strategies for the seeps, springs and wetlands, we refined, categorized, and filtered the list of impacts and intervention points developed at the previous workshops (Appendix J). These priority intervention points were used as starting points for strategy development to address the three climate scenarios.

Questions

To assist us with filtering and prioritizing the impacts and interventions, we asked three primary questions:

1. Which impacts are most likely to be significant across all climate scenarios?
2. Which intervention points are most likely to work across all three climate scenarios?
3. Which intervention points are likely to work at a landscape-level scale?

Methods

In order to answer the above questions, we organized the interventions by the impacts that they addressed. We devised a process to score and prioritize the impacts and their interventions by their anticipated significance, likelihood across all scenarios, and landscape scale (Large, medium, or small). Impacts and interventions with a high score denoted a significant potential for addressing climate change. Thus, the higher ranking interventions would be the focus of our adaptation strategies workshop. We devised a ranking spreadsheet to determine the scores, summarized in Tables 3-4. The strategies on which we focused were considered: 1) likely to be effective in reducing climate impacts at a large landscape-level scale and 2) likely to be effective across the range of the three potential climate scenarios.

Table 3. Top impacts to seeps, springs, and wetlands across the three climate scenarios. The higher the score, the greater the scope and severity of the impact across all three climate scenarios.

Impact	Score
Altered fire regime	6
Altered groundwater recharge	4
Altered species and soil composition in watershed	6
Altered water regime	7
Decreased soil health and function	6
Forest mortality	6
Wetland habitat loss	6
Trampling of SSW from grazing	6

Table 4 presents the Intervention Category total score as a sum of the intervention and impact scores. Generally, there were multiple impacts and interventions associated with an intervention category, thus we took the average. The total score, coupled with scale, was used to define which intervention categories would be the focus of our adaptation strategy workshop. The bolded intervention categories were selected for additional development as our initial strategies. Cross-cutting denotes the need to subsume these interventions into all strategies.

Table 4. Intervention categories with total score and landscape scale. The total score is a sum of the intervention and impact scores. Generally there were multiple impacts and interventions associated with an intervention category, thus we took the average. The total score, coupled with scale, was used to define which intervention categories would be the focus of our adaptation strategy workshop. The bolded intervention categories became our strategies. Cross-cutting denotes the need to subsume these interventions into all strategies.

Intervention Category	Average of Total score	Average of Intervention Score	Average of Impact Score	Scale
Assist/ allow transformation	10.0	6.0	4.0	Lower zones
Cross boundary coordination	12.7	6.3	6.3	Cross-cutting
Manage wetland grazing for resilience	**13.0**	**7.0**	**6.0**	**All zones**
Identify and protect refugia	**14.0**	**7.0**	**7.0**	**All zones**
Proactive fire management	10.0	4.0	6.0	Cross-cutting
Proactive management for resilience	**11.0**	**5.9**	**5.1**	**All zones**

The final three strategies identified for further development include:

1. **Identify and protect refugia**: protection, management and restoration are much more likely to succeed if these activities occur within a climate refugia
2. **Proactive management for resilience**: this strategy had numerous interventions and generally mirrors much of what managers are already doing. It is most likely to succeed in areas that are considered "refugia"
3. **Manage grazing for resilience**: as wetlands are valuable and sought after resources, grazing by domestic and wild animals can dramatically impact their viability and long-term resilience.

Goals and Objectives for Seeps, Springs, and Wetlands

Goals

In the face of a changing climate, protect, enhance, connect, and maintain seeps, springs, and wetland resources to support native biodiversity of viable populations of target plant and animal species of concern* *(or spring/wetland obligates)* while suppling human communities with a suite of human values and ecosystem services, e.g., clean and abundant water, recreation opportunities, hunting, food and shelter, and cultural or spiritual values.

**Animals of Concern: Boreal toad, Northern leopard frog, Canyon tree frog, Bighorn sheep, amphibians, Nokomis fritillary butterfly, Black swallowtail butterfly, Gunnison Sage Grouse*

**Plants of Concern: Parish's alkali grass, Giant helleborine, Slender rock-brake, ferns, Kachina daisy, Russet cottongrass, Eastwood monkey-flower*

- Enhance resiliency of seeps, springs and wetland ecosystems to climate change by maintaining hydrological connections and processes, restoring or improving the condition of these ecosystems to support a variety of wildlife species, and ecosystem services including livestock grazing and recreation.
- Manage human uses on the landscape in ways that benefit the hydrologic connections and health of the native species, e.g., recreation, residential development, grazing, ranching, energy development, water systems, mining, roads, research.
- Reduce stressors that will be exacerbated in a changing climate.
- Maintain a diverse composition of desirable hydrophytic plants, trees, and shrubs sufficient to be vigorous and self-perpetuating.
- Maintain vegetation cover sufficient to catch sediment, dissipate energy, prevent erosion and enhance aquatic and terrestrial habitats.
- Seeps, springs and wetlands are resilient to change from disturbances from floods, fire, drought, and other changes in climate.
- Composition of seeps and hanging gardens are intact, including native plant species, organic soils, and hydrology.
- Water quantity, flows, and hydrologic systems are sufficient to support and sustain these communities.

Objectives

Utilize the following zones when considering the objectives: infiltration zones, ground-water recharge zone at a watershed level, and the immediate wet zone. Emphasis is placed on seeps, springs, and wetlands that are most likely to persist under extreme long-term droughts, i.e., climate refugia sites.

Within 5-20 years:

- Restore the ecological integrity of deciduous wetland sites, increasing the canopy cover of native hydrophytic shrubs.
- Determine the functional condition of wetland communities using appropriate assessment methodology.
- Eradicate tamarisk, Russian olive, and other noxious invasives, (e.g., Canada thistle, oxeye daisy) from infested areas within refugia; and if needed, conduct follow-up treatment to prevent the establishment or spread of other invasive species.
- Maintain native seeps, springs, wetlands and upland communities that have been treated to control non-native species on stream reaches over the next 20 years.
- Protect springs and wetland vegetation and soils from non-climate stressors, such as managing grazing by stock or feral animals to protect wetland refugia.
- Protect springs and wetlands from contamination and groundwater depletion and non-climate stressors.
- Restore and reconnect groundwater supplies.

Adaptation Strategies, Outcomes and Actions for Seeps, Springs, and Wetlands

The climate adaptation strategies for seeps, springs, and wetlands are presented below in both table format and results chains. These strategies incorporate all of the information gathered over the course of this project, e.g., climate scenarios, ecological response models, situation analyses, chain of consequences, identification of interventions and impacts, and social science research findings.

Three Priority Adaptation Strategies

Adaptation strategy
Identify and Protect Refugia (persistent areas) We can identify and manage the areas that are most likely to persist under our future climate. Conservation, management, and restoration are much more likely to succeed if within a climate refugia.
Proactive Management for Resilience These strategies allow us to develop management and/or restoration plans that will improve the resiliency of seeps, springs, and wetlands, especially within those areas that are likely to be persistent.
Proactive Grazing Management for Resilience It is important to recognize the important role of seeps, springs and wetlands for livestock and wildlife and to manage for the persistence and resilience of these resources

Strategies are summarized and depicted in results chains below.

Strategy 1: Identify and Protect Persistent Ecosystems

Desired Outcome
Seeps, springs, and wetlands have improved hydrologic functioning even in the face of drought. Loss of seeps, springs, and wetlands is reduced.

Identifying, protecting, and managing communities that are likely to persist in the face of climate change will assist in maintaining resilient seeps, springs, and wetlands that support viable populations of species of concern and supplies our human communities with a suite of ecosystem services.

►Intermediate outcomes (objectives) ✧Actions to achieve outcome

Refugia are persistent communities that are likely to support current communities into the future.

- ► Biophysical attributes that are in persistent seeps, springs, and wetlands are identified
  - ✧ Gather available data (location, trend, soils, etc.)
  - ✧ Determine physical characteristics for seeps, springs and wetland persistence, such as: soils, geology, aquifers
  - ✧ Identify watershed catchments and depressions
  - ✧ Use soil conservation district information to determine soil characteristics likely to support seeps, springs, and wetlands
  - ✧ Gap analysis to determine where geomorphology and water characteristics are likely to support seeps, springs, and wetlands
  - ✧ Use water chemistry to identify deep to shallow aquifers
  - ✧ Use NDVI 2002 and 2012 to identify areas that remain wet in dry periods
- ► Linkages are identified between persistent areas that support SSW ecosystems and viable populations of obligate SSW species
  - ✧ Identify fragmentation patterns for current and future uses: roads, infrastructure, etc.
  - ✧ Review NRCS soil maps
  - ✧ Develop a regeneration plan for each species for refugia, based on the life history and structure of each wetland community
  - ✧ Identify existing species management areas that support refugia
  - ✧ Identify edges of pinyon-juniper woodlands
  - ✧ Identify cultural values and sites related to seeps, springs, and wetlands
  - ✧ Create map of potential refugia and linkages (identify attributes: patch size)
- ► Private land support is secured for persistent seeps, springs, and wetlands identified and preserved through conservation easements
- ► Viable livelihoods are maintained
  - ✧ Ranching livelihoods
  - ✧ Cultural tourism: Consult tribal members regarding sensitive areas / refugia

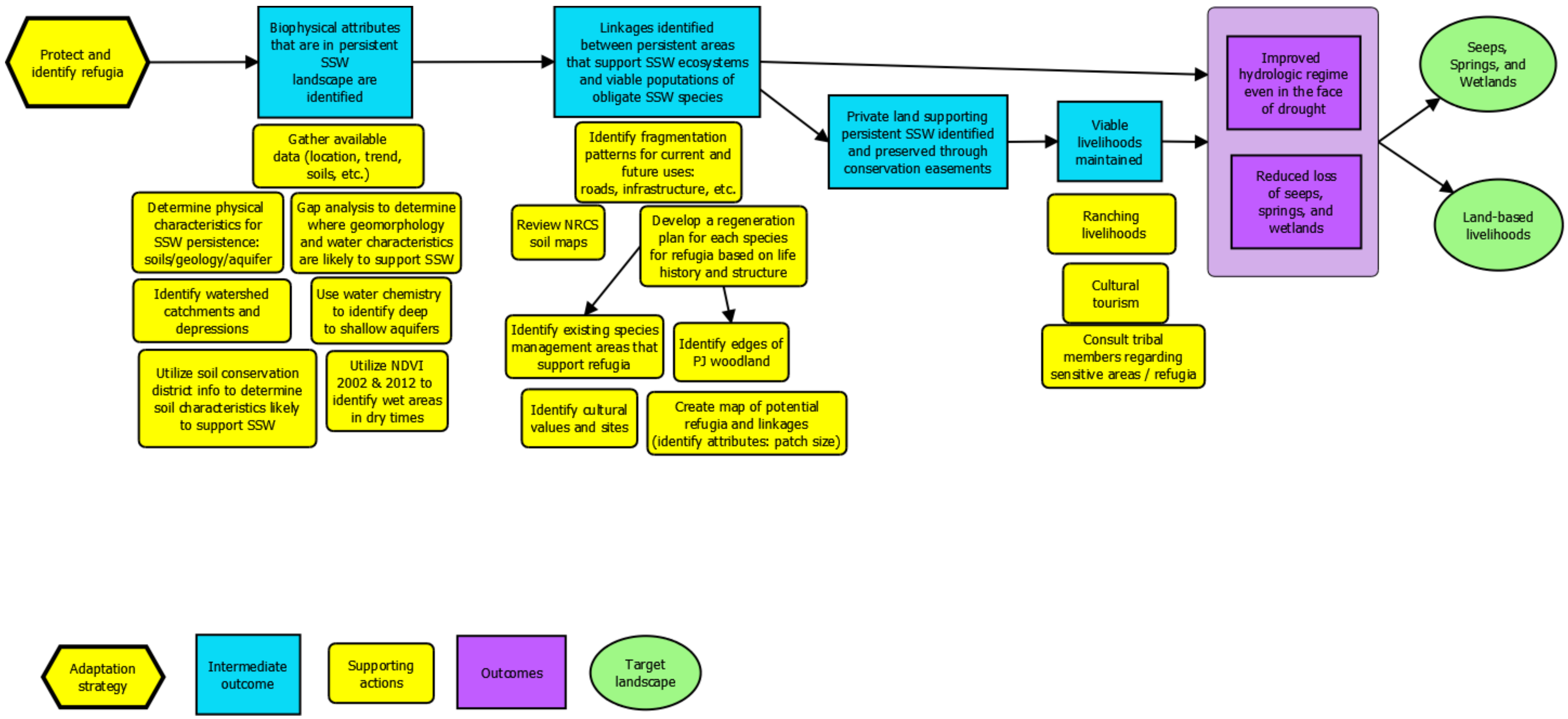

Figure 3. Results chain describing outcomes and actions to identify and protect persistent areas strategy.

Strategy 2. Proactive Management for Resilience

Desired Outcome

Watershed health, soil health and water holding capacity, and groundwater health are improved. Condition of seeps, springs, and wetlands is improved. The loss of seeps, springs, and wetlands is reduced.

Maintaining ecological processes, restoring and improving the natural conditions, and reducing climate stressors may increase the resiliency of seeps, springs, and wetlands and thereby sustain traditional, aesthetic, and ecosystem values and services.

►Intermediate outcomes (objectives) ✧Actions to achieve outcome

- ► Additional partners, regulations, and funding with mutual goals, such as migratory birds, are identified
- ► Constituency for water law reform is built
    - ✧ Lobby lawmakers to appropriate flexibility
- ► Alternative water exchanges are developed
    - ✧ Sponsoring Colorado Water Conservation Board-supported flows to support seeps, springs, and wetland systems to obtain a bigger water right to maintain wetlands and floodplains
    - ✧ Secure recreation in-stream flow
    - ✧ File more water rights for wildlife
    - ✧ Educate landowners about water rights options
- ► Water law renegotiated to support wetlands
    - ✧ New development encourages rain catchment
    - ✧ Change rural rain barrel law
- ► Incentives for efficiency developed in municipal and county policy
    - ✧ Discourage development with wells near seeps, springs, and wetlands buffer
- ► Degraded historic wetlands are restored
    - ✧ Develop tax incentives for restoration
- ► Efficiency and infiltration of irrigation systems are improved
    - ✧ Incentivize water efficiency
- ► Infrastructure for infiltration is improved and maintained
    - ✧ Design gravel mines and develop projects to infiltrate
    - ✧ Promote the use of retention ponds
- ► Degraded streams are restored
    - ✧ Restore incised/degraded surface water systems to restore groundwater tables
- ► Groundwater recharge areas are protected
    - ✧ Improve/slow stream channel flow to improve infiltration
    - ✧ Identify recharge areas and methods to protect them
- ► Floodplain oxbows are reactivated
    - ✧ Secure water rights
    - ✧ Revegetate riparian buffers and encourage beavers
- ► Watershed vegetation is restored to hold water and facilitate recharge
    - ✧ Prevent and suppress fires in pinyon-juniper

  - Focus post-burn revegetation (climate-smart seed mixes)
  - Manage grazing
  - Silviculture techniques for snow retention
  - Remove invasives such as tamarisk and Russian olive
- Erosion is reduced
  - Prevent and suppress fires in pinyon-juniper
  - Manage/utilize and restore buffers
  - Expand existing buffers
- Groundwater holding capacity is increased
  - Protect infiltration
  - Improve irrigation efficiency
  - Reduce demand for groundwater
  - Limit impervious surfaces
  - Inject water into aquifers
- Water re-use innovations are developed
  - Promote water reclamation techniques and science

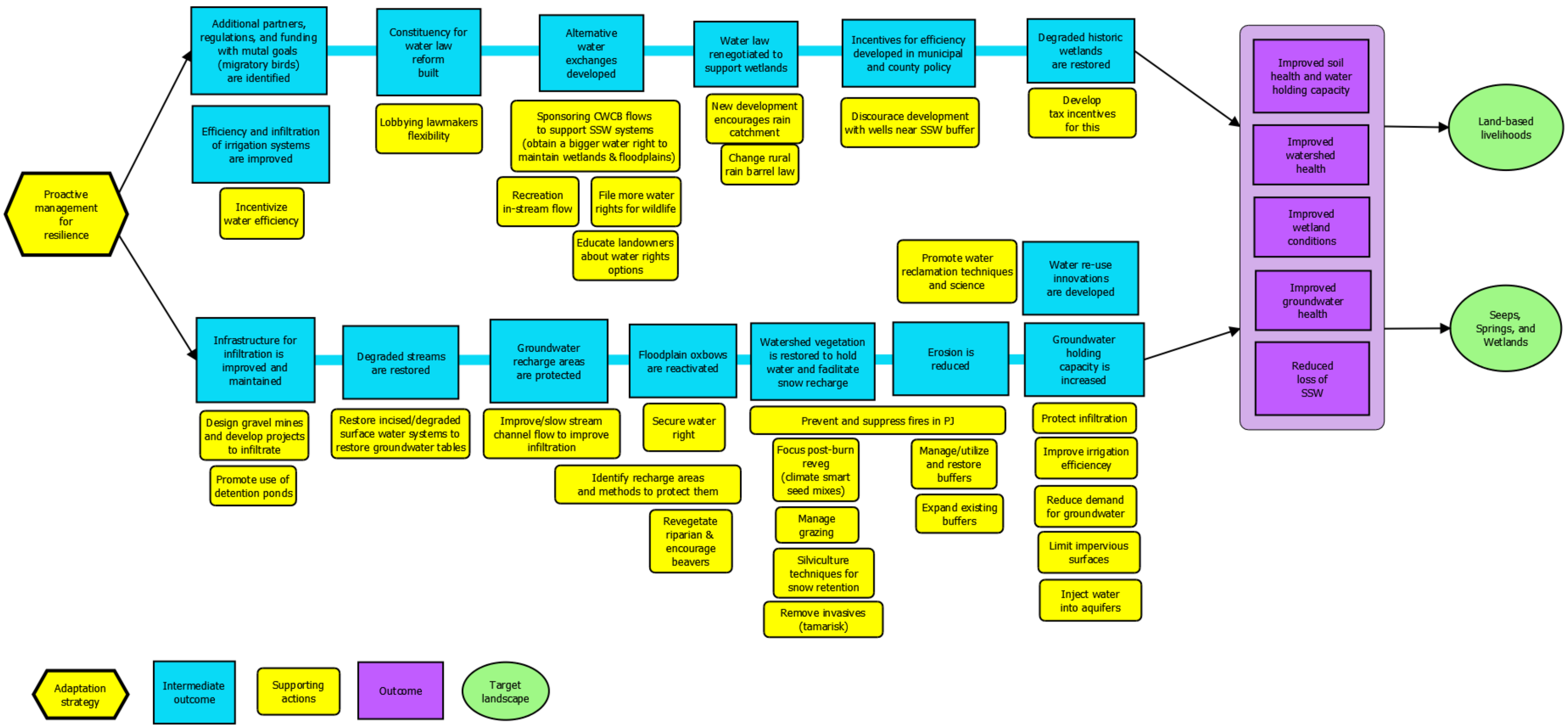

Figure 4. Results chain describing outcomes and actions for proactive treatment for resilience strategy.

Strategy 3: Grazing Management

Desired Outcome

Condition of seeps, springs, and wetlands is improved. Loss of seeps, springs, and wetlands is reduced.

►Intermediate outcomes (objectives)
✧Actions to achieve outcome

- ► Water available to animals is placed outside seeps, springs, and wetlands
  - ✧ Provide drinkers outside wetlands
  - ✧ Exclude grazing from sensitive zones
  - ✧ Remove feral animals from sensitive seeps, springs, and wetlands
- ► Watershed and catchment are managed for healthy forbs, shrubs, and soils
- ► Wetland vegetation biodiversity within seeps, springs, and wetlands is improved
- ► Water retention is improved
- ► Buffers and setbacks associated with seeps, springs, and wetlands are utilized
- ► Proactive climate-smart restoration plan for encouraging emergent species is developed
- ► Think tank / extension programs for innovating best management practices are developed
  - ✧ Work with ranchers
- ► Policy incentives for municipal and state tax structures for private grazing BMPs are developed
- ► Variable age classes are maintained for seed production by large cone-producing trees
  - ✧ Focus on ecosystem services
  - ✧ Ensure that appropriate agricultural practices receive tax credit
- ► Permit flexibility for managers is increased
  - ✧ Develop in-season flexible terms and conditions that address seasonal variability and drought years
  - ✧ Use seasonal forecasts to determine measures
  - ✧ Develop adaptable on/off dates for grazing permits
  - ✧ Permittees develop drought management plans
  - ✧ Adjust grazing in seeps, springs and wetland areas during productive seasons
  - ✧ Pre-approve NEPA to offer alternative water resources to augment during drought
  - ✧ Build support with permittees to protect seeps, springs, and wetlands and connection to human livelihoods

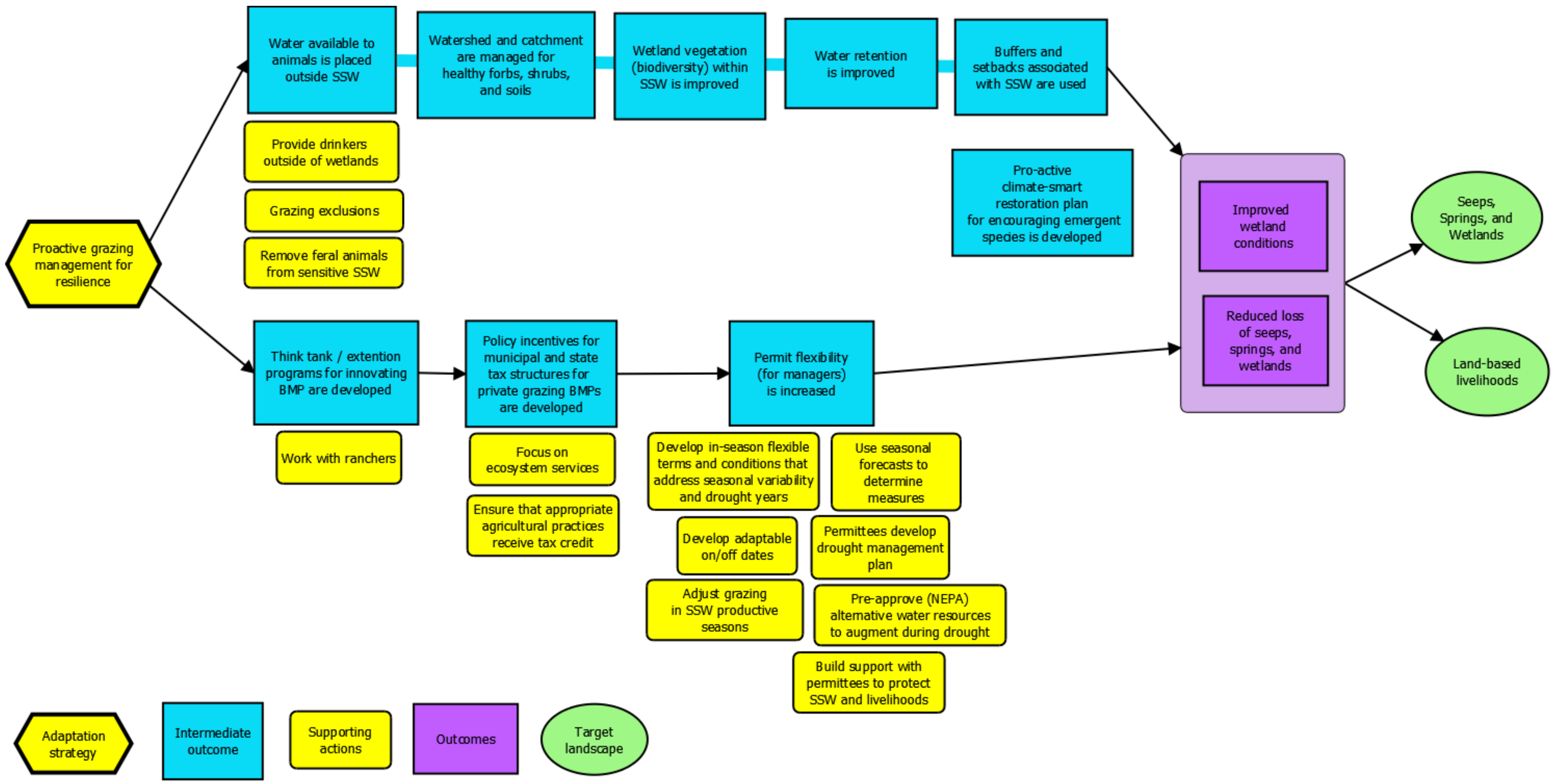

Figure 5. Results chain describing outcomes and actions for grazing management strategy

NEXT STEPS

1. Share project results and seek feedback from upper level managers of USFS, BLM, NRCS, NPS, etc.
2. Develop an outreach plan for the key strategies; initiate research and monitoring; and design workshops.
3. Further develop the strategies, particularly the grazing resilience strategy, to help clarify the desired outcomes and audience.
4. Develop strong partnerships with the grazing community who also depend upon the ecological resources of seeps, springs, and wetlands.
5. Develop a clearinghouse for sharing maps, GIS data, charts, graphs, bio-climate models, and other products that are accessible to managers, participants and stakeholders.
6. Apply and refine the social-ecological framework to additional conservation targets and in other regions.
7. Publish a concept paper.
8. Develop diverse and creative communication packets that can be utilized by various audiences.
9. Develop a streamlined template of the framework that can be applied to other conservation projects across the state and to other states.

CONCLUSIONS AND LESSONS LEARNED

The planning framework used for this project consisted of assessing ecological vulnerabilities; selecting multiple social-ecological landscapes; developing climate scenarios; developing narrative scenarios and ecological response models; conducting social science interviews/focus groups, developing social-ecological response models; identifying impacts and interventions, and developing adaptation strategies. The framework was applied using a stakeholder-driven process with natural resource managers and researchers to develop robust climate adaptation strategies for the pinyon-juniper landscape in the San Juan Basin.

The project team worked with the San Juan Climate Initative and other stakeholders to apply the planning framework to two targeted landscapes (pinyon-juniper woodlands and seeps, springs and wetlands) in the San Juan Basin in Colorado. At the same time, another group of stakeholders focused on spruce-fir forests and sagebrush in the Gunnison Basin (described in a separate report). The two groups ended up with similar themes of adaptation strategies: conserve climate refugia, proactively treat for resilience, and assist and allow transformation within emergent and threatened zones.

Important next steps include developing an adaptation strategy plan, implementing actions, and designing a monitoring plan to detect trends, and evaluate the efficacy of actions. This framework could be applied in other landscapes and inform on-the-ground work to prepare for change.

Lessons Learned

Climate Scenarios and Bio-Climatic Models

Developing impacts and interventions for one climate scenario (Feast and Famine) first and then evaluating how well those strategies addressed the other two scenarios helped to streamline the process. A number of workshop participants commented about the utility of the bio-climatic models to help visualize geographically opportunities for implementing strategies. One participant suggested the need for more consideration of extreme events in all scenarios, interventions and strategies.

Situation Analysis and Chain of Consequences Methods

Workshop participants suggested using Situation Analysis first to brainstorm and explore a broad range of impacts followed by the Chain of Consequences to drill down into more specific consequences and interventions. Some participants found it challenging to follow the use of sticky notes for developing the Situation Analysis and suggesting using sideboards to help guide the process and outcomes. It is important to allow enough time to develop comprehensive chains and interventions, potentially up to one-half day per impact. Additional preparation may improve efficiency given the time constraints, e.g., having a "pre-loaded" list of primary consequences from which to react to and build from may have saved time at the workshop.

Opportunity to compare results developed by different groups

Different participant groups produced different results at the 2015 workshop using the two different methods, Situation Analyses and Chain of Consequences. While the primary consequences were similar among groups, the choice of which chains to further develop, chain length, and the focus on ecological versus socioeconomic consequences differed among groups. Some results clearly reflected the composition of the group (e.g., groups with more social scientists explored more social and economic issues). Therefore, in order to have a balanced outcome that integrates social and ecological interests requires careful attention to recruiting participation from the full suite of stakeholders within a system of interest.

Social Science

The social science research can help ecologists, climate scientists, and stakeholders understand how decision makers view and currently address climate change, which leads to more robust strategies. The use of narrative scenarios in a participatory workshop allowed natural resource manager and permittes to discuss climate impacts and their responses to impacts in a facilitated group setting. Coupling the results of the social science interviews and participatory narrative scenarios workshops provided an initial set of responses and challenges that decision makers are faced with. One example of an important result is that the mangers view a feast and famine scenario as extremely challenging even though the ecological impacts were not as severe as the hot and dry scenario. The social scientist were not able to attend all of the additional workshops that were held, e.g. developing impacts and interventions workshop and building strategies workshop. In an ideal world, social scientist would have been at all of the workshops, thus ensuring a fully integrated social-ecological project.

Results Chains

Workshop participants noted that walking through the Results Chains step by step, discussing gaps or redundancies, was useful in developing the strategies and stimulating discussion and refinement. The Results Chains provided a structure to develop actions, but due to time constraints we were not able to develop more detailed and measurable action items. Having workshop participants present the results chains was informative and it was helpful to link them to the goals and objectives.

Workshops

The workshops provided an opportunity for thought-provoking discussion, interaction and learning for an interdisciplinary group of stakeholders, managers, and academics with different perspectives. The process of discussing goals and outcomes with state and regional stakeholders enabled participants to put their work into the larger perspective. Engaging participants to present results of breakout group work, goals/objectives or strategies helped with understanding and buy-in and stimulated good discussion. Participants noted the importance of providing all materials developed through this project for reference at each workshop. The workshops provided a wonderful opportunity for managers, tribal staff, scientists, and resource specialists to engage with others from different agencies, tribes, and districts. After the earlier workshops, several participants commented that it would have been useful to have more diverse user groups, e.g., non-governmental stakeholders. The team worked to broaden representation for later workshops.

Approach and Duration

This project applied multiple methods to identify impacts of climate change on the pinyon-juniper landscape and to develop social-ecological adaptation strategies, e.g., ecological response models, Chain of Consequences, Situation Analysis, social science, and Results Chains. This stakeholder-driven process took over three years to conclude. Application of different methods resulted in similar adaptation strategies- for instance, the basic strategies of protect refugia rose to the top for all of the landscape targets. Thus, in the future, to increase efficiency in developing adaptation strategies for other landscapes or ecosystems, teams may utilize only one or two methods to develop robust strategies. Developing the products over a shorter time period might help with ensuring consistent participation at workshops.

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APPENDICES: SEEPS, SPRINGS, AND WETLANDS

Appendix A. Glossary

Adaptation
Climate change adaptation for natural systems is a management strategy that involves identifying, preparing for, and responding to expected climate changes in order to promote ecological resilience, maintain ecological function, and provide the necessary elements to support biodiversity and sustainable ecosystem services.

Adaptation Actions
Specific on-the-ground management or conservation actions associated with adaptation strategies that will strengthen the resistance and resilience of sites, habitats, and species under a changing climate. Designed specifically to address the impacts of climate change.

> *Example: Plant riparian vegetation along target streams in areas that have been denuded to provide stream shading and buffer floods.*

Adaptation Strategies
Management efforts designed to help nature and people prepare for and adjust to climatic changes and associated impacts. Strategies are focused on reducing impacts of climate change on nature and people, reducing non-climate stressors, protect ecosystem features, ensure connectivity and restore ecosystem structure and function a large scale.

In-depth strategies have nested actions and articulate what you are trying to do, how, when and where you will implement actions to meet goals and objectives. Ideally, they are robust across different climate scenarios. They are not intended to be decision making, rather for informing decision-making.

> *Example of a high-level adaptation strategy for the Gunnison sage-grouse brood-rearing habitat: Retain water in most-vulnerable brood-rearing habitats through water management: restore wet meadows across the Gunnison Basin to build ecosystem resilience and help the Gunnison sage-grouse and other wildlife species adapt to drought and intense precipitation events associated with climate change.*

> *Example: Shift the age class distribution of conifer forest in 10 locations across the basin, by planting diverse species of trees, followings best practices.*

Chain of Consequence
Identifies the potential short- and long-term environmental, social, and economic cascading consequences of an event or disturbance, and determines intervention points. Methods developed by the Department of the Interior (US Geological Survey). Method used at the April 2015 climate adaptation workshop.

Climate Scenarios
To aid in decision-making in the face of uncertainty, climate scientist Imtiaz Rangwala (PSD/NOAA; WWA/CIRES, University of Colorado) developed three climate change scenarios for southwestern

Colorado based on a range of temperature and precipitation projections by 2035 from 72 global climate models that considered 2 RCPs-representative concentration pathways (8.5 and 4.5). These scenarios represent three plausible but divergent future climate pathways for southwestern Colorado during the 21st century (Rangwala, 2015).

> *Climate scenarios for this project are: 1) Hot and Dry, 2) Warm and Wet; and 3) Feast and Famine (moderately hot, no change in precipitation, increased climate variability).*

Conservation Target

For the purposes of this project, a conservation target consists of a large-scale landscape, consisting of both natural and human systems, that is targeted for conservation and adaptation strategy development. The targeted landscapes for the San Juan Basin include pinyon-juniper woodlands and seeps, springs, and wetlands. Numerous animal species, plant species and human communities in the San Juan rely on functioning sagebrush and spruce-fir landscapes that are at risk of a changing climate.

The pinyon-juniper landscape consists of a mosaic of ecosystems dominated by a mix of pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), and at upper elevations Rocky Mountain juniper (*J. scopulorum*). Smaller patches of oak, mountain shrubland and grassland ecosystems are scattered throughout the landscape. It is the core habitat for Pinyon jay. Pinyon-juniper obligate birds species are Pinyon Jay, Gray vireo, and Juniper titmouse. Other animals of concern include Gunnison Prairie dog, Fringed myotis, Hoary bat, Spotted bat, and Merriam's turkey. These woodlands are also important habitat for larger game animals including mule deer and elk.. This landscape ranges in elevation from 5,400 and 7,650 feet.

Seeps, springs, and wetlands within the San Juan Basin are found throughout every elevation band and major vegetation type. In general the seeps, springs, and wetlands above 8,500 feet are considered less vulnerable to climate change, primarily due to the amount of winter precipitation that is likely to fall as snow. The lower elevations (4,500-8,500 ft) types (slope wetlands, depressional wetlands, mineral and soil wetlands, riverine wetlands, springs, and seeps) are considered highly vulnerable to future climate change, and will be the focus of adaptation strategy development. At the lower elevations these wetlands will most often be associated with desert shrublands/grasslands, and pinyon-juniper, sagebrush, or mountain shrubland ecosystems. Ponderosa pine and oak shrublands are the most common ecosystem type within the upper elevation areas. The most important (primary) driver is groundwater recharge. Winter and spring moisture are the most critical months for recharge as most of the precipitation events will percolate down into deeper depths, including the aquifer. Snow is generally better at recharging an aquifer than rain, thus monsoonal rains generally are not as critical for recharging the aquifer.

Ecological Response Models

Ecological response models, based on literature review and expert opinion, describe how the landscape operates and provides a context for evaluating potential impacts of different climate scenarios. Models help identify outside environmental influences or drivers, and show the relationships among the main contributing factors that drive one or more of the direct threats that, in turn, impact the landscape. The purpose of assessing the model under 3 different climate scenarios is to provide a foundation of scientific understanding and inform the development of robust social-ecological adaptation strategies in the face of an uncertain future.

Goals

Broad aspiration or overarching vision for focal features. Should be forward looking rather than retrospective.

> *Example: Maintain forest cover of sufficient structural and compositional complexity that it can sustain key ecosystem functions, particularly providing habitat for forest-dependent songbirds and other wildlife.*

Intervention Points

Elements in the system that can be manipulated or influenced through management and/or conservation actions; *starting points for developing in-depth adaptation strategies, policies and actions.* For this project, interventions were identified through situation analyses and chain of consequences for the Feast and Famine scenario at the May 2015 workshop. Interventions were then evaluated to see how well they work for the other two scenarios.

> *Examples for managing altered fire regime: create fire breaks; suppress fires; control cheatgrass spread*

Linkages

Also known as corridors. Any space, usually linear in shape, that improves the ability of organisms move among patches of their habitat. What serves a corridor for one species may not serve as a corridor for other species. Corridors can be natural features of a landscape or can be created by humans. Connectivity is a measure of the ability of organisms to move among separate patches of suitable habitat and can be viewed at various spatial scales (Hilty et al. 2006)

Objectives

Specific, measurable aims towards achieving goals. Ideally, defines the what, when, why and where.

> *Examples: By 2035, increase abundance of historically dominate boreal conifers, e.g., white spruce, white pine, tamarack, by 5 % with 80% confidence; Increase native fish populations to viable numbers, restore 1200 acres of salt marsh habitat with 90% confidence.*

Refugia

Physical environments that are less affected by climate change than other areas (e.g., due to geographic location) and are thus a "refuge" from climate change for organisms. Protection, management and restoration are much more likely to succeed if within a climate refugia.

Representative Concentration Pathway (RCPs)

Representative concentration pathways (RCPs) are climate scenarios implemented in the IPCC Fifth Assessment Report. Each RCP (2.6, 4.5, 6.0, and 8.5) provides projections of atmospheric greenhouse gas concentrations over time, based on assumptions about economic activity, energy sources, population growth and other socio-economic factors. RCPs have generally replaced the emissions scenarios (A1, A2, B1, B2, etc.) used in previous climate projection efforts.

For each category of emissions, an RCP contains a set of starting values and the estimated emissions up to 2100, based on. (The data also contain historic, real-world information). While socio-economic projections were drawn from the literature in order to develop the emission pathways, the database does not include socio-economic data.

Resilience

Traditionally, resilience refers to actions designed to improve the capacity of a system to return to desired conditions after disturbance, or as a means to maintain some level of functionality in an altered state. In the adaptation literature, resilience is considered part of a continuum of strategies, from resistance, to resilience and transformation. Recently, the concept of resilience has been used more expansively to embrace the potential for continued functionality and self-organization in the process of ecological transitions. Managing for resilience can be considered a way to enhance the natural adaptive capacity of systems by increasing their ability to self-organize in response to change (Stein et al. 2014).

Because the term has multiple meanings, it is important to clearly state the context in which it is being used, e.g., resilience of what (e.g., ecosystems, livelihoods), to what changes (floods, drought) and how much of what kinds of changes (in structure or function).

> *Example: Resilience of North Woods Forests to negative effects of warming, drying of forest vegetation; keep system a forest, prevent conversion to shrub/grassland, but accept changes in composition.*

Resistance

The ability of an organism, population, community, or ecosystem to withstand a change or disturbance without significant loss of structure or function. From a management perspective, resistance includes both (1) the concept of taking advantage of/boosting the inherent (biological) degree to which species are able to resist change and (2) manipulation of the physical environment to counteract/ resist physical/biological change.

Results Chain

A diagram that depicts the assumed causal linkage between a strategy and desired outcomes needed to reduce climate impacts (and other threats) through a series of expected intermediate outcomes and actions (modified from Margoluis 2013). Results chains are important tools for helping teams clearly specify their theory of change behind the strategies/actions they are implementing. Results chains can help teams to make assumptions behind strategies/actions and develop relevant indicators to monitor and evaluate whether their actions will have the intended impact.

Situation Analysis

Identifies specific connections between people and nature and allows exploration and understanding of the political, socioeconomic, cultural, institutional and ecological context of a landscape. This analysis describes the current understanding of a project's ecological status and trends, and the human context; and is used to identify intervention points for developing strategies. Methods were developed by the Conservation Measures Partnership and used at the April 2015 climate adaptation workshop.

Transformation

The expectation and acceptance that a conversion to a new ecosystem type is likely to occur, i.e., a transformation from one ecosystem type to a new ecosystem type. Transformation strategies support and facilitate system changes to an altered state based on predicted future climate. The altered state is unlikely to support the climate processes necessary for regeneration of the dominant species that the system is known for.

> *Example: Due to a new climate, a low-elevation sagebrush stand is unlikely to support sagebrush and is likely to transform into a new ecosystem type such as a desert grassland or a grassland dominated by cheatgrass.*

> *Example: A low-elevation montane aspen stand is killed due to a drought and mountain sagebrush moves into the area, and the climate no longer supports aspen regrowth.*

Appendix B. Workshop Participants, Seeps, Springs, and Wetlands

Participants of Seeps, Springs, and Wetlands Climate Adaptation Workshops:

NAME	Organization	2 Dec. 2013	27 July 2014	1 Mar 2015	4 May 2015	15 Mar 2016	7 Apr 2016
Aaron Kimple	Mountain Studies Institute				1		1
Allan Loy	Mesa Verde National Park		1				
Andrew Straub	San Juan National Forest						1
Austin Mathes	Mesa Verde National Park		1				
Barb Sharrow	Bureau of Land Management						1
Ben Martinez	San Juan National Forest			1		1	1
Bill Baker	Scientist		1				
Bill Neligan	Mesa Verde National Park		1				
Bill Zimmerman							1
Bruce Rittenhouse	Colorado Bureau of Land Management	1					1
Cara Chadwick	San Juan National Forest						1
Cara Gilder	San Juan National Forest				1		
Carina Wyborn	University of Montana	1					
Carol Sperling	Mesa Verde National Park		1				
Celene Hawkins	The Nature Conservancy					1	1
Chris Rasmussen	Scientist				1	1	
Cliff Spencer	Mesa Verde National Park		1				
Curtis Hartenstein	Southern Ute Indian Tribe						1
Cynthia Dott	Fort Lewis College						1
Daniel Long	Mesa Verde National Park		1				
Duncan Rose	Trout Unlimited						1
Emily Olson	Chama Peak Land Alliance, MSI	1	1				1
Esme Cadiente	Mountain Studies Institute	1	1	1	1	1	1
George San Miguel	Mesa Verde National Park	1	1		1	1	1
Gretchen Fitzgerald	San Juan National Forest	1			1	1	
Heidi Steltzer	Fort Lewis College				1		
Imtiaz Rangwala	NOAA, North Central Climate Science Center	1			1		
Isaac Cadiente	San Juan National Forest						1
Jeff Morrisette	North Central Climate Science Center	1					1
Jesse Ramerez	Southern Ute Indian Tribe						1
Jessie Farias	Mesa Verde National Park		1				
Jim Friedley	Southern Ute Tribe BIA			1		1	1
John Toolen	BLM						1
Kelly Palmer	San Juan National Forest			1	1		
Lindsey Eoff	Tres Rios FO Bureau of Land Management				1		
Marcie Bidwell	Mountain Studies Institute	1	1	1	1	1	1
Marty Moses	NRCS, Bird Observatory of the Rockies						1
Marybeth Garmoe	Mesa Verde National Park		1				
Matt Azhocar	Colorado Bureau of Land Management						1
Nina Burkhardt	USGS Fort Collins Science Center	1					
Paul Morey	Mesa Verde National Park		1	1	1	1	1
Pauline Ellis	San Juan National Forest						1

NAME	Organization	2 Dec. 2013	27 July 2014	1 Mar 2015	4 May 2015	15 Mar 2016	7 Apr 2016
Renee Rondeau	Colorado Natural Heritage Program	1	1	1	1	1	1
Scott Travis	Mesa Verde National Park		1				
Shannon McNeally	North Central Climate Science Center	1					1
Shauna Jensen	San Juan National Forest			1		1	1
Steve Monroe	Scientist, National Park Service		1	1	1	1	1
Steve Underwood	Mesa Verde National Park		1				
Steve Whiteman	Southern Ute Indian Tribe						1
Tim Cutter	Mountain Studies Institute				1		
Tim Hovezak	Mesa Verde National Park		1				
Tomoe Natori	Ute Mountain Ute Tribe			1	1		
Tova Spector	Mesa Verde National Park						1

APPENDIX C. CLIMATE SCENARIOS

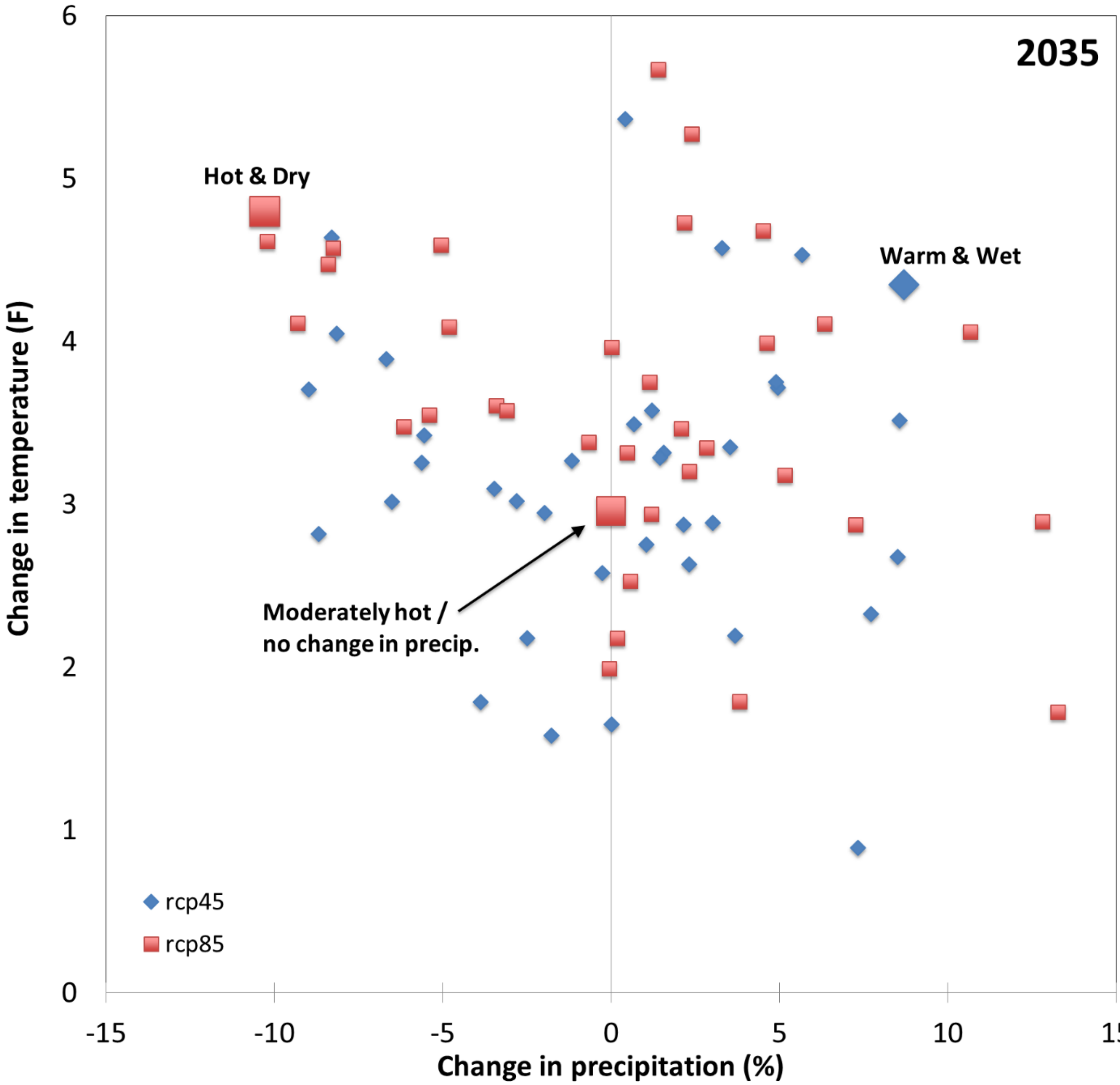


Figure B-1. Models selected for the three climate scenarios used in the project.

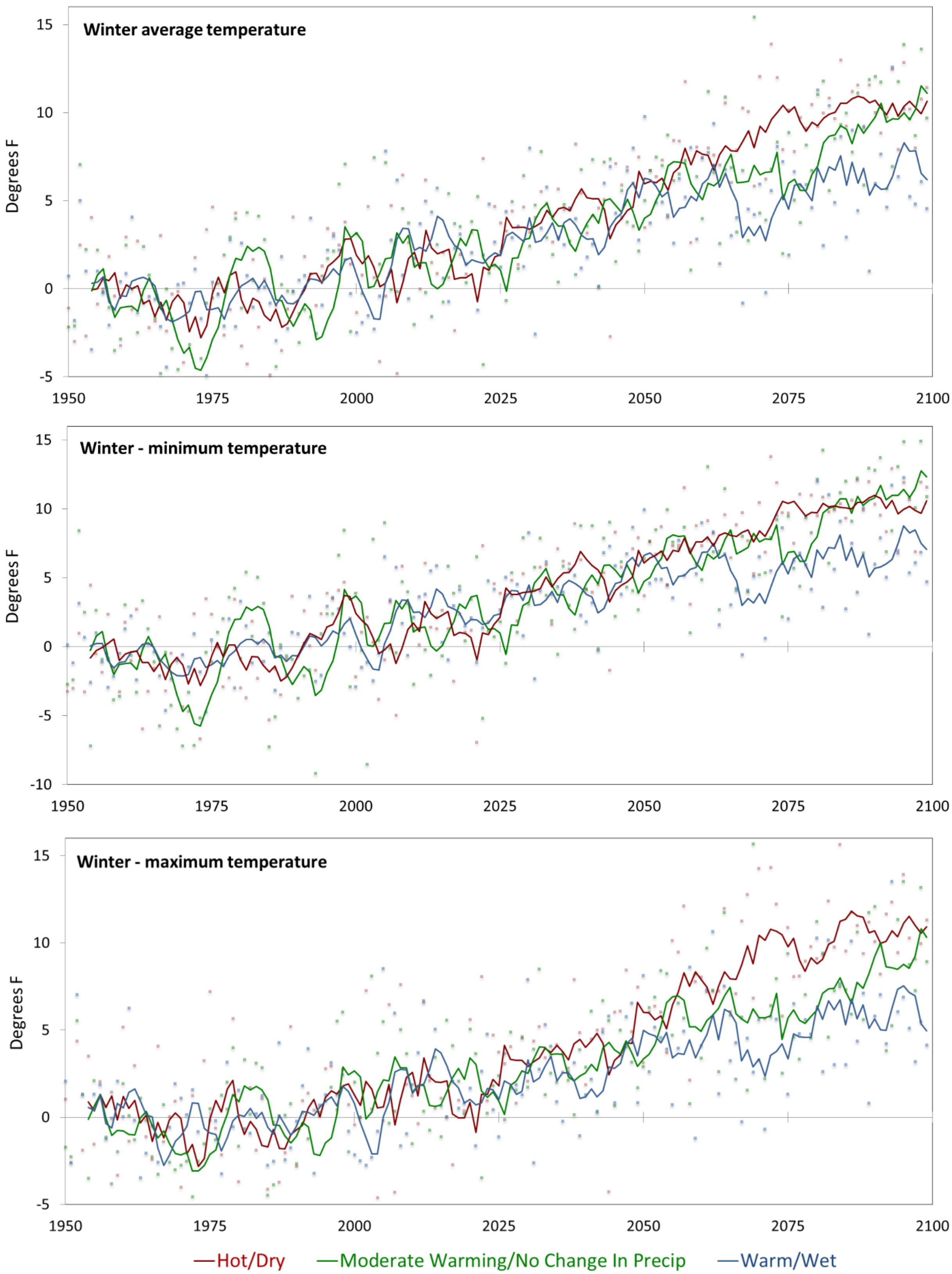
Table B-1. Three Climate Scenarios for the San Juan Basin Region by 2035. The following summary was compiled from three climate scenarios and a review of literature. The **Hot and Dry** scenario is from hadgem2-es.1.rcp85; the **Moderately Hot and No Net Change in Precipitation** is from cesm1-bgc.1.rcp85; and the **Warm and Wet** is from cnrm-cm5.1.rcp45. Imtiaz Rangwala, Western Water Assessment and NOAA.

	Hot and Dry	Moderately Hot/No Net Change in Precipitation	Warm and Wet
Temperature	Annual temperature increases by 5°F; At lower elevations: summer days with temperature above 77°F (25°C) increases by 1 month, and nights with temperature above 68°F = 10	Annual temperature increases by 3°F; At lower elevations: summer days with temperature above 77°F (25C) increases by 2 weeks, and nights with temperature above 68°F = 20	Annual temperature increases by 2°F; At lower elevations: summer days with temperature above 77°F (25°C) increases by 1 week
Precipitation	Annual precipitation decreases by 10%; less frequent and more intense individual rain events; summer monsoon rains decrease by 20%	Annual precipitation does not change but much greater fluctuations year to year (leading to more frequent feast or famine conditions); El Nino of 1982/83 strength occurs every 7 years	Annual precipitation increases by 10%; more intense individual rain events; summer monsoon rains increase by 10%
Runoff	Runoff decreases by 20% and peak runoff occurs 3 weeks earlier	Runoff decreases by 10% and peak runoff occurs 2 weeks earlier	Runoff volume does not change but peak runoff earlier by 1 week
Heat Wave	Severe and long lasting; every summer is warmer compared to 2002 or 2012 (5°F above normal)	Hot summers like 2002 and 2012 occur once every 3 years	Hot summers like 2002 and 2012 occur once every decade
Drought	More frequent drought years like 2002/2012 - every 5 years	Drought years like 2002/2012 occur once every decade	No change in frequency but moderate increases in intensity; fewer cases of multi-year drought
Snowline	Snowline moves up by 1200ft	Snowline moves up by 900ft	Snowline moves up by 600ft
Wildfire	Fire season widens by 1 month; greater fire frequency (12x) and extent (16x) in high elevation forest	Fire risk during dry years is very high at all elevations b/c of large fuel build up from wet years; on average fire frequency increases 8x, and area burnt increases 11x	Increases in fire frequency (4x) and extent (6x)
Dust Storms	Extreme spring dust events like 2009 every other year; causing snowmelt and peak runoff to be six weeks earlier	Frequency of extreme dust events increases from current but tied to extreme dry years	Same as current
Growing Season	Increases by 3 weeks	Increases by 2 weeks	Increases by 1 week

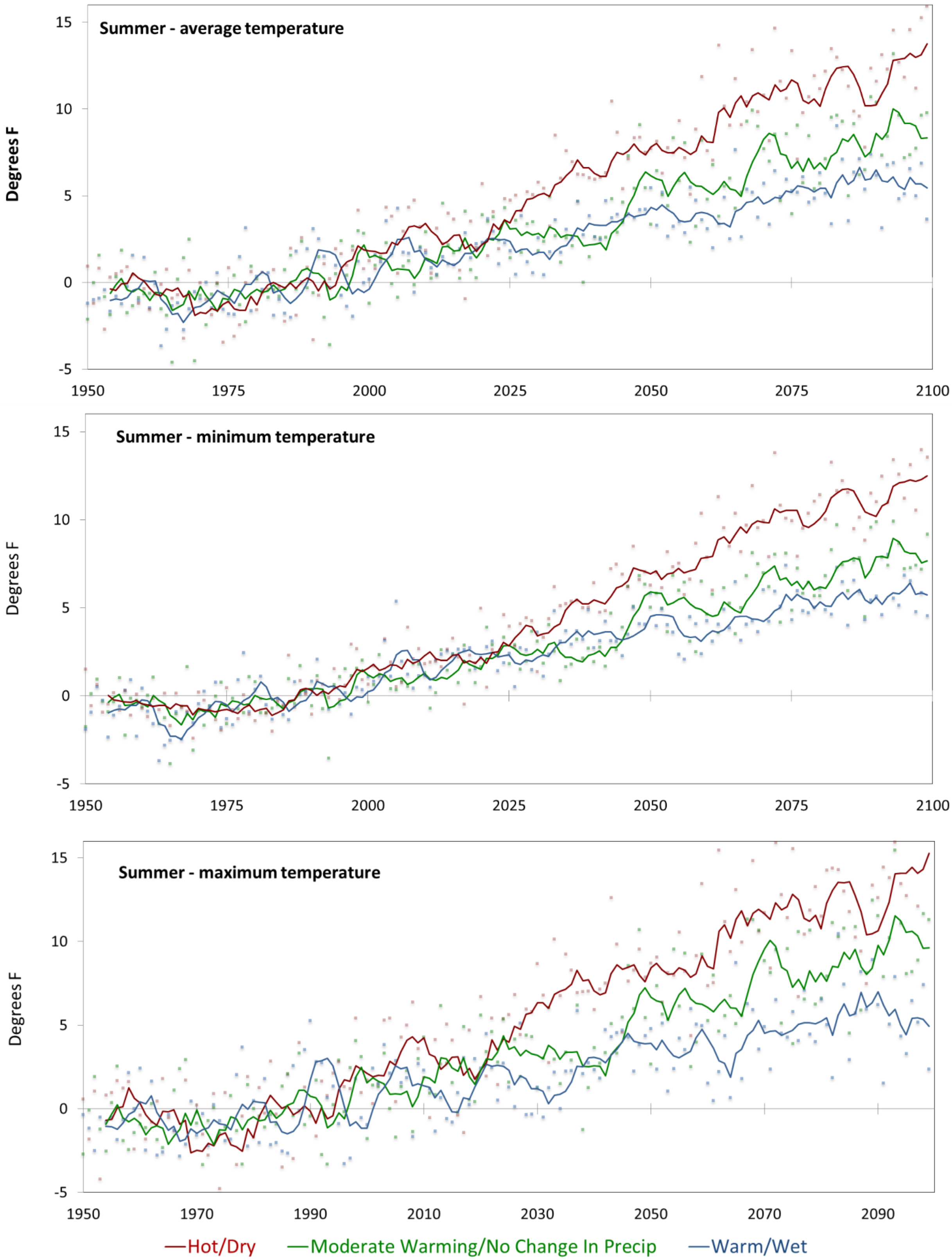
Seasonal Temperature and Precipitation Graphs

Winter
mean temperature
avg minimum temperature
avg maximum temperature
mean precipitation

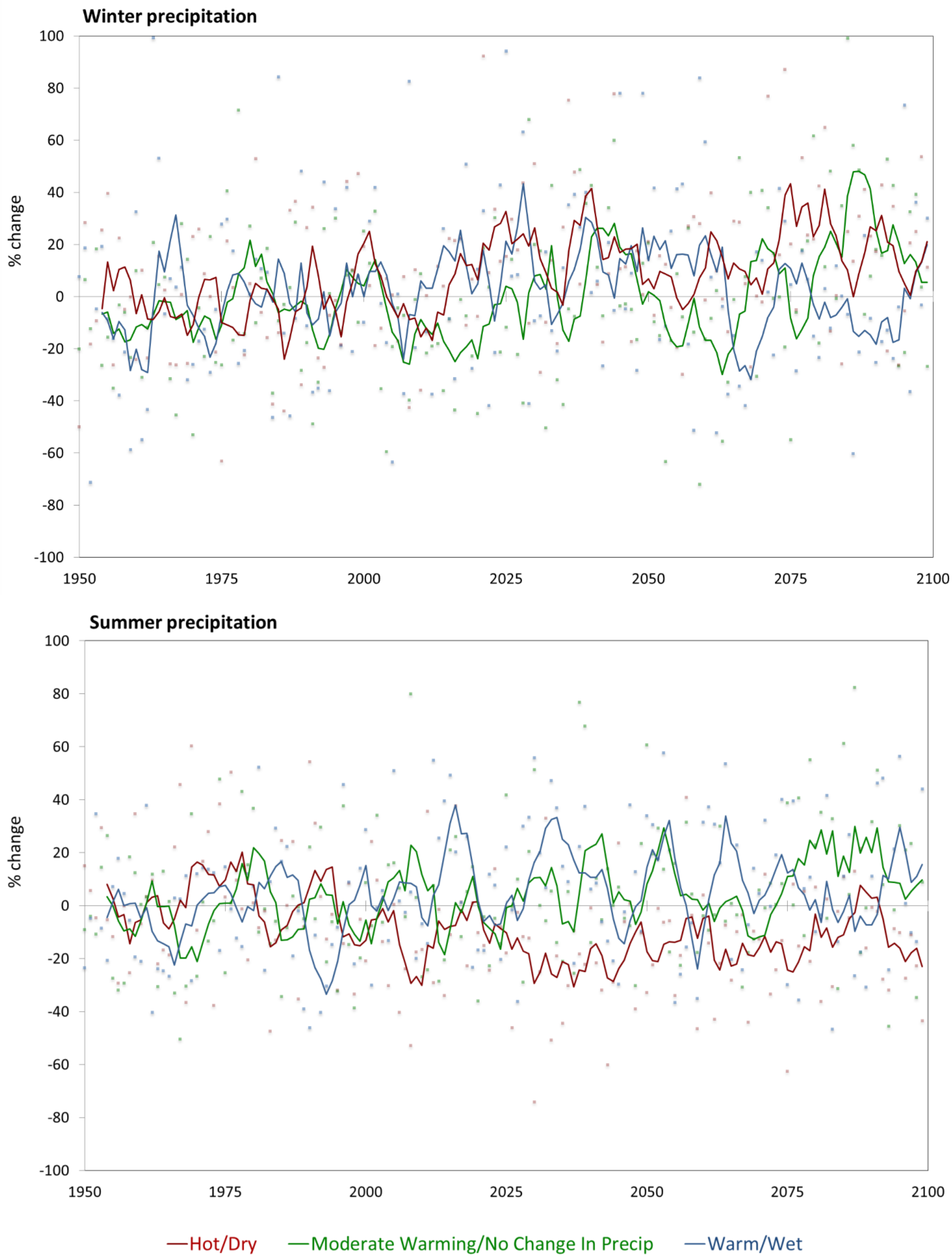
Summer
mean temperature
avg minimum temperature
avg maximum temperature
mean precipitation



Difference in winter (Dec-Jan-Feb) temperatures compared to 1971-2000 normals.



Difference in summer (Jun-Jul-Aug) temperatures compared to 1971-2000 normals.



Difference in winter (Dec-Jan-Feb) and summer (Jun-Jul-Aug) precipitation compared to 1971-2000 normals.

Appendix D: Three Narrative Scenarios

Scenario 1: Hot and Dry ("Some Like it Hot")

In this scenario annual temperature increases approximately 5 F by 2035. To put that in perspective, Durango's temperature becomes similar to the current climate of Grand Junction or Delta, CO. By 2035, every summer will be warmer than 2002 and 2012 – years when we experienced excessive heat waves. At elevations below 7,000 ft, for at least two weeks during the summer, nighttime lows will not dip below 68 F (a typical tropical night), and summer will expand by a month. **Annual precipitation will decline by 10% and there will be more frequent drought years.** Roughly every fifth year, we experience droughts similar to 2002 and 2012 (in these years, precipitation was 40% below average).

Fire: The average fire season will lengthen by one month and the average total area burned in any given year will increase 16 times. Not every year will be an exceptional fire season but average fire frequency, intensity, and size will increase. Fires in the San Juan region have been larger and more intense since 2000, with the 2002 Missionary Ridge fire burning 70,000 acres, destroying 56 homes, and with the 2013 West Complex Fire burning nearly 110,000 acres. Nearly 50% of Mesa Verde National Park has burned since 2000. These fires occurred in drought years similar to what we might expect every five years under this scenario. Under these conditions, pinyon-juniper in some places will not regenerate post-fire and will transition to a shrub dominated system. The largest burns will be in coniferous forests, including spruce-fir, mixed-conifer, ponderosa pine, and pinyon-juniper. These areas are likely to transform into aspen, mountain shrublands, or grasslands. While the growing season increases by three weeks, with less precipitation, understory herbaceous growth (fine fuels) does not necessarily increase.

Drought: In this scenario we have less annual precipitation and increased evapotranspiration. This decreases available water by nearly 20% (from today's baseline), as every 1.8 F of temperature increase effectively causes another 5% decrease due to evapotranspiration increasing. Thus, Durango's annual precipitation becomes similar to the current precipitation that Ignacio receives. Spring snowpack will decline, although the 20% decrease in monsoon precipitation will have as large, if not larger, impact on vegetation. Snowline shifts up by 1200 feet; note the bottom of Durango Mt ski resort is at 9000 feet and very near snowline today. In addition, the average timing of snowmelt will shift a full three weeks earlier, due to temperature changes and more frequent dust-on-snow events (which will occur every year). Higher than average peak spring flows followed by reduced summer flows will reduce the amount of water available for fish, riparian vegetation, migratory birds, and grazing animals, especially during summer. Endangered fish may suffer from lower in-stream flow and increased stream temperature. Less precipitation in winter and summer will significantly decrease surface water and shallow ground water. Seeps and springs associated with shallow groundwater will decline and species composition will be greatly altered. For example, cottonwood trees will dieback, invasive species will increase, and associated fauna will decline. Annually, a water deficit will occur at all elevations and will be most pronounced in summer and fall.

Insects: Tree mortality due to insect and disease outbreaks will greatly increase with a hot and dry climate, more so than in any other scenario. For example, in 2002-2003, due in part to drought, SW Colorado experienced a 53% pinyon pine die-off due to ips beetle. In some pinyon-juniper forests, the species composition will change to nearly all juniper. Species that rely on pinyon pine (e.g., Pinyon-jay, Gray vireo, and Mexican spotted owl) and spruce-fir (e.g., Lynx, boreal owl, and snowshoe hare) will decline due to lack of food or shelter. Aspen trees at lower elevations will experience die-back associated with increased temperatures and decreased soil moisture. However, aspen stands at upper elevations may increase as coniferous trees decline due to fire and beetle kill. Heat and moisture stress will make it challenging for coniferous forests and wetlands to maintain their current condition, function, and species composition at their present locations. Shrubland ecosystems will likely expand.

Scenario 2: Warm and Wet ("The Seasons, They are a Changing")

In this scenario, annual temperature increases 2^0 F by 2035. To put this in perspective, temperatures in Durango will resemble current temperatures in Cortez and Wolf Creek Pass will resemble Silverton. Summer will expand by a week. Annual precipitation will increase by 10% (in terms of soil moisture and stream flows a 5% increase in precipitation is needed to offset a 2^0 F increase in temperature with its associated higher rate of evapotranspiration). Drought years, such as 2002, will occur every 15th year, similar to today's frequency. However, the intensity and severity of droughts will increase because of higher temperatures.

Change: While a 2 F temperature increase with negligible change in precipitation sounds close to business as usual, ecosystems will change in subtle ways. For example, the ratio of warm season to cool season grasses will change, and we will likely see declines in western wheat grass, needle and thread grass, while blue grama and galleta grass will expand. The snowline will shift upwards by 600 feet. As a result, the current vegetation in the 8,500-9,000 ft band will begin to shift from mixed conifer or aspen towards a ponderosa pine forests. Due to increased snowfall, overall runoff will increase by 10%, while warmer temperatures will mean that runoff will occur a week earlier. In this scenario, warmer summers similar to 2002 (5 F above normal) will occur once every decade. Fire risk in this scenario is the lowest of any scenario but fires will be present, and intermittent dry conditions may cause severe fire hazards because of high fuel loads. These high fuel loads are a result of increased winter, spring, and summer precipitation producing more foliage. A 2 F increase in temperature will increase the annual area burned by 3-4 times. Pinyon pine nut production will be reduced 50% with a 2 F increase in summer temperatures. While pinyon pine seedlings may have the ability to sprout at higher elevations, it is important to note that pinyon pines need 75 years or more to become good seed producers. Numerous species rely on pinyon pine seed crop production; therefore, this decline will reduce the populations of birds and small mammals that rely on pinyon pine nuts.

Weeds: We will have greater than normal winter snowpack above 10,000 feet and spring, summer, and fall precipitation will increase at all elevations. The increase in year-round moisture coupled with a moderate increase in temperature will promote invasive species (more so than any other scenario). Current invasive species such as leafy spurge, knapweed, and yellow toadflax will expand into low to montane elevations and new invasive species such as Japanese brome or purple loosestrife will likely move into the area. Rangelands will become degraded by invasives, and knapweeds and leafy spurge expand into rangelands that have never had a serious weed problem. Further, invasive species will out-compete the native vegetation and create a high density of fine fuels for fires, especially at the lower elevations.

Water: We will still experience droughts; however, they will be less frequent than in the other scenarios. In this scenario, disease and insect outbreaks are less likely than the other scenarios, however, insect outbreaks will still increase, as the droughts that do occur will be more intense than droughts experienced during the 20th century. When we do experience a beetle outbreak, the recovery time may be quicker than in the other scenarios. Seeps, springs, and other groundwater dependent wetlands will increase or experience very little change in this scenario. There will be some drought years that impact low elevation wetlands but for the most part wetlands will benefit from the years of increased annual precipitation. The upper elevation wetlands will do exceptionally well and possibly expand due to the greater snowpack above 10,000 ft. Higher soil moisture will likely eliminate or reduce wetland invasive species. Cottonwoods will likely experience good years where expansion is possible.

Scenario 3: Moderately Hot ("Feast or Famine")

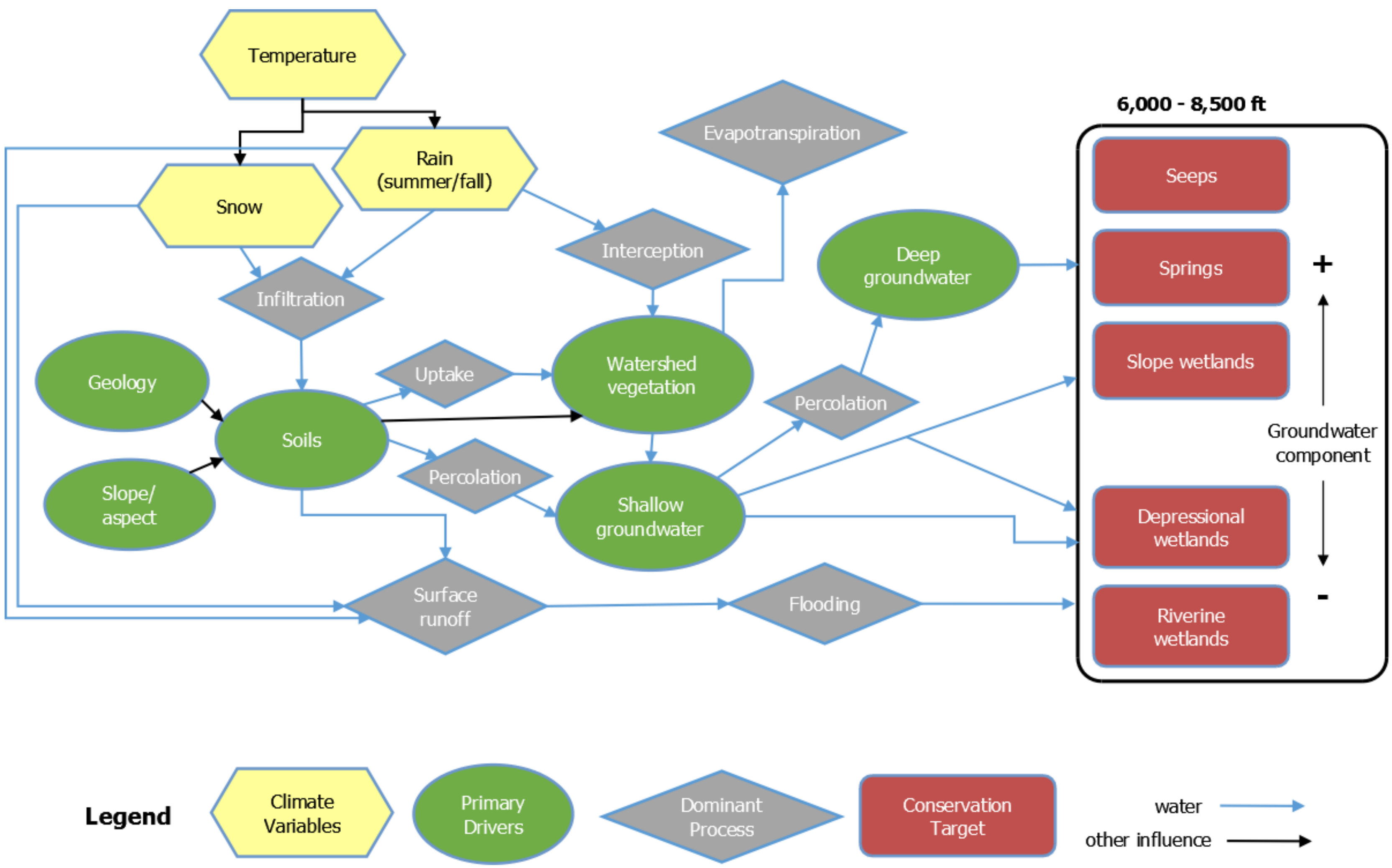
In this scenario, annual temperature will increase approximately 30 F by 2035. To put that in perspective, Pagosa Springs' temperature will be similar to the current temperature of Ignacio. Average annual precipitation does not change; however, we will experience larger year to year fluctuations in precipitation, with some very wet years and some intense drought years, as compared to our current climate. Winter precipitation will increase, but precipitation will decline in the other seasons. When droughts occur, they will be more intense than present but generally less than two years long. Once every decade we will experience a drought similar to the 2002 and 2012 droughts (years when precipitation was 40% below average).

Feast: The growing season will expand by 2 weeks and during wet years vegetation growth will be exceptional with trees, shrubs, and ground cover greatly increasing. The frequency of severe El Nino and La Nina events will double to an average of once every seven years. We experienced severe El Nino years in this region in 1982/83 and 1997/98 with annual precipitation at roughly 20% above average. Invasive species will do well under El Nino conditions but decline in La Nina conditions (drought years). The annual fire risk is lower in this scenario than the hot and dry scenario. Large fluctuations between wet and dry years will increase fuel growth during wet years. This means that when a fire does occur, the severity, intensity, and size could be very high, and in a bad fire year the average fire frequency will increase up to 8 times and the area burned will increase 11 times[1]. Year to year, summer monsoons will be more variable than they are currently. Large spring floods will be more likely as earlier rain on snow events will cause abrupt snowmelt. Dust-on-snow events, coupled with warmer spring temperatures, will also increase the chance of spring flooding, especially during El Nino years. The largest flooding events will generally occur from heavy monsoon precipitation. During these floods, there will be severe erosion in small streams as water runs over banks and culverts.

Famine: Intense droughts will more frequently follow extreme wet years. Bark beetles will expand during these drought years, causing extensive conifer mortality. The difference between this scenario and the hot and dry scenario is that multi-year droughts will be less likely, thus the bark beetle dieback may not be as severe as in the hot and dry scenario. It is important to note that most conifer forests can regenerate more easily following beetle outbreaks than fires because bark beetles do not kill the young trees. However, insect kill in mature trees will diminish seed production. This reduction in seed crop will hurt the animals that rely on conifer seeds. In the event that a fire occurs after a beetle outbreak, tree regeneration is nearly impossible. The large fires associated with drought years will result in younger forests, more open structure, more early successional species, and more invasive species. Large landscape scale disturbances, such as fire and insect outbreaks, will fragment coniferous forests and negatively impact species such as lynx, snowshoe hares, pinyon jays, and other species that rely on large intact functioning forests.

Seeps, springs, and other groundwater dependent wetlands may experience a moderate decline, especially below 9,500 feet, where precipitation will fall as rain rather than snow. Increased evapotranspiration, driven by higher temperatures, will reduce soil and stream moisture. Consequently, species that can handle drier soil conditions, for example sagebrush and shrubby cinquefoil, will flourish; invasive species such as cheatgrass and knapweed will likely increase,

APPENDIX E. ECOLOGICAL RESPONSE MODEL



The ecological response model above represents the basic hydrologic and ecological processes and influences for seeps, springs, and other groundwater dependent wetlands in the area.

APPENDIX F. SOCIAL SCIENCE INTERVIEWS

Climate Adaptation in the San Juan Basin: Interviews on Pinyon-Juniper and Seeps, Springs, and Wetlands

By Carina Wyborn, Laurie Yung, Marcie Bidwell, and Renee Rondeau

I. Key Findings

As part of the Southwestern Colorado Social-Ecological Resilience Project, twenty-six agency staff from three agencies and eight grazing permittees were interviewed about landscape changes in the San Juan Basin. Interviews focused on changes to pinyon-juniper woodlands (PJ) and seeps, springs, and wetlands (SSW), and on climate change, adaptation and uncertainty in land management. Both agency staff and permittees envisioned changes to these systems in terms of impacts to specific resources (e.g. water and forage) and activities (e.g. recreation). For agency staff from the BLM and USFS in particular, pinyon-juniper was the location for key management activities (e.g. gazing, oil and gas, and recreation) and not managed for specific ecosystem features. Similarly, permittees focused on rangeland conditions and the management of grazing permits in pinyon-juniper. For most of the NPS interviewees, the management of PJ revolves in part around questions about appropriate fire management and different views on how to best conserve the human infrastructure of the park (both contemporary and historic dwellings) and less often to conserve the ecosystem itself. Similarly, BLM and USFS participants suggested that they were unsure of the "natural" state of PJ, questioned what the management goals for the system should be and wondered whether PJ is a "climax" community or one that is encroaching on other communities that are valued more highly (i.e. sagebrush). For all participants, changes to seeps, springs, and wetlands were seen as important and raised concerns about water availability for a range of human uses, including grazing and recreation. Permitees also expressed concerns about long-term drought, the timing of their on-off dates, staff turnover within the agencies, communication with the agencies, and the length of time taken to receive permission to undertake actions related to their permits.

Participants had different views of what climate adaptation might mean in the San Juan Basin. Both agency staff and permittees conveyed that they had a limited capacity to extend beyond current activities and undertake climate adaptation. Limited capacity for adaptation was linked to budget and staffing constraints. In particular, inadequate resources for monitoring translated into a lack of understanding of how the system/resource is changing over time, knowledge necessary to assess the efficacy of adaptation efforts. In the context of uncertainty and incomplete knowledge, agency staff discussed drawing on a broad, interdisciplinary group of specialists to form a more complete picture to inform decision-making. Uncertainty was believed to promote a risk-averse, conservative approach to decision-making within the agencies.

Given these findings, effective climate adaptation on federal lands in the San Juan Basin may benefit from a focus on current management activities that incorporates the need to improve current conditions that will benefit people and wildlife in the face of climate uncertainties.

II. Background

Environmental change is a constant feature of land management within the US Interior West. Fire, drought, insect infestations, and invasive species present pervasive challenges to the management of western lands. Southwestern Colorado is already experiencing higher temperatures, more frequent and prolonged drought, earlier snowmelt, larger and more intense fires, more extreme storms, and spread of invasive species, changes expected to intensify as a result of climate change. These changes put livelihoods, ecosystems, and species at risk.

The interviews described in this report are part of the larger Southwestern Colorado Social-Ecological Resilience Project (hereafter referred to as the SWCO Project). The SWCO Project is a three-year effort funded by the Department of Interior's North Central Climate Science Center, an agency office that provides climate science, information and tools to land and natural resource managers to anticipate, monitor, and adapt to climate change. In the San Juan and Gunnison basins, the SWCO Project works with scientists, land managers, and stakeholders to facilitate the development of adaptation strategies that contribute to community and ecosystem resilience and species conservation, and reduce the negative impacts of climate change.

A diverse group of stakeholders involved with the larger SWCO Project selected adaptation targets for the San Juan Basin in early 2014. An adaptation target is a feature (livelihood, species, ecological system, or ecological process) of concern that sits at the intersection of climate, social, and ecological systems (adapted from Cross et al 2012). SWCO stakeholders chose to focus on two systems, pinyon-juniper woodlands (PJ) and seeps, springs, and wetlands (SSW). Thus, the interviews described below focus specifically on these target systems.

III. Methods

This report is based on 34 in-depth semi-structured interviews with line-officers and specialists from the San Juan National Forest, Bureau of Land Management Tres Rios Field Office, and Mesa Verde National Park, and ranchers with cattle grazing permits on the San Juan National Forest (referred to here as permitees) (see Appendix A for a detailed description of the sample). Interviewees are referred to below as participants. Interviews were conducted in April and May 2014. The interviews were conducted to:

(1) gather information on current use, importance, and status of the targets,
(2) provide insight into current agency decision-making related to the targets and agency approaches to uncertainty, and
(3) identify human communities living within the San Juan Basin that are likely to be impacted by climate induced impacts to the targets.

Interview questions for the agency participants were organized in three sections: current conditions and impacts, future conditions as envisaged under a changing climate, management approaches, capacity to realize goals, and decision making in the face of uncertainty. Agency participants were asked to select one of the two adaptation targets upon which to focus, pinyon-juniper and seeps, springs, and wetlands. Permittee interviews followed a parallel but modified set of questions focused on their operation and allotment, their experiences of changes to the two targets, and their relationship with and expectations of the agencies in the context of change and uncertainty. Below we report the views and perceptions of the interviewees on these topics.

IV. Findings

Perceptions of the Targets and Current Conditions

The two targets present very different adaptation challenges for the agencies. SSW are small, site-specific resources that provide critical water for vegetation, wildlife, livestock, and people in an arid environment. Because water is a limited but highly valued resource, there is significant conflict surrounding the status and use of SSW. In addition, baseline understandings of surface-groundwater connections are lacking, which means knowledge of how SSW will be impacted by climate change is limited. In contrast, PJ is a ubiquitous habitat that covers 19% of the basin and serves as the 'stage' or place where many of the management activities occur, including mining and grazing on BLM and USFS lands, and recreation and cultural resource management on all federal lands. While PJ is widespread, it is not often highly valued for its ecological qualities. PJ also is not typically viewed as vulnerable to climate change. Interestingly, most participants discussed the targets in terms *of what they provide* (e.g. water, forage, recreational experiences). Few participants focused on the value of SSW and PJ in and of themselves.

> *I just don't think we really focus on that PJ community in the direct [way] that you're focusing on it. We've really never had to ask these questions from that perspective. We operate, at least in BLM's world, on an extensive pinyon juniper habitat, and we never really look at the specifics of that declining habitat. (USFS/BLM)*

Responses regarding the importance of PJ were complex. While people recognized the value of PJ for wildlife habitat and as a component of the region's biological diversity, they were somewhat confused about the "value" of PJ itself. This confusion stemmed from the ongoing debate about whether PJ is a desirable "climax" community or a problematic "invasive" community that is encroaching on the landscape. Lack of concern over changes and impacts to PJ were connected to many participants' ideas about its resilience and role in the landscape. Many participants suggested that PJ was quite resilient to change. However, a small minority of participants argued that PJ was in fact vulnerable to climate change, citing recent scientific studies demonstrating how changes to PJ impact PJ-dependent species. To the extent that participants saw PJ as "invasive," they were less concerned over impacts to or declines in the PJ ecosystem. At the same time, some participants mentioned that the recent Ips beetle outbreak had made them see that PJ may not be as resilient as they had once thought. Agency staff were spilt as to whether or not their constituents would 'notice' if PJ changed, with some agency staff wondering whether grazing permittees would prefer less PJ (due to a perception that forage would increase if PJ decreased) or whether recreational users could distinguish a “P from a J.” Despite the lack of concern many participants expressed regarding the PJ, many acknowledged that PJ is an iconic feature of the Southwest landscape. This aesthetic value of PJ was emphasized by NPS staff who discussed the value of PJ to the cultural and ecological landscape of Mesa Verde. Some participants talked about pinyon nut collection; however, they reflected that it was not as significant in this area as in other parts of the Southwest.

In contrast, there was widespread agreement that SSW were vulnerable to change. For SSW the primary goal driving all three agencies and the permittees was to maintain current function and ensure water availability for various social, cultural, and ecological uses. Many cited concerns about anticipated water shortages that would impact the entire community and increase the potential for conflict. Despite agreement about the vulnerability and value of SSW, many participants felt that they were largely powerless to do anything about the drivers of change (e.g. the amount of snow and rain).

It is important to note, again, that for both SSW and PJ, most participants largely expressed concerns about the resources derived from and the activities taking place in these systems, rather than concerns about impacts to the systems themselves. In other words, most participants situated climate change impacts within a local, human context by focusing on the specific goods and services that each target system provided, as opposed to changes to specific ecological features of the target system.

Impacts to Permittees and Local Communities

Participants discussed how different climate impacts to the targets effect different groups of people depending on their relationship to the resource. For example, people or institutions whose livelihoods depend on access to public lands (e.g. grazing permittees and hunting outfitters) and with rights to water that flows off the public lands were seen as particularly vulnerable to changes to SSW and PJ. These groups were viewed as directly impacted.

For both targets, permitees were most frequently identified as the primary human community impacted by change given their dependence on both water and forage. However, some agency staff and a few permittees suggested that declines in PJ would be beneficial for ranchers due to increases in available forage. But others questioned whether forage would increase given predicted increases in drought, fire, and invasive weeds.

The permittees themselves expressed very little concern for the specific target systems. Approximately half of the permittees had PJ on their allotments, but they were not concerned about changes in and impacts to PJ. In fact, they were somewhat perplexed the PJ had been selected as a system of concern. Most permittees had stock ponds, fed from either developed springs or runoff, and a handful also had some wetlands on their allotments. Major concerns for the permittees revolved around water availability, the timing of their livestock on-off dates, high staff turnover within the agencies, and channels of communication. Most reported having good relationships with the agencies. However, all emphasized a need for open communication, more advance notice of changes to their permits, and a greater respect for local, historical, and experiential knowledge. All of the permittees reported that small changes to their animal unit months (AUMs) and the timing of their on-off dates had significant impacts on their operations. All said that being held off at the beginning of the season had a far greater impact than having their season cut short in the fall because it is easier to find forage for cattle in the fall. The limited availability and fragmentation of private land within the San Juan Basin contributes in significant ways to the vulnerability of the permittees because it is difficult to find affordable private grazing land to lease.

Some participants discussed secondary or indirect impacts that would emerge as a consequence of these direct impacts. For example, if permittees were impacted economically, they might spend less money in local communities which would create ripple effects on other businesses and community members. Water use and availability upstream might impact downstream users. Ecosystem changes might impact landowners in the wildland urban interface (WUI) due to changes in fire regimes. Some participants also mentioned aesthetic changes in the landscape. For example, in reference to Mesa Verde, a handful of participants talked about the intangible or symbolic impacts associated with the loss of ecological communities. While interview participants identified community members who might be affected by changes to SSW and PJ, the focus of the interviews on ecosystem targets meant that a broader understanding of how climate change might impact people in the San Juan Basin was beyond the scope of the research.

Management Goals and Challenges

Beyond the broad mandates that the agencies have to "maintain and improve condition" and "minimize the impact of disturbance" (BLM and USFS) and "cultural and natural heritage preservation" (NPS), most participants did not identify specific management goals related to either of the targets. This was particularly evident relative to PJ because many participants were not managing PJ specifically, but rather managing activities in PJ. This is consistent with the finding described above, that most participants focused on PJ as a place or location for a set of valued activities that they manage, rather than an ecological system that they manage for valued ecological benefits.

> *I believe the agency has the capability of holding its own. I'm not sure the agency has the capability to advance protection, but what is protection? Does protection mean hands-off? Natural processes dominate? How do you factor in, then, natural processes that might have a poor effect? In general I would say the agency has that ability. It's a struggle, but it's a struggle that exists with everything we do. (USFS line officer)*

The agencies identified similar management challenges in relation to the two targets (Box 1). All participants reported a substantial lack of capacity to undertake the management they believed necessary to meet their goals, particularly in the context of climate change. Lack of capacity emerges from the usual challenges: insufficient budgets and personnel (e.g. both BLM and NPS participants discussed declining specialist expertise) and a lack of capacity to undertake relevant monitoring. Many participants saw this lack of capacity as constraining their ability to respond to change, both now and in the context of climate change. Many participants reported that additional resources and staff would enable them to achieve current management goals. Participants explained that while they might have the capacity to maintain current conditions, they lacked the capacity to further protect or restore, or to mitigate the impacts of large scale change. Finally, because the agencies did not have specific management goals for PJ, some participants were unable to comment about their capacity to achieve specific goals in this system.

Box 1. Management Challenges Identified for Two Targets		
Seeps, Springs, & Wetlands	Both	Pinyon-Juniper Woodlands
• Drought • Overgrazing • Lack of baseline knowledge (i.e. location and condition) • Increased demand for water	• Limited budget & personnel • Invasive species • Restoration • Sensitivity to disturbance	• Soils sensitive to disturbance • Fire dynamics • Interactions between fire and invasive species • Fragmentation in the wildland urban interface (WUI) • Travel management

Monitoring and Sources of Information

Agency staff reported varying degrees of confidence in the knowledge they have to adequately manage the resource. Agency specialists were the most frequently cited source of knowledge, followed by experiential knowledge from within the agency and local communities. Academic networks and the scientific literature were less frequently mentioned. Despite this, many discussed an increasingly reliance on external networks for expertise, particularly with regards to managing the effects of climate change. Participants expressed similar needs for additional knowledge across the agencies (see Box 2).

Box 2: Additional Knowledge Desired

<u>Seeps Springs Wetlands</u>

- Inventory and evaluation of current status
- Response rates to drought
- System function and groundwater connectivity
- Wildlife use data
- Connections between natural and cultural resources (NPS)

<u>Pinyon-Juniper</u>

- Fire regimes
- Appropriate fire mitigation
- Successional dynamics
- Cumulative impacts

<u>Both</u>

- Climate impacts over next 10 years
- Management for long-term drought

Monitoring varied across the agencies and participants differed in their perceptions regarding whether the current monitoring efforts are adequate. For the BLM and USFS, monitoring was almost always driven by external requirements – documenting project impacts or meeting legal mandates – rather than monitoring the specific condition of the targets. Conversely, the NPS Colorado Plateau Inventory and Monitoring Network were monitoring PJ and SSW in Mesa Verde with a focus on the impacts of climate change. Given the lack of direct monitoring of the condition of targets, many suggested they did not have adequate baselines on the condition of these systems. The USFS has two data sets on the condition of some SSW. However, many participants believed monitoring could be substantially improved. Across all agencies, poor inventory of the current condition of SSW was readily reported as a constraint on management, as "you can't manage what you don't know."

Maybe we know about 60% of the seeps and springs. It'd be great to have the time to get the other 40%. The problem is that the work we do tends to be driven by an environmental assessment for a grazing allotment or a water rights case. There's reasons why we get the data. We kind of drift with whatever's most compelling to collect. We don't have the luxury of just going to do it for the sake of doing it. There's usually so much work that there's a reason why we're doing it. It leaves holes in the landscape. (USFS)

Climate Change and Adaptation

Agency participants uniformly characterized climate change as bringing hotter and drier conditions to the San Juan basin and mountains. Some spoke of interacting effects with other stressors (e.g. fuel build-up, invasives, grazing, fragmentation) and the cascading impacts of climate change in the region. All believed that a hotter, drier climate would drive declines in the condition of SSW. However, some also pointed to the differential impacts in relation to drought (e.g. recent droughts demonstrated that some SSW were more susceptible to drying up than others). For PJ, responses were more mixed, with the majority believing that PJ would expand due to climate change, moving up in elevation. NPS staff and a handful of USFS staff discussed the potential for more dramatic changes to PJ. However, most participants did not discuss the potential for PJ to disassociate or completely transform.

The majority of agency participants perceived climate change to be a significant challenge for the future. A handful of agency participants questioned whether there was complete scientific certainty regarding human-caused or anthropogenic climate change, with one participant reporting outright skepticism. Permittees perceived climate change to be driven by natural cycles, something that has always been happening, and questioned whether human activities were driving local landscape change. Many permitees did, however, report noticing changes in the area over the duration of their lifetime, which they attributed to cyclical changes in the climate.

Participants expressed different views about the ways that climate change influenced agency management. Many participants reported a general sense that climate change would influence planning but little specific detail regarding how that might happen. Climate change was explicitly considered within the Mesa Verde fire management plan (which is a significant driver of PJ management at Mesa Verde) and the jointly authored USFS/BLM Forest Plan/Resource Management Plan. However, participants stated that climate change had not yet influenced or

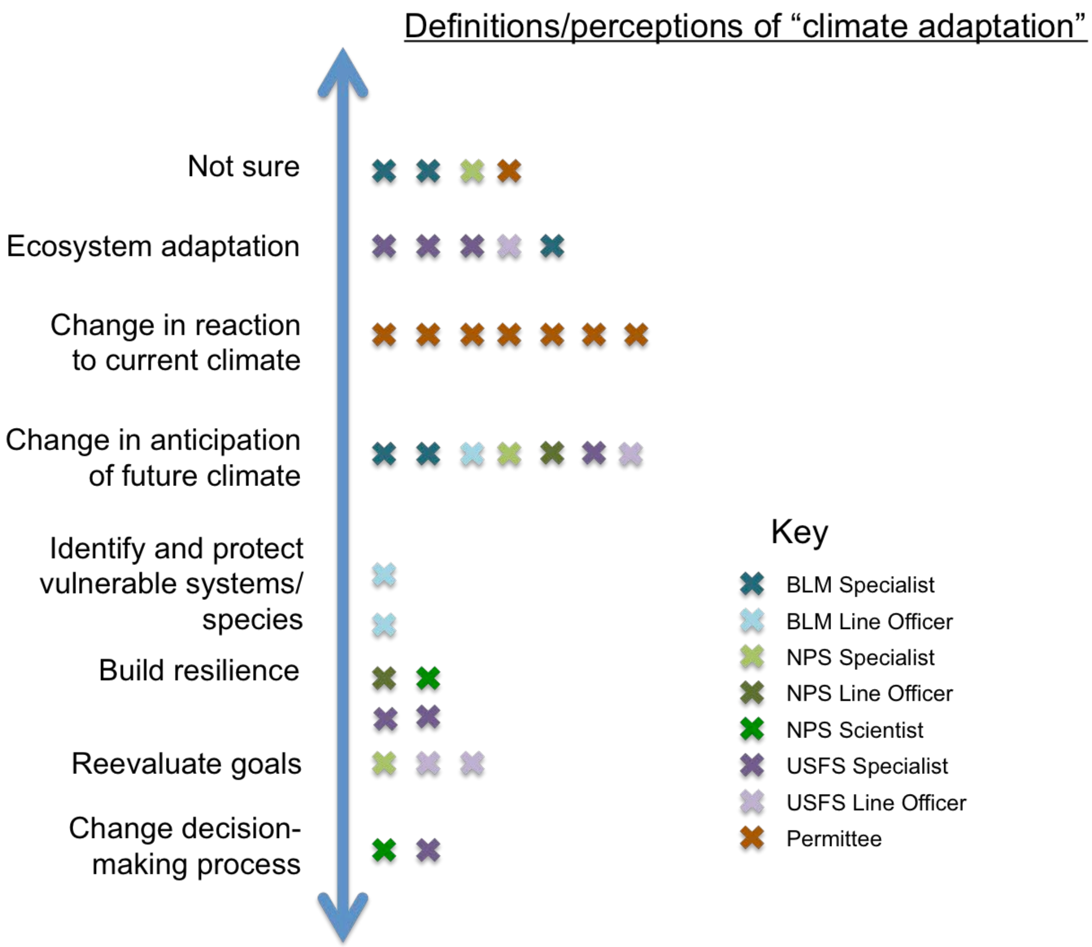
The thing that people really respond to is some type of fiat. There's good things and bad things about that, but if there was more of an emphasis on climate change at the level of project-level decision-making, then I think over time… we start getting our heads around. But right now I see it as something that's been, "Deal with it if you feel like you've got the understanding at your level. If you don't deal with it, you'll get a pass." Our feet haven't been held to the fire, so to speak, on addressing climate change in our analyses. (USFS Line Officer)

changed the management of SSW. Few agency participants mentioned specific policy directives related to climate change or adaptation in relation to how they manage the targets. However, many line officers reported "needing to deal with" climate change in management decisions. Participants across all three agencies repeatedly emphasized the need to be realistic about what can actually be achieved within the current capacity of the agencies across diverse topics from current management of the targets to any future adaptation strategies.

When asked what climate change adaptation meant to them, participants expressed a range of views. A handful of agency staff and all of the permittees were unfamiliar with the term (see Figure 1). A number of USFS staff responded by describing the ways that ecosystems or species change or adapt in response to climate change and were uncertain how the term might be applied to agency management or decision-making. The participants who did connect adaptation to decision-making focused on the ways that they would recalibrate what they currently do to match future climatic conditions. Very few participants discussed the ways that adaptation might require changing the way decisions are made. Given uncertainty about the meaning of climate change adaptation, some BLM and the USFS suggested that they needed more specific directives from their agencies to define adaptation and how they would be expected to implement it. In short, very few participants envisioned that adaptation might require changing the decision-making processes or management goals or objectives. Rather, most saw adaptation as simply recalibrating what they do to match the future climate of the region.

These different perceptions of adaptation will likely have implications for the ways in which agency staff and permittees respond to different adaptation strategies proposed in later stages of this project (e.g. workshops). This suggests that some time could usefully be spent in later workshops discussing the various dimensions of adaptation (e.g. adaptation strategies related to resistance, resilience, and transformation) as well as the more procedural aspects of adaptation (e.g. building capacity to undertake actions or changing the way that the agencies currently make decisions).

Figure 1. Definitions and perceptions of the term "climate adaptation" from the question "What does climate adaptation mean to you?"



Managing for Ecological Change

When it came to managing for increasing rates of ecological change, participants talked about a need to "get ahead of the change" to be out there on the land to get an understanding of how the resource is changing, and to have good information and monitoring data upon which to base their decisions. Many reflected on the time it takes for the agencies to make decisions and expressed concerns that long decision timeframes would be a barrier to responding to change. A handful of participants spoke about the need to acknowledge that change is the new normal and from that there is a need to adapt decision-making processes to be more effective in dealing with change. Suggestions regarding how to adapt decision-making processes involved streamlining NEPA and having clear policy direction from Washington as to what was expected from agencies in addressing climate change.

Scenarios that provide a picture of the range of different possible futures land managers may face are increasingly being promoted as a mechanism for decision-makers to deal with uncertainty. As

For us, we have over 100 species that we have to take into consideration. To try to manage for not only that, but multiple climate scenarios, future desired conditions, really, it sounds good, but in practicality, what you would say would not be accurate. (USFS)

I don't know how you'd do that. Presumably there are two different management actions you would need to take if you are needing to manage for the threat of a hotter, drier climate, you're gonna take one management action. If you're managing for a wetter, colder climate, you're gonna take another management action. You can't take 'em both. (BLM)

It would be possible. It would take some more effort to get a few more folks in and more resources focused on that. (NPS)

the SWCO Project has adopted this approach, the interview guide included a question about whether managers could envisage managing for a range of possible futures.

Responses to this question varied widely, with some suggesting that a scenario based approach was the direction they could see the agencies headed, others suggesting that it was a good idea in theory but would be far too complex in practice, and still others who said they would manage for the average or the worst case scenario. Responses to this question highlight a need for greater communication around what scenario-based decision-making is, as responses suggested that participant understanding of managing for a range of possible futures is very different from approaches promoted in the academic literature. Conversely, responses also suggest that the academic discussion of scenario approaches would benefit from greater input from the intended users. Given the additional analysis burden that comes with assessing actions in light of a number of potential futures, the utility of a scenario approach must be questioned in light of existing critiques suggesting that decision-processes are already overly time consuming.

Climate change may result in transformational change to some of the ecological systems that these agencies managed. Participants were asked whether they felt their agencies were prepared for such transformational change and whether they believed there was a role for the agencies to assist these types of transformations. The majority of participants believed that their agencies were not prepared for such change, citing slow responses to any kind of change, institutional inertia, and the attachment that individuals within the agencies and the general public have to particular systems being in particular parts of the landscape.

No, I think we're pretty resistant to it… we don't like pinyon juniper encroaching on the sagebrush. We don't like tree line moving into the alpine…but we don't necessarily do things about it, either, because we don't have the capacity. (USFS)

I don't know if we're prepared or not. If that's what's happening, it's going to come, and there's not a whole lot we can do to change it. (NPS)

The majority of participants believed that the agencies do have a role in assisting transformation, with many from the BLM and USFS suggesting this is simply an extension of their current active management. For the NPS, this question raised issues related to the agency mandate and the appropriate role of active intervention in the ecological systems they manage. However, all NPS participants reported that these issues were being actively discussed within the agency. The NPS participants discussed intervention in transforming systems more in relation to minor interventions designed to prevent the negative impacts of change, such as shifts in the management of fire or invasive species rather than broad scale changes like revegation using different species adapted to future climatic conditions.

Management in the Face of Uncertainty

Making adaptation decisions requires agencies to plan and act in the context of various types of uncertainties. Thus, a critical component of adaptation requires understanding how agencies negotiate uncertainty in decision-making. Agency staff and permittees uniformly suggested that uncertainty does not prevent them from making decisions. As one BLM specialist suggested, "ultimately, a decision has to be made." However, they all suggested that uncertainty makes decision-making more challenging.

> *Working in the context of uncertainty is something that the agency is very capable of, because we do it all the time. We never have complete information, I don't think. (USFS, Line officer)*

Despite perceptions that agency decision-making processes can deal with uncertainty, some interviewees suggested that NEPA processes do not adequately incorporate uncertainty because analyses assume that knowledge of past actions can inform future actions which limits considering how conditions will change in the context of climate change.

Further, while incomplete knowledge did not prevent the agencies from making decisions, the absence of more detailed information about climate change was viewed by some as a barrier to action. Without more accurate information about climate impacts, people suggested that management would be a continuation of the status quo. More specifically, they argued that they would likely continue to "muddle through" and assess impacts where they could, or use their professional judgment, make conservative decisions, and then monitor and adjust. Agency staff commonly referred to the importance of professional judgment and engaging a broad group of experts when there is incomplete knowledge. Many talked about "doing the best they could" with available data, bringing together different types of expertise to gather as much insight into the issue as possible, using professional judgment, and the need to be clear with the public about what they did or did not know within the NEPA process. In particular, they described drawing on various specialists with expertise relevant to a problem to try and compile as complete of a picture as possible.

Many suggested that incomplete knowledge drove more conservative decision-making, as line officers were unwilling to take risks. Line officers suggested that they would be less inclined to "go out on a limb" as they "didn't want to be on the chopping block" for a decision when there was incomplete knowledge. A risk-averse culture, what people commonly referred to as taking a "conservative approach," was common across all three agencies. For the USFS in particular, concerns about litigation seem to motivate conservative or risk-averse decision-making.

> *The Forest Service, I guess you could think of it as being gun-shy. We've been sued and litigated, and we're trying to avoid that, so we put all these impositions on ourselves to try to avoid litigation. (USFS specialist)*

Let's assume that we're going in a particular trajectory management-wise, in a certain direction, and that instead of making a radical change in any particular direction, we would make a slight adjustment or multiple slight adjustments and hopefully adapt based on the results of monitoring. (NPS)

When asked how they believed the agencies should make decisions when they do not have complete knowledge, permittees also suggested that a conservative approach was appropriate, and, similar to agency staff, discussed the importance of different types and sources of knowledge. Permittees spoke at length about the importance of local and experiential knowledge gained from observation of the landscape and the impacts of change. They viewed the incorporation of experiential knowledge into decision-making as necessary to their acceptance and support of management decisions. All permittees questioned an over reliance on scientific knowledge in management decisions and, while they believed science was important; they suggested that the agencies needed to draw on a broader knowledge base. While these sentiments echo the emphasis of the agency staff on a the importance of a broad set of knowledge, it is important to note that knowledge about *future* climate impacts gained through modeling is fundamentally different from the type of *historical* and *observational* knowledge that the permittees believed to be so valuable. For the permittees, *observed* trajectories of change are important to justify adaptation. This indicates that the agencies may face challenges when communicating to different stakeholders about decisions made in anticipation of future climate impacts.

These different perspectives on the standards of proof needed to support management changes are a potential source of conflict between the agencies and their constituents with regards to climate adaptation. The permittees suggested that they would be willing to accept reductions in numbers of livestock or grazing days in cases where the agencies demonstrated "hard evidence" of impacts. Many suggested that the agencies focused too heavily on available forage as an indication of when they should be on the range, arguing that water availability is a more important factor. Permittees also spoke of decision-making processes that would make them more willing to accept restrictions. Concerns included a need for better communication, consistency in staffing, early warning about potential restrictions, and the sharing of responsibility between the agencies in relation to the risk associated with decision-making in the context of uncertainty.

If something's happening that requires attention and you can get together with the Forest Service and make a plan together, and it fails, then you're both at fault. If it works, you're both credible. So if the Forest Service comes up with a plan and they leave the permittee out, that doesn't work. If the permittee comes up with a plan and they leave the Forest Service out, that doesn't work, either… I don't need proof, I need cooperation. (Permittee)

Adaptive management was regularly invoked as a mechanism to deal with uncertainty, although perceptions of how effectively the agencies were currently implementing adaptive management varied. Many suggested monitoring was inadequate and that the process for going back to change a decision was time-consuming and cumbersome. In this context a number of participants discussed a need to "streamline" NEPA processes, although few provided details regarding how this might be achieved. Given limited resources for monitoring of both SSW and PJ, and thus limited knowledge of how climate change is affecting these targets and about the efficacy of management actions, adaptive management efforts may be challenging. Further research is needed to understand whether and how monitoring efforts can be tailored to include information that could support adaptive management regarding climate impacts and adaptation strategies.

> *Professional opinion, professional judgment. That's kind of where we are right now in how we're addressing climate change… we know that it's happening, we know that we are sensitive to that fact, but we can't address it…All you can say is that we know it exists, but we have no data… that's in my personal opinion why the adaptive management thing doesn't work in trying to apply it to climate change,... It's easy to say, "We'll just use adaptive management. We'll monitor and modify." But what are you monitoring for? What specifically are you monitoring for to see that it's a function of climate change and not of overutilization or standard regional climate? Or if it's something bigger? That's the thing I struggle with. (USFS)*

V. Conclusions

Based on interviews with 34 agency staff and permittees, we found the following:

- There was widespread awareness about climate change and recognition that climate change would impact target systems and that these impacts needed to be addressed. However, most participants felt challenged to effectively deal with climate impacts, due to limited resources and knowledge, and uncertainty.
- The focus on ecological targets enabled in-depth discussion of particular systems and insights into how management agencies and permittees think about and manage these systems. However, this focus did not produce detailed understanding of broader social vulnerabilities as they relate to climate change.
- The focus on targets did enable us to uncover a critical disconnect between the adaptation literature and the way agencies actually manage public lands. In short, most agency management addresses specific activities that occur within ecosystems (e.g. grazing, recreation, forestry, fire management) rather than specific ecological targets within those systems.
- Thus, for adaptation within SSW and PJ in the San Juan Basin to be effective, it needs to wed the agency emphasis on activities and the adaptation focus on ecological values. One way to do so is to focus adaptation on existing management actions by integrating adaptation strategies into current management activities. Such an approach would:
    - Leverage existing resources. All participants expressed concerns about their lack of capacity to pursue additional management activities related to climate adaptation. Integrating adaptation into existing management activities (e.g. range management, silviculture, etc.) might provide a mechanism to leverage existing resources and increase overall capacity for adaptation action.
    - Nest the emphasis on vulnerable species and systems within programs and monitoring that have already been prioritized. There was widespread agreement that agencies do not manage for the ecological values of PJ or SSW per se, but rather focus on specific management activities within these systems, with an understanding that these activities influence ecological processes and individual species. Further, improved monitoring was seen as critical for effective adaptive management.
    - Resonate with the public and key stakeholders. Federal agencies will likely find more support for adaptation actions if these actions are meaningful to local

community members. A focus on the uses and values of the landscape that people care about may help build support for adaptation.

- Efforts to prepare federal land management agencies for climate adaptation may also need to consider the following:
  - Effective responses to climate change may require that the concept of climate adaptation be well-defined and mainstreamed in the agencies. We found that agency staff had very different definitions of climate adaptation and many participants were uncertain about the relationship between adaptation and land management.
  - Adaptation efforts need to be cognizant of the ways that uncertainty influences agency decision-making. Agency staff are accustomed to dealing with uncertainty, but tend more toward conservative, risk-averse strategies and longer decision-making processes as uncertainty increases.
  - Climate change may drive system transformations in some places, but many agency staff are just beginning to consider the possibility of transformative change.
  - The notion of managing for a range of futures is not yet well-established in agency decision-making. It is important to provide useful information about how scenarios and other tools can be used to consider different possible futures and integrate uncertainty into management decisions. At the same time, efforts to integrate new processes such as scenarios into decision-making need to consider the increased analysis burden.
  - More work is needed to determine how to adapt decision-making processes to enable more nimble management. In particular, lengthy decision timeframes and NEPA processes may present barriers to effective climate adaptation.
  - Agencies and different stakeholder groups, such as permittees, may benefit from dialogue regarding the types of knowledge integrating into decisions and the burden of proof required to shift management approaches in the context of change and uncertainty.
  - Dialogue processes that enable managers and stakeholders to share knowledge might also help address disagreements regarding the value and vulnerability of PJ. Building a common understanding of the ways that climate change potentially impacts PJ may be important to adaptation efforts in response to changes in this system.

Appendix: Interview Sample

The interview sample included 26 agency staff and 8 permittees (all ranchers with grazing permits on the San Juan National Forest). The agency staff included 11 Forest Service staff, 7 Park Service staff, and 8 Bureau of Land Management staff. Nine line officers and 17 specialists were interviewed. Specialists included staff focused on planning, wildlife, range, forestry, hydrology, air quality, climate change, recreation, renewables, non-renewables, natural resources, fire, inventory and monitoring, and NEPA. Four interviewees worked with more than one agency.

Appendix G. Social Ecological Response Models Methods Overview

Situation Analysis and Diagram: Method Overview

Background

A Situation Analysis assesses the important ecological, socioeconomic or political factors and trends affecting the ability to meet management and conservation goals. These factors may act as constraints or provide opportunities for making progress toward goals. Key factors include direct and indirect threats, opportunities and enabling conditions.

The analysis describes the current understanding of a project's ecological status and trends, and the human context. A clear understanding of what is happening within a large-scale landscape is critical for developing strategies that make sense for the specific conditions.

A Situation Analysis probes the root causes of critical threats, degraded species and vegetation, and other values to make explicit the contributing factors — the indirect threats, key actors and opportunities that enable successful action. By understanding the biological and human context, the team can develop appropriate goals and objectives, identify intervention points, and design adaptation strategies.

A Situation Analysis answers:

- "What factors, positive and negative, affect our conservation targets and ability to achieve our goals?"
- "Who are the key stakeholders linked to each of these factors and what motivates each of them?"
- What ecosystem services and human wellbeing targets (livelihoods) are provided by the landscape
- How will the targets, factors, and ecosystem services be affected by climate change?

The process of creating a Situation Analysis helps us:

- Articulate and test the logic of our thinking
- Identify the most critical factors that cause threats
- Summarize compelling evidence concerning trends in these factors
- Highlight key stakeholders and opportunities

Focus on what is most important

- Identify intervention points for developing the most appropriate strategy

A common understanding can bring together:

- Different visions of what will be accomplished through conservation work
- Different perspective of the project's context
- Disparate knowledge and understanding of trends in socioeconomic, political and ecological factors
- A wide variety of assumptions about these trends and what is most important to address
- A range of perspectives about leverage opportunities
- Multiple definitions or uses for the same term

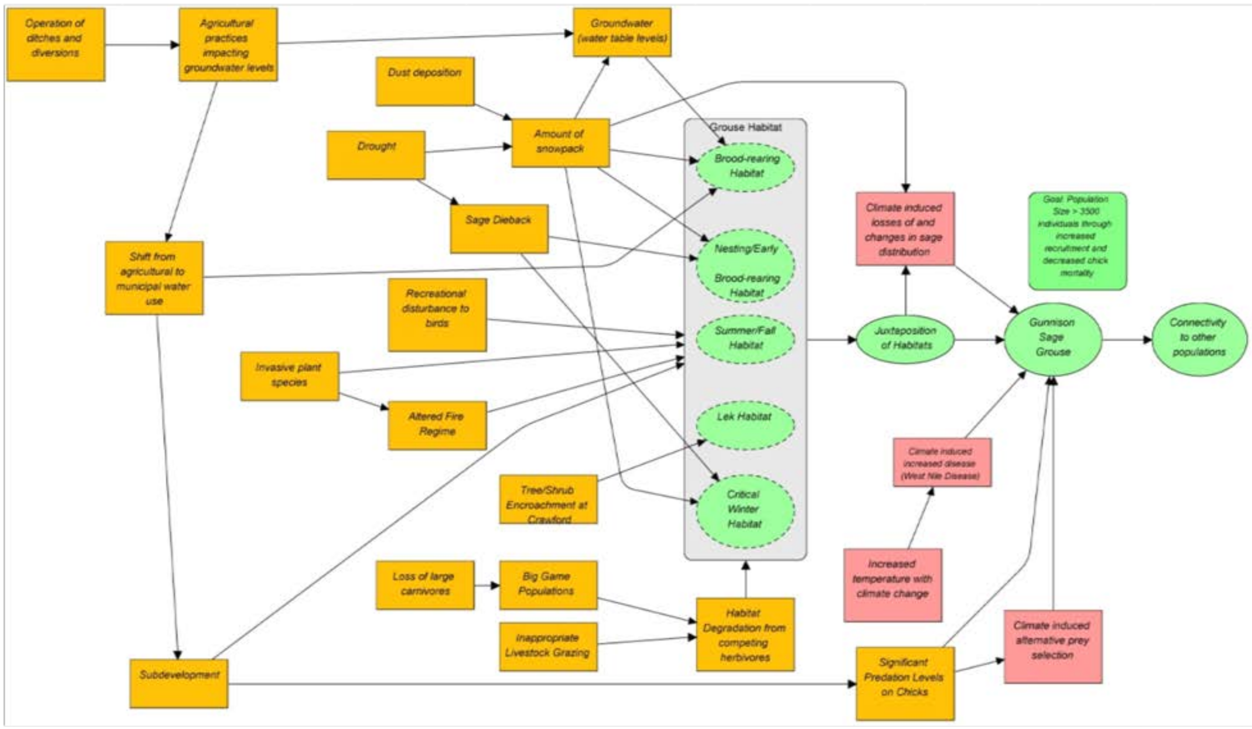
Method

1. Diagram the current condition of the system describing the socioeconomic, political and ecological factors
2. Add in the climate change scenario and determine whether any additional factors need to be added. Discuss whether any of the existing factors significantly increase or decrease with the climate change scenario in mind.
3. Identification of intervention points. Where is action needed?
4. Identification of the high level strategies that are needed at the intervention points.

A Situation Diagram is a box and arrow model that shows the linkages between the conservation values, threats, and other factors. By creating a diagram, intervention points become clear.

Example

Developed for Gunnison sage-grouse at the Gunnison Basin Climate Change Adaptation Workshop for Natural Resources Managers held in 2009.

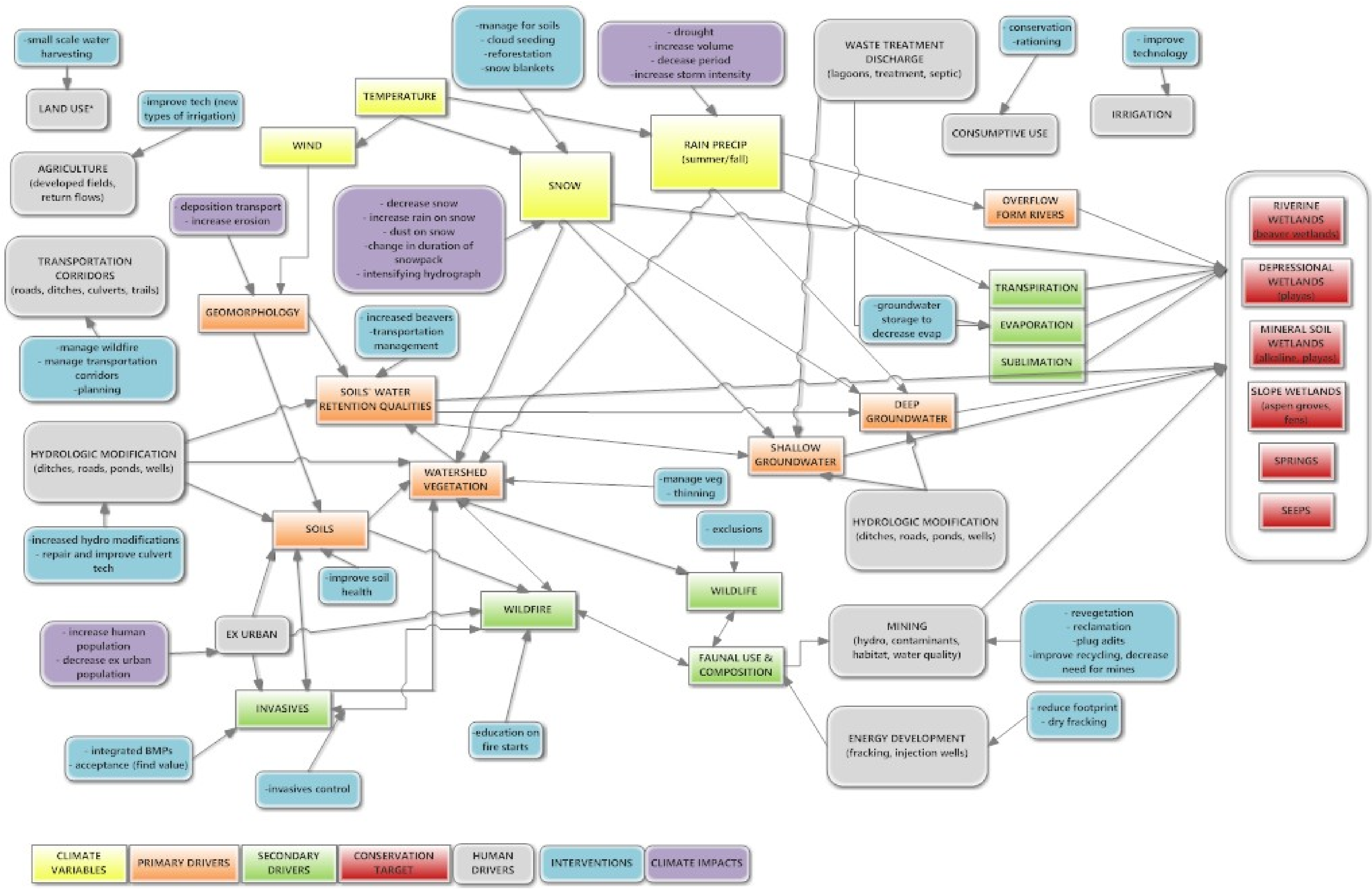


Additional resources and information about the Situation Diagram process can be found at the website below:

Conservation Measures Partnership. 2013. *Open Standards for the Practice of Conservation Version 3.0.* http://www.conservationmeasures.org/wp-content/uploads/2013/05/CMP-OS-V3-0-Final.pdf

Gunnison Basin Climate Change Adaptation Workshop for Natural Resource Managers (2010) http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/Colorado/science/climate/gunnison/Pages/Climate-Change-Adaptation-Workshop-for-Natural-Resource-Managers-in-the-Gunnison-Basin.aspx).

APPENDIX H. SITUATION ANALYSIS DIAGRAM



APPENDIX I. CHAIN OF CONSEQUENCES

Method Overview

Background

Established by Secretarial Order 3188 in 2012, the Department of the Interior (DOI) Strategic Sciences Group[1] (SSG) provides the DOI with the capacity to rapidly assemble teams of experts to conduct science-based assessments of environmental crises affecting DOI resources, and provide results to leadership as usable knowledge. To do this, SSG "crisis science teams" effectively act as "pop-up think tanks" to identify the potential short- and long-term environmental, social, and economic cascading consequences of the crisis, and determine intervention points.

Method[2]

Through facilitated discussion, the team of experts builds *Chains of Consequences.* This process is used by the SSG and was developed by its predecessor, the DOI Strategic Sciences Working Group in 2010. The process involves four main steps:

1) Establish the scope (ecological and geographic area of interest, focal time period) and define assumptions.
2) Develop detailed Chains of Consequences that illustrate important cascading effects on the coupled natural-human system.
3) For each element in a chain, assign a level of scientific uncertainty (see example below).
4) Identify potential interventions at points in the chain at which scientists, policy makers, and others might take specific actions to significantly alter the outcomes of the cascade.

Example[3]

Chains of Consequences developed by the SSG Hurricane Sandy crisis science team determined that overwash and breaches of barrier islands were certain to occur as a result of the storm (assigned an uncertainty value of 5), leading to advance of bay shoreline (beach growth as a result of sand redeposition following the storm; assigned a value of 5), and to the probable creation of new habitat (assigned a value of 3). This information was used to develop *interventions* such as mapping and measuring the protection services of key ecosystems such as dunes and wetlands).

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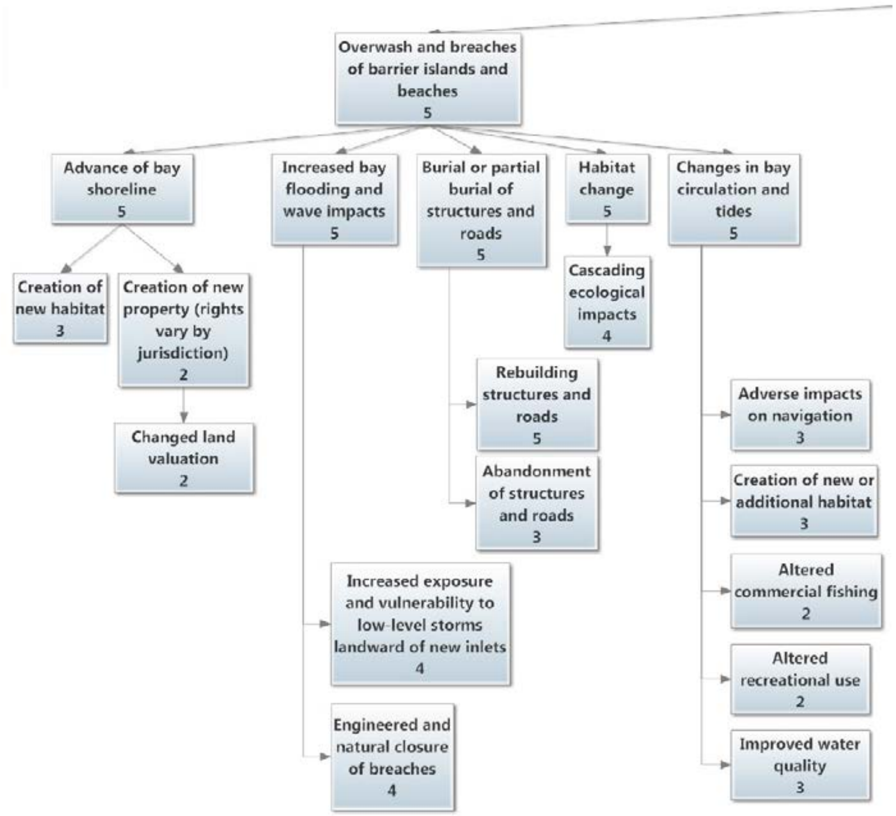
[1] For more information on the Department of the Interior Strategic Sciences Group, please see www.doi.gov/strategicsciences

[2] Department of the Interior Strategic Sciences Working Group, 2012, Mississippi Canyon 252/Deepwater Horizon Oil Spill Progress Report Department of the Interior, Washington, D.C., 58 p. Available online at: http://www.doi.gov/strategicsciences/publications/index.cfm

[3] Stoepler, T. and Ludwig, K. 2015. Strategic science: new frameworks to bring scientific expertise to environmental disaster response. *Limnology & Oceanography Bulletin*.

Interventions were delivered to decision-makers during briefings and in the final SSG Hurricane Sandy report.



Uncertainty	Value
5	Certain
4	Reasonably Certain
3	Probable
2	Plausible
1	Unlikely
0	Not Possible
NA	Not Known

Figure I-1. Example Chains of Consequences developed by the SSG Hurricane Sandy crisis science team: Changes in coastal geomorphology as a result of Hurricane Sandy. *Credit: Department of the Interior, 2013*.

Note: This Appendix is formatted to print on 11" x 17" paper.

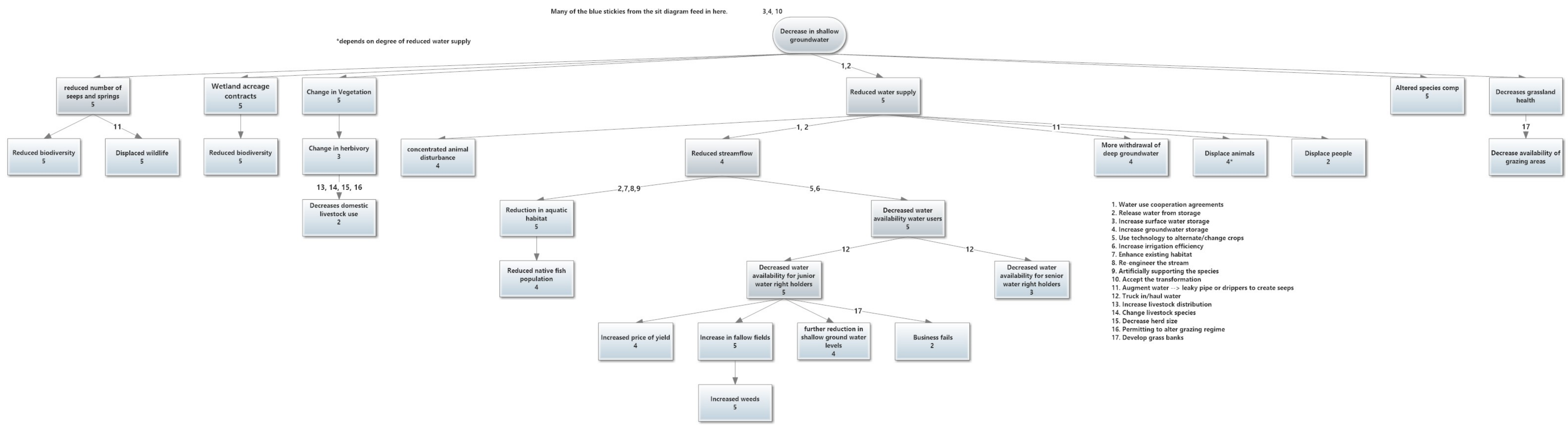


Figure I-2. Seeps, Springs, and Wetlands, decrease in shallow groundwater.

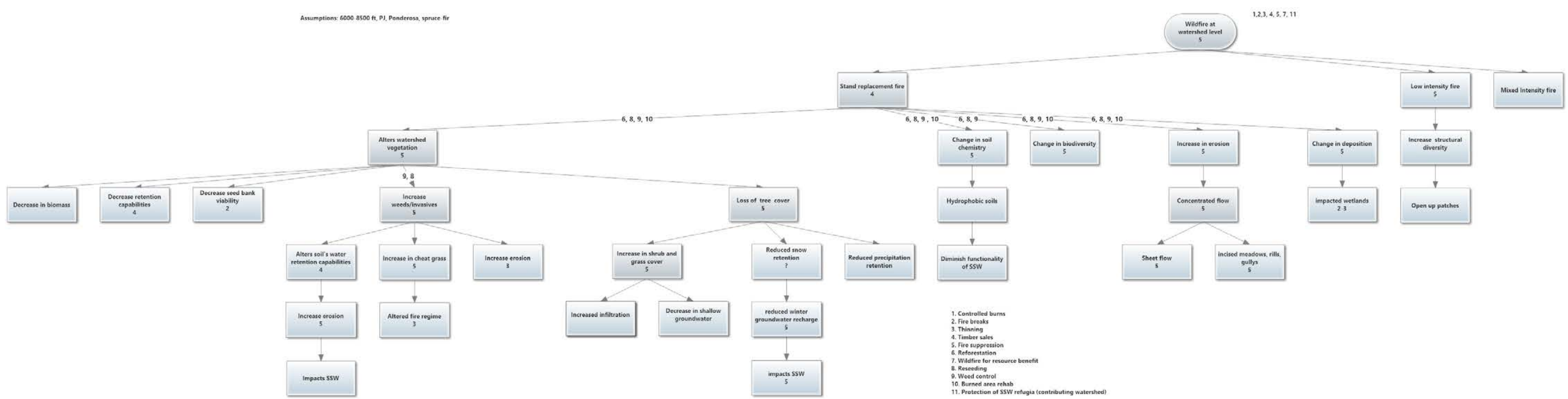


Figure I-3. Seeps, Springs, and Wetlands, wildfire.

APPENDIX J. IMPACTS AND ACTIONS (INTERVENTIONS) ASSOCIATED WITH THREE CLIMATE ADAPTATION STRATEGIES

The following tables (1-3) summarize the impacts and actions associated with the three strategies.

Table J-1. Impacts and actions currently identified for the "Identify and Protect Refugia" strategy.

Impact	Action	Strategy
Altered water regime	Protection of refugia springs/seeps that contribute to watershed flows	**Identify and protect refugia**
Altered water regime	Protection of persistent wetlands (still wet during severe droughts) within intact native landscapes	**Identify and protect refugia**
Altered water regime	Protection of persistent wetlands (still wet during severe droughts) within special management areas	**Identify and protect refugia**

Table J-2. Impacts and actions currently identified for the "Grazing Management" strategy.

Impact	Action	Strategy
Trampling of SSW from grazing	move water used for cattle away from SSW	**Grazing management**
Trampling of SSW from grazing	Encourage increased animal distribution (domestic and wild)	**Grazing management**
Trampling of SSW from grazing	Change domestic livestock species	**Grazing management**
Trampling of SSW from grazing	Decrease herd size	**Grazing management**

Table J-3. Impacts and actions currently identified for the "Proactive Treatment for Resilience" strategy.

Impact	Action	Strategy
Habitat loss in wetland	Build deep pools	**Proactive treatment for resilience**
Altered species and soil composition in watershed	Timber sales: ponderosa pine	**Proactive treatment for resilience**
Altered species and soil composition in watershed	Reforestation- tree planting	**Proactive treatment for resilience**
Altered species and soil composition in watershed	Reseeding after a disturbance	**Proactive treatment for resilience**
Altered species and soil composition in wetland	Weed control	**Proactive treatment for resilience**
Habitat loss of wetlands	Enhance existing habitat	**Proactive treatment for resilience**
Altered groundwater recharge regime	Increase water induction storage (subsurface)	**Proactive treatment for resilience**

Impact	Action	Strategy
Altered groundwater recharge regime	Increase wetland water storage	**Proactive treatment for resilience**
Altered groundwater recharge regime	Change crops to use less water	**Proactive treatment for resilience**
Altered groundwater recharge regime	Improve irrigation efficiency	**Proactive treatment for resilience**
Altered groundwater recharge regime	Augment water (drip irrigation, leaky pipe wetlands)	**Proactive treatment for resilience**
Altered fire regime in watershed	Timber sales: P/J	**Proactive treatment for resilience**
Altered groundwater recharge regime	Release water from storage (short term)	**Proactive treatment for resilience**